Designing Pathways toward Climate Neutrality

District heating as an important contributor in the energy transition of the heating sector in Slovenia

Results of the LIFE ClimatePath2050 project

Gašper Stegnar, PhD., Damir Staničić, msc., Jure Čižman, msc., Stane Merše, msc.

Josef Stefan Institute – Energy Efficiency Centre

7th October 2021

LIFE CLIMATE PATH 2050

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Why is modelling of heat demand and supply important?

- Around 50 % of total energy demand in EU27 account for heating & cooling, only 22.1 % (Eurostat, 2019) comes from renewables
- District heating can have a considerable role in integrating local renewable sources, sector coupling and CO_2 reductions.
- Decarbonizing heating sector is crucial.
- Lack of knowledge in municipalities:
  - Where to start? How to start?
  - DH is investment intensive

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Motivation and research questions

- **Motivation**
  - Climate change
  - CO2 savings / heat supply
  - Exploitation of the local/micro potential
- **Research questions**
  - What could heat supply look like in Slovenia in 2050?
  - To what extent can existing and new DH contribute to energy transition?
  - What role can renewables have in the future DH systems?
- **Background**
  - Local projects
  - No data on DH modeling on a micro level

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Objectives

- Creation of a Slovenian heat map with the bottom-up approach
- Identify technical potential for expansion of existing DH and new systems
- Explore the economic feasibility of investment of seeting up a new DH plant and grid
- Determine the economic/market potential for new DH systems
- Determine the location of new DH systems and estimate the heat demand in order to integrate the RES and waste heat sources

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Why models?

- The purpose of the model is to **understand** a specific segment and show how such a segment **affects society**, its **sociological** components, **economy** and **environment**
- Model results are usually in a form of **projections**
- Assessment of **scenarios for reducing GHG** in the sectors of transport, industry, buildings, energy supply, agriculture, LULUCF
- **Results** of the model must reflect selected **assumptions** and the **approximations** used, which the designer of the model assumed in the planning

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Models used in the scope of LIFE Climate Path 2050

- **REES-SLO** (**R**eference **E**nergy and **E**mission **S**ystem model for **SLO**venia→ simulation model)
- **Power System Optimisation** model (Monte Carlo opt.)
- **CETRA** (**C**entral **E**uropean **TRA**nsport model)
- **Macroeconomic model** (General Equilibrium Model)
- **LULUCF Model** (Land Use, Land Use Change and Forestry Carbon Budget Model)
- **Agricultural model** (AGRI LIVESTOCK and AGRI SOILS)

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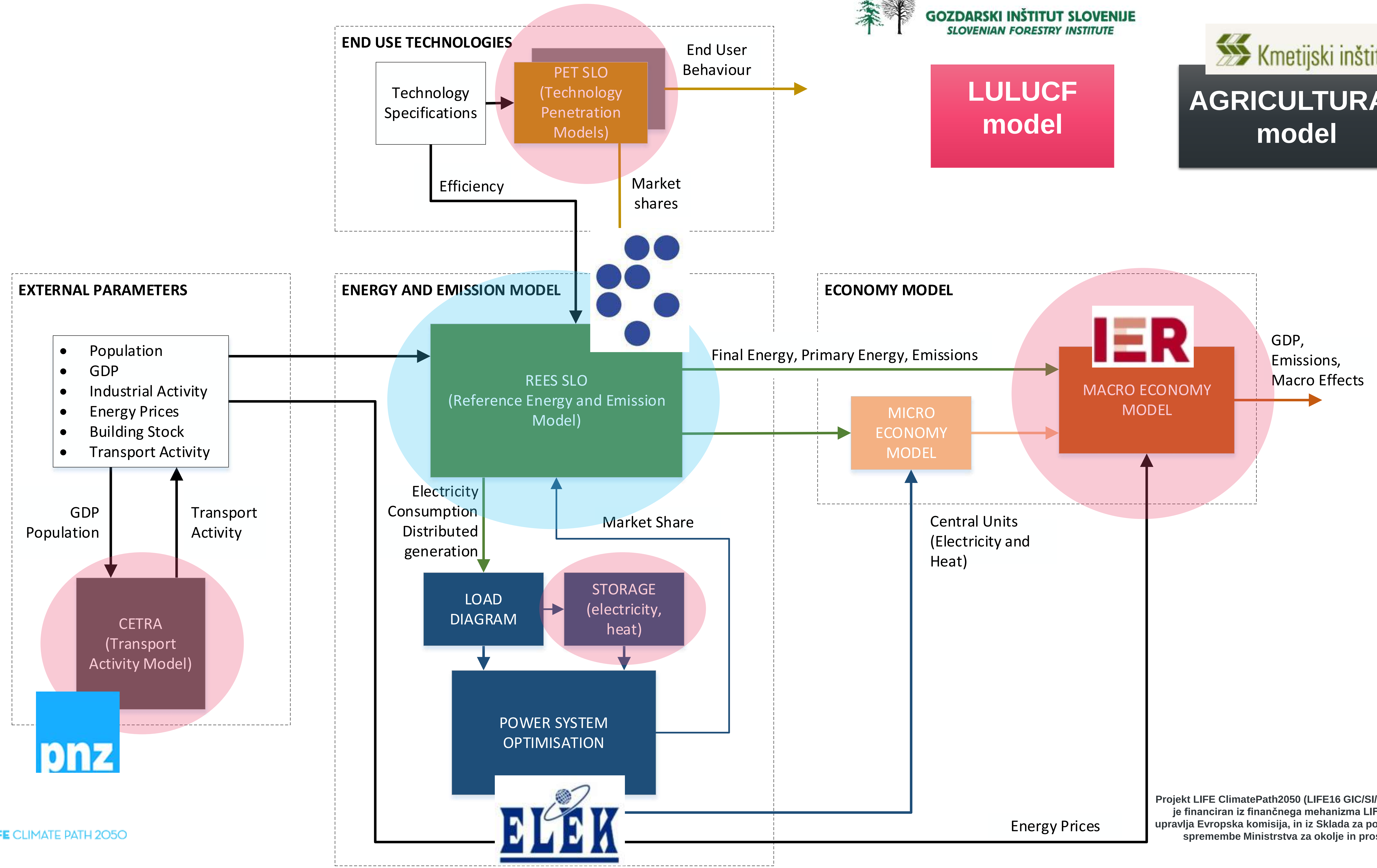
GOZDARSKI INŠTITUT SLOVENIJE
SLOVENIAN FORESTRY INSTITUTE

Kmetijski inštitut Slovenije

LULUCF model

AGRICULTURAL model



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DH MODEL

- DH modelling is necessary for the purpose of heating demand and supply balance analysis.
  - Heating demand is dependent from (local) building energy efficiency and is observed through heat maps.
  - Heating supply is dependent from (local) energy sources available (mainly) on-site.
- Created DH model in the scope of LIFE ClimatePath 2050 enables to analyse possibilities of exploitation/expansion on existing DH grids as well as new DH areas, areas where currently DH is not present, but could be a cost-efficient option.
- This is a unique mode that uses bottom-up approach and as such derives from the actual building condition/efficiency.
- The model is based on Python programming code and can be replicated on any arbitrary area/municipality/region/country.

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Modelling approach

1. **Calculation of building‘s energy performance**
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Calculation of building‘s energy efficiency

Buildings are analyzed according to:

- dense/spare areas
- building type: 2 types of residential and 11 types of non-residential buildings
- technologies for heating
- energy renovation (partial, full, nZEB)
- energy use for heating, DHW and electric appliances

Aspects taken into account:

- buildings under protection of cultural heritage (buildings that cannot be extensively renovated)
- growth of population (impacts the need for new households)
- user behavior

Calculation of energy indicators is executed with either results from EPC either building typology.

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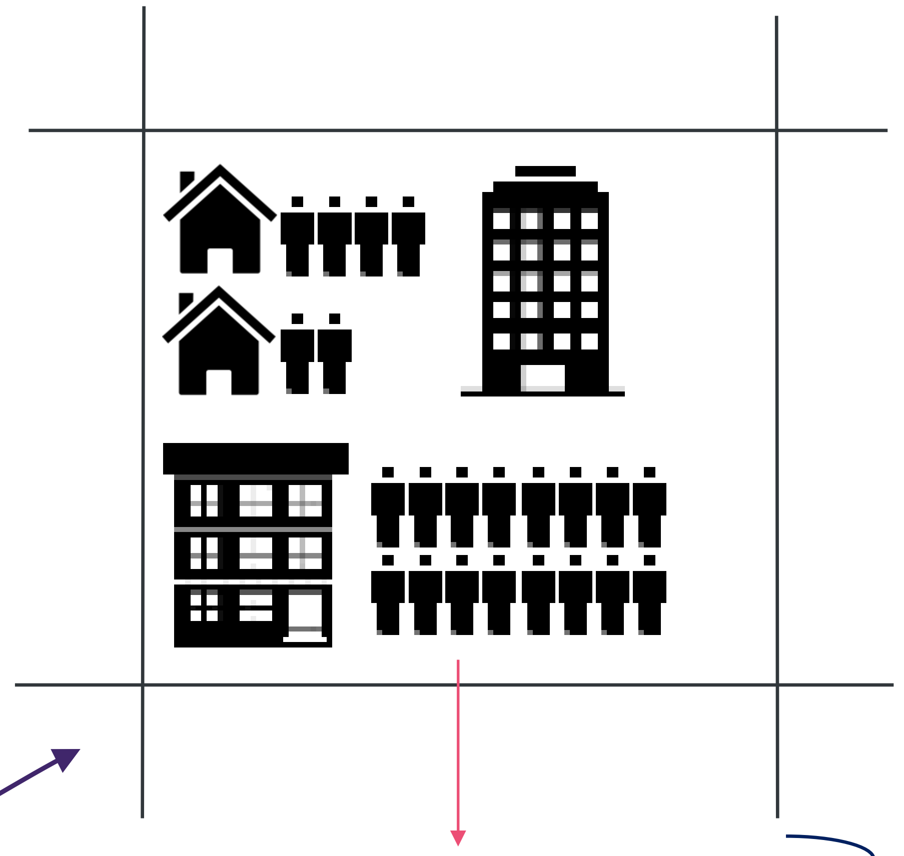
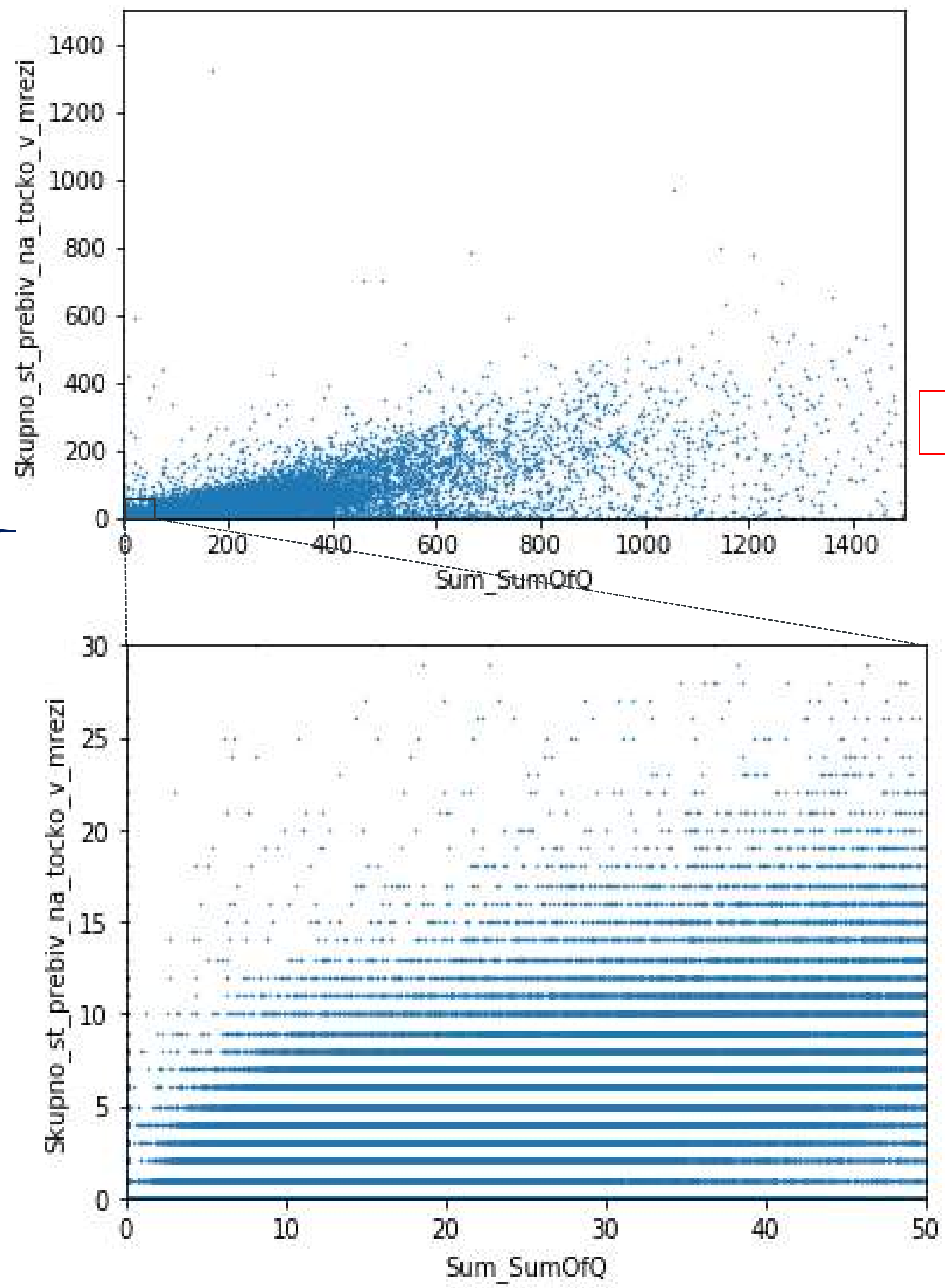
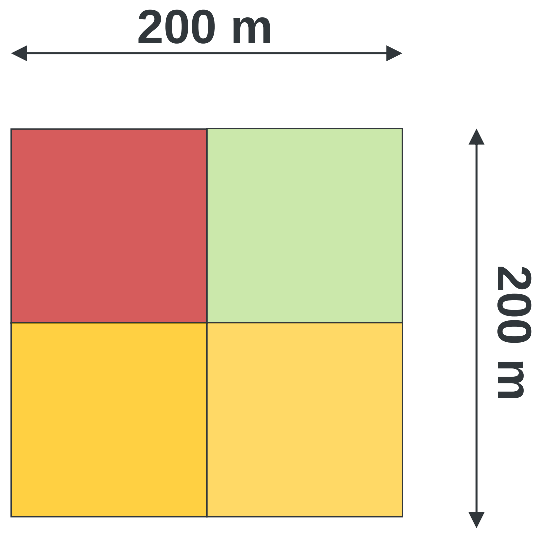
“Bottom-up” approach



1. Number of residents
2. Energy need for heating, cooling and DHW
3. Distinction between dense and sparse areas





- 100 x 100 m grid
- Results come from an analysis of the energy performance of an *individual* building.
- **Status today**: based on available databases, Statistical office of RS and APEGG survey
- **Status 2050**: All buildings are going to be energy renovated, which lowers the heat aggregated heat demand

ı2050 (LIFE16 GIC/SI/000043)
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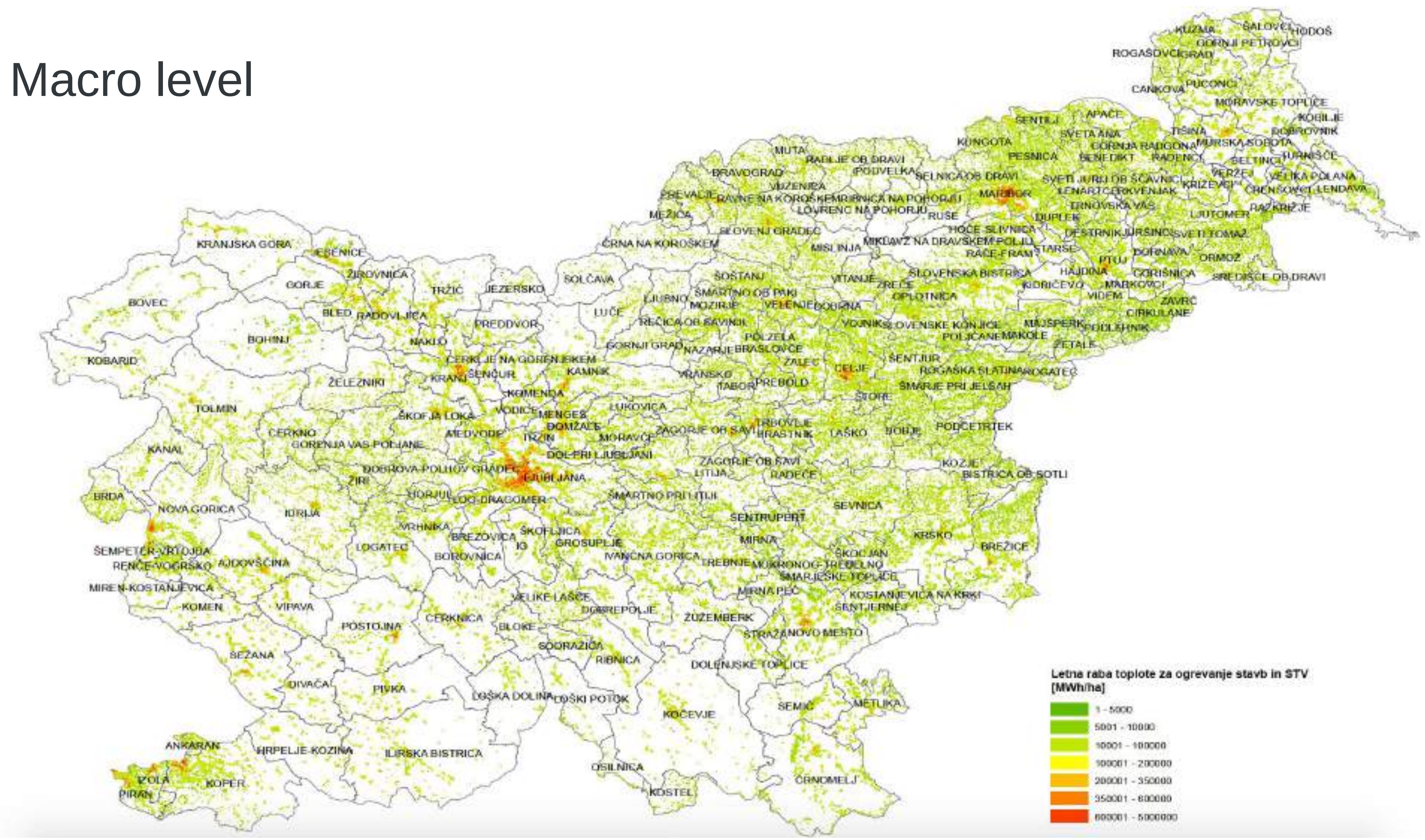
Heat map of Slovenia

Result of energy efficiency of all buildings in Slovenia, taking into account its actual condition.

Macro level



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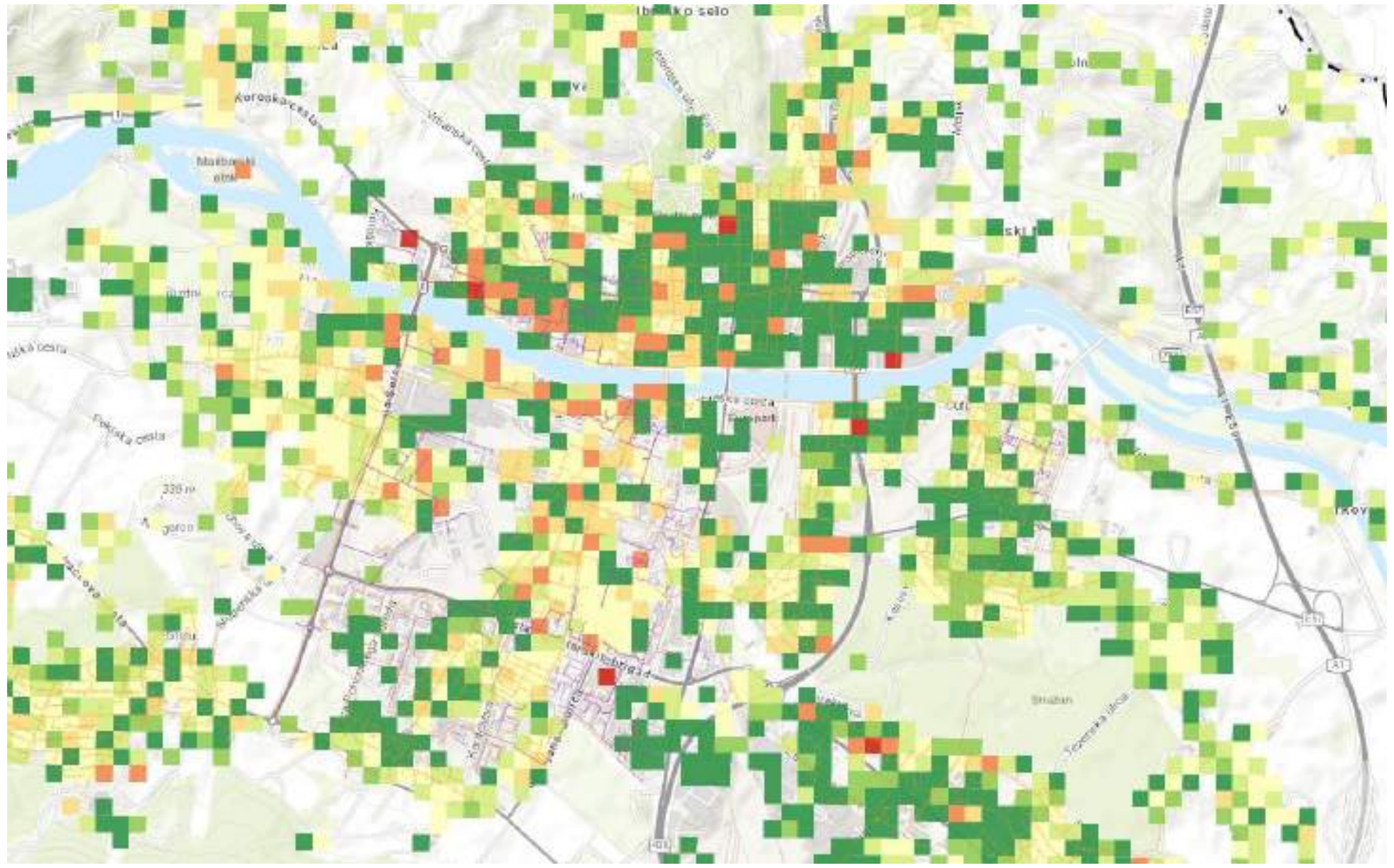
Micro level



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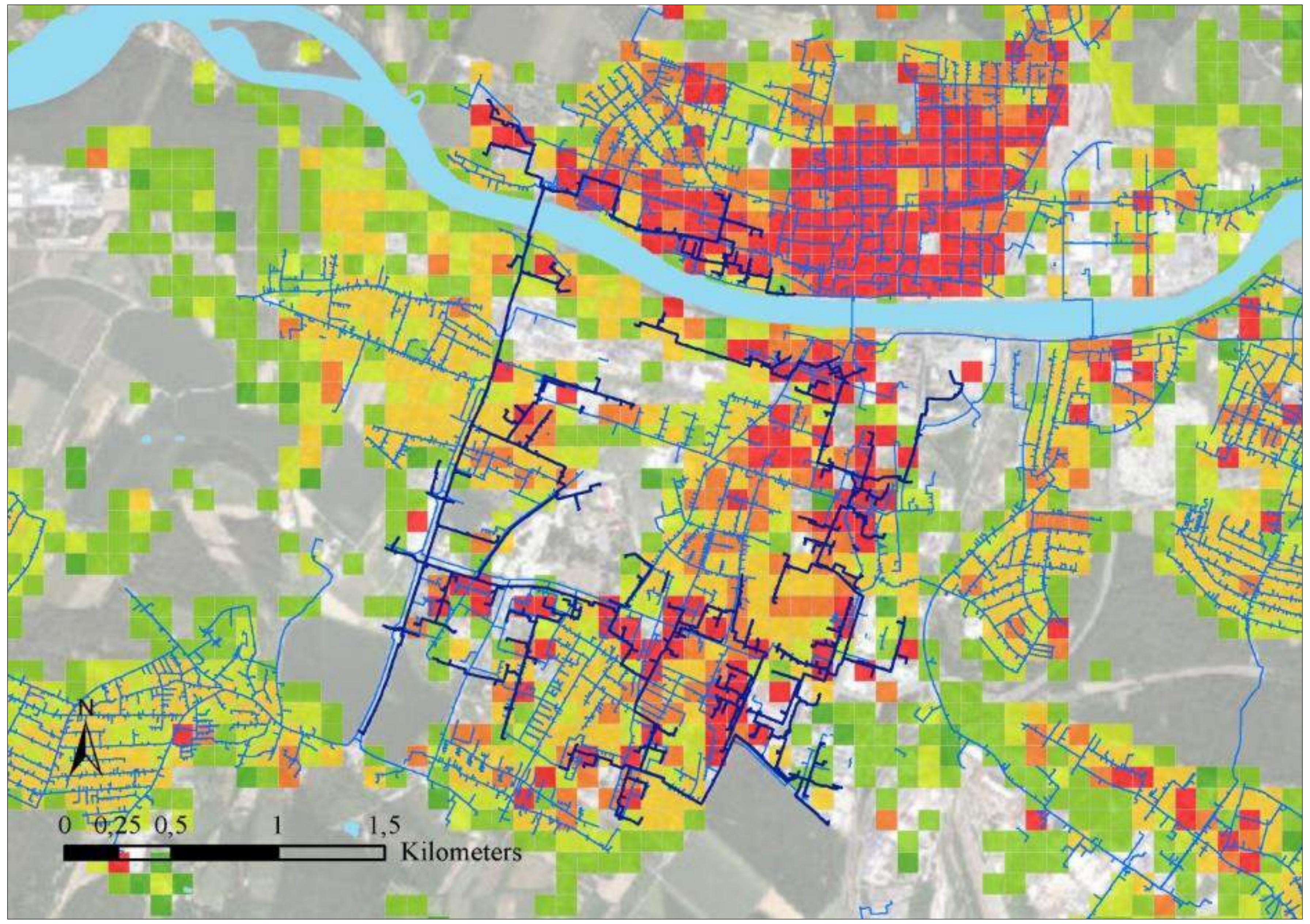
DH grid

Slovenia has almost 100 DH grids and each has been specifically addressed and buildings near the grid, analyzed. Furthemore, scope of buildings with unused connections has been identified.

City of Maribor with DH grid and local energy needs



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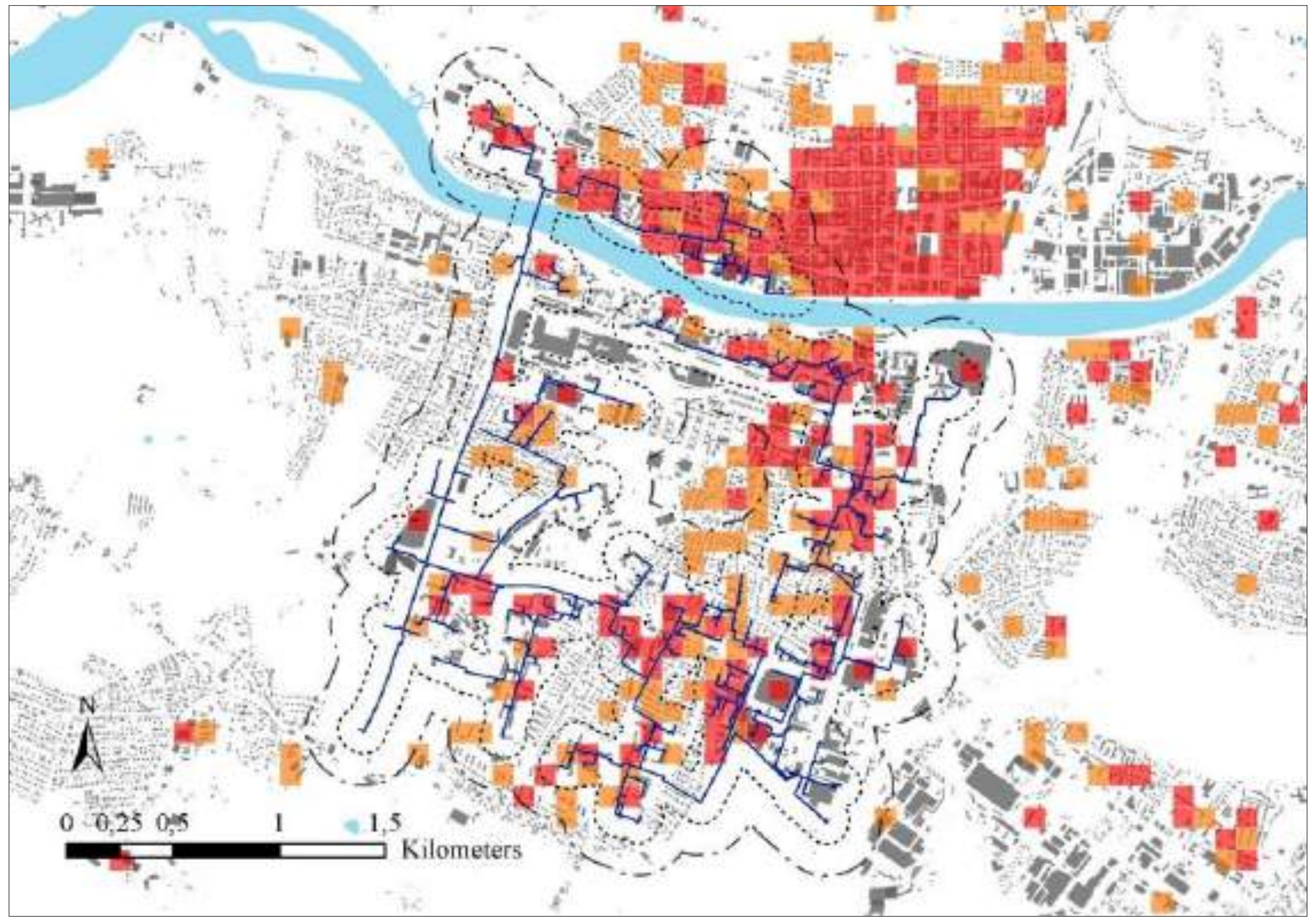
Expanding the network

Through various aspects and parameters, existing DH expansion was addressed and evaluated.

Expansion of DH infrastructure in Maribor and Kranj



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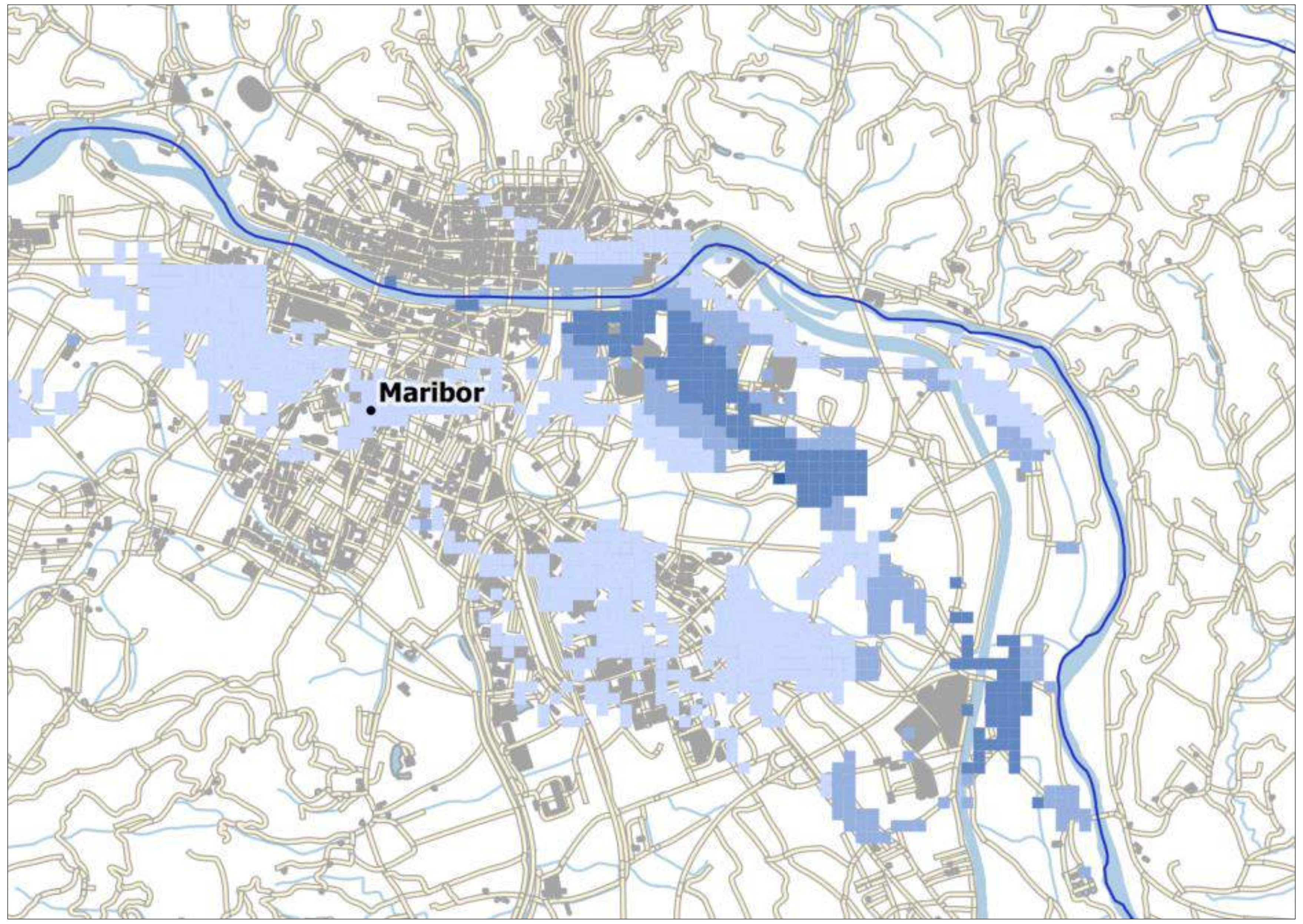
From needs to supply options

Ongoing research is focusing on identification of local potential of deep and shallow geothermal energy, solar energy and DH expansion.
The main goal is to offer actual feasible solutions.

Potential for exploitation of shallow geothermal energy



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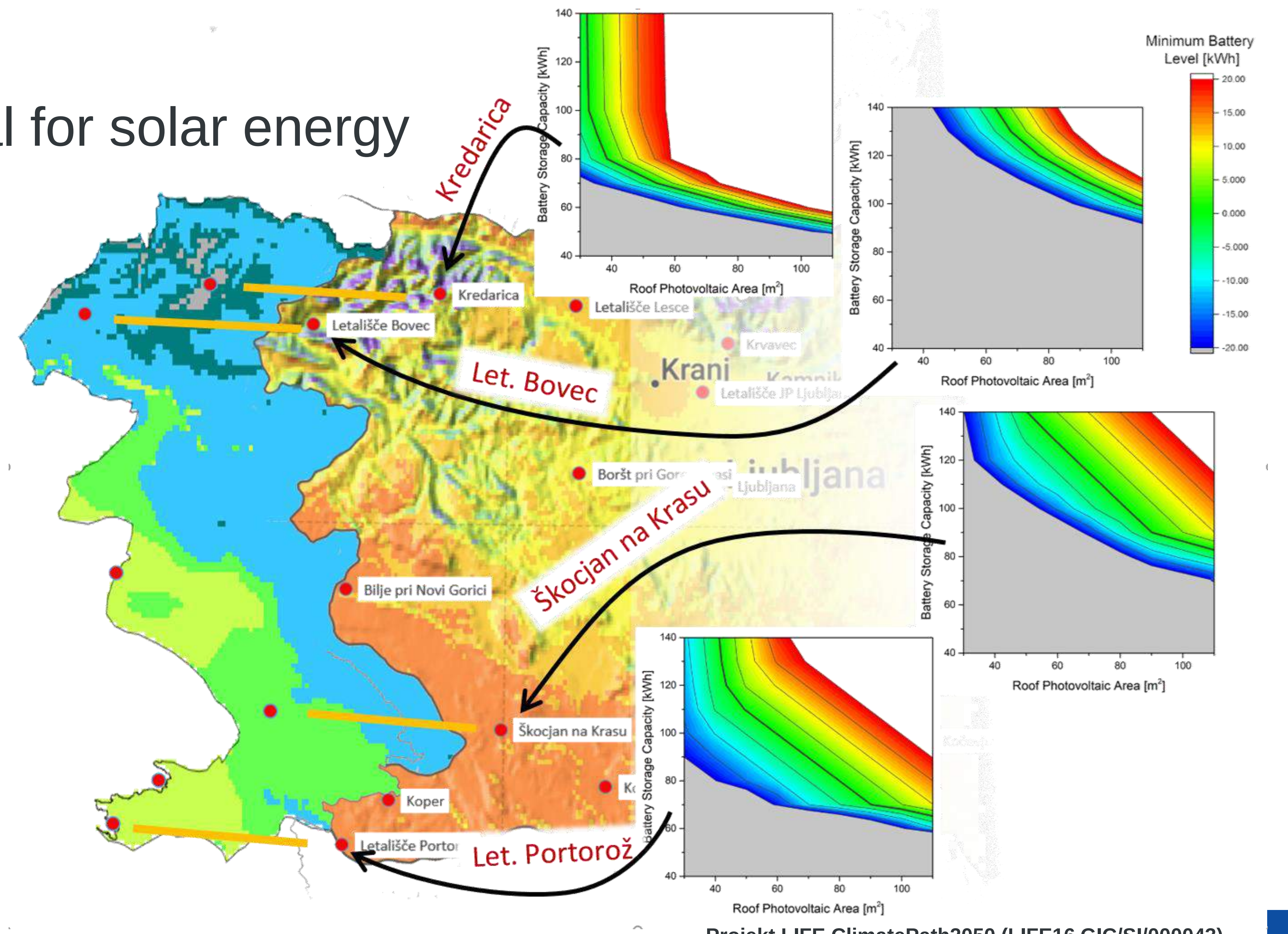
Potential for solar energy



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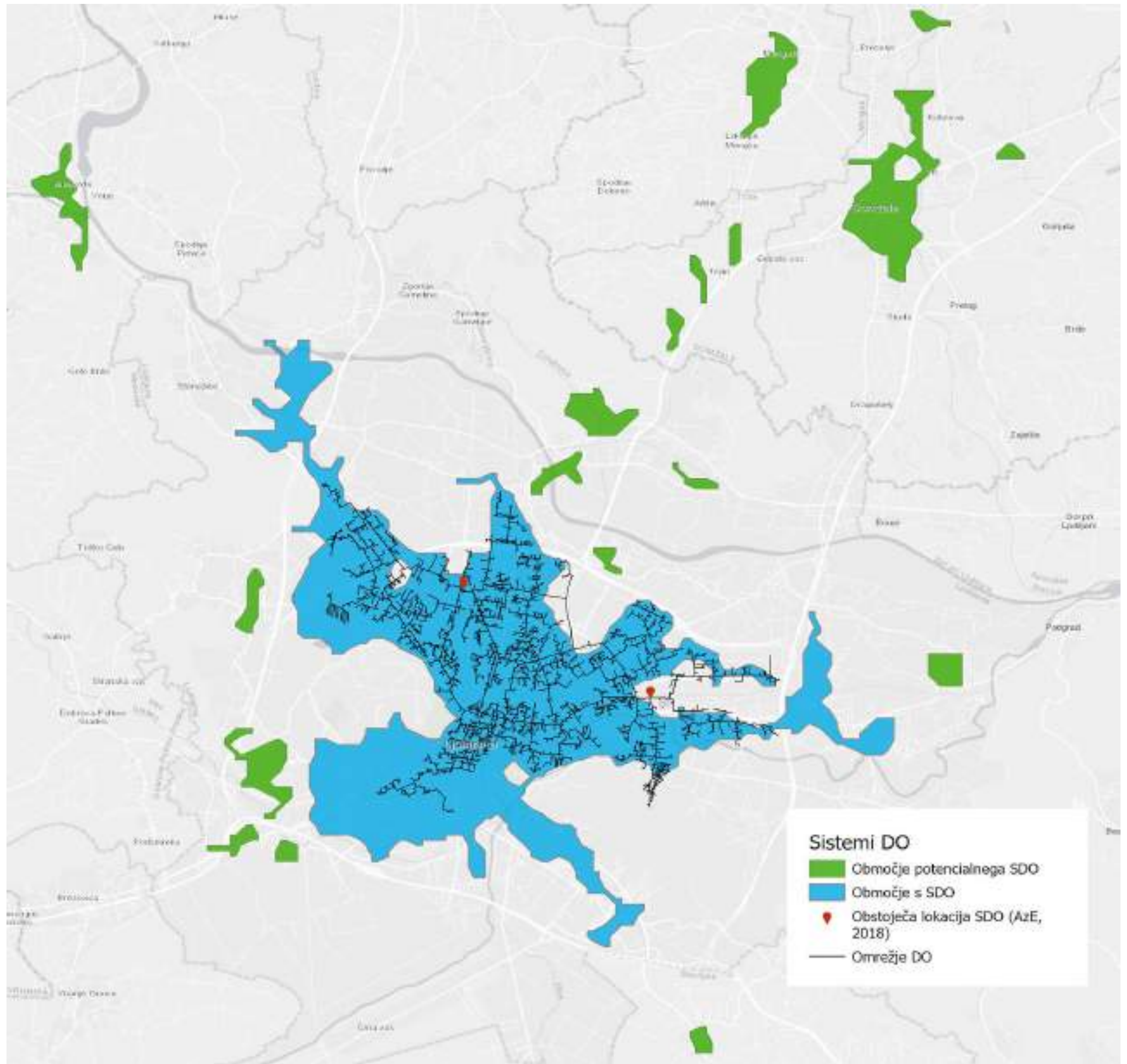
Step 1: Technical potential

Identification of ares with sufficient (100 – 200 – 300 MWh/ha) heat demand in Slovenia, outside the existing DH infrastructure.



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Step 1: Technical potential

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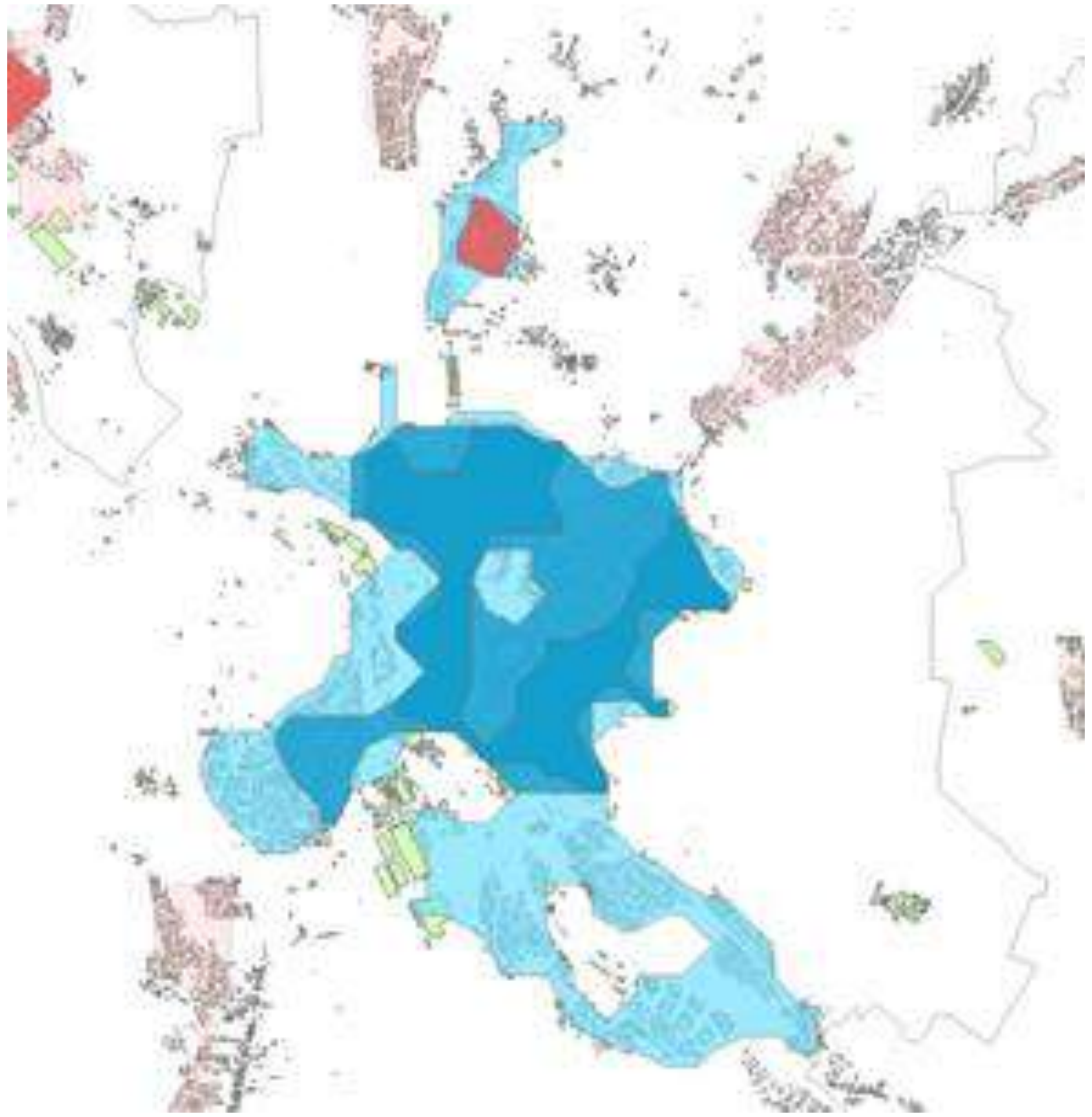
But, is it cost efficient?



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Cost efficiency – levels 1 and 2

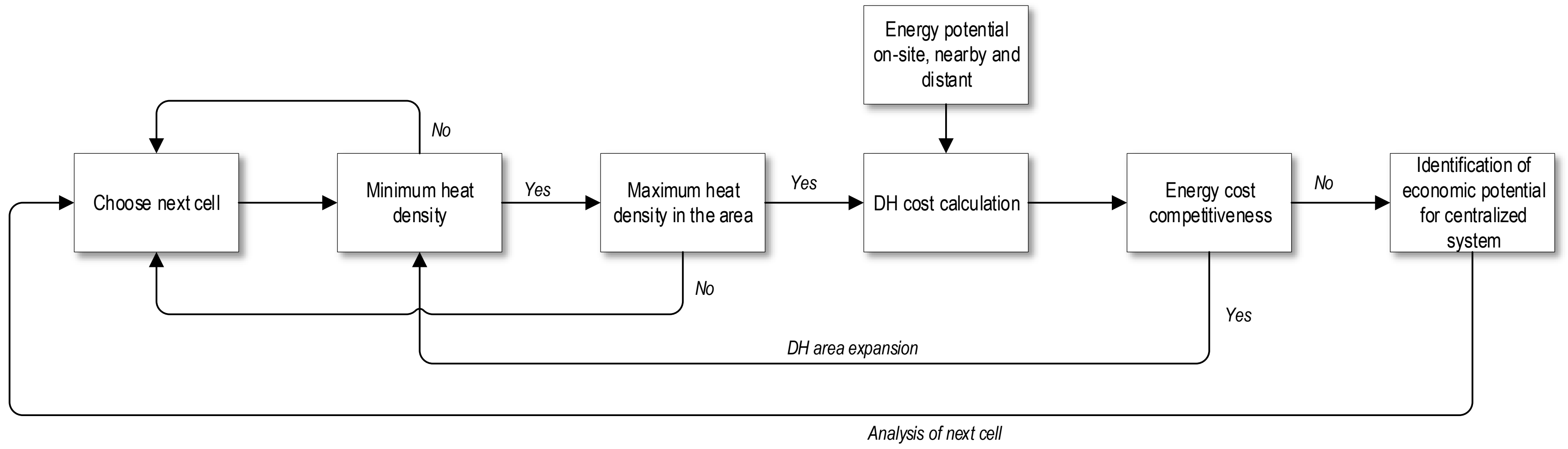
Areas with potential:
HEAT DENSITY > 100 – 200 – 350 MWh/ha

DH area size: Areas where DH energy price competitiveness in ensured.

Economic feasibility: investment, distribution, O&M (methodology by Heat Roadmap Europe 4, D2.3)

Competitiveness: LCC comparison with the cheapest and “clean” technology available in dense (HP air-water) and sparsely (HP air-water and biomass boiler) populated areas

Level of detail: 100 x 100m area



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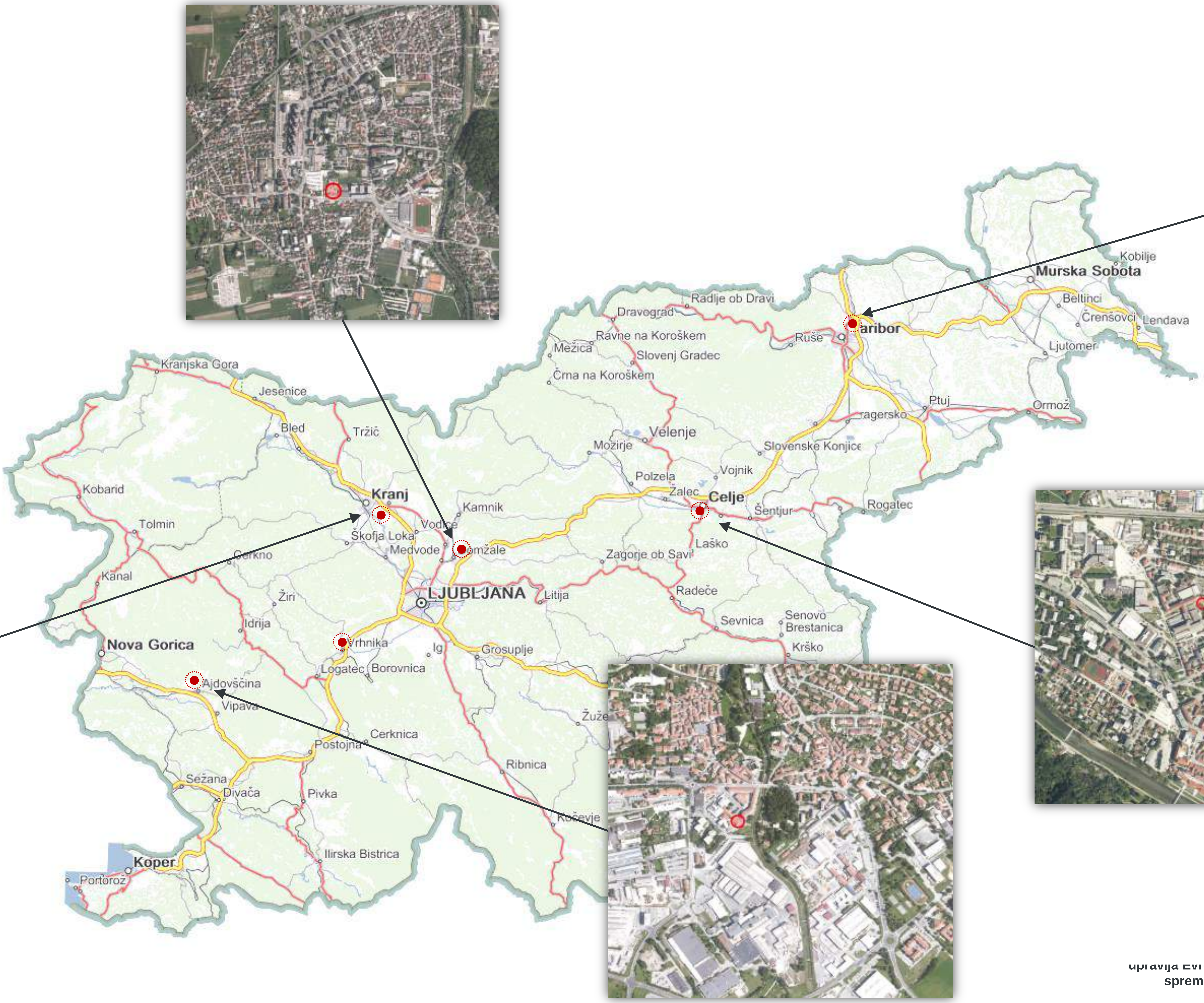
DH potential for new DH systems in Slovenia



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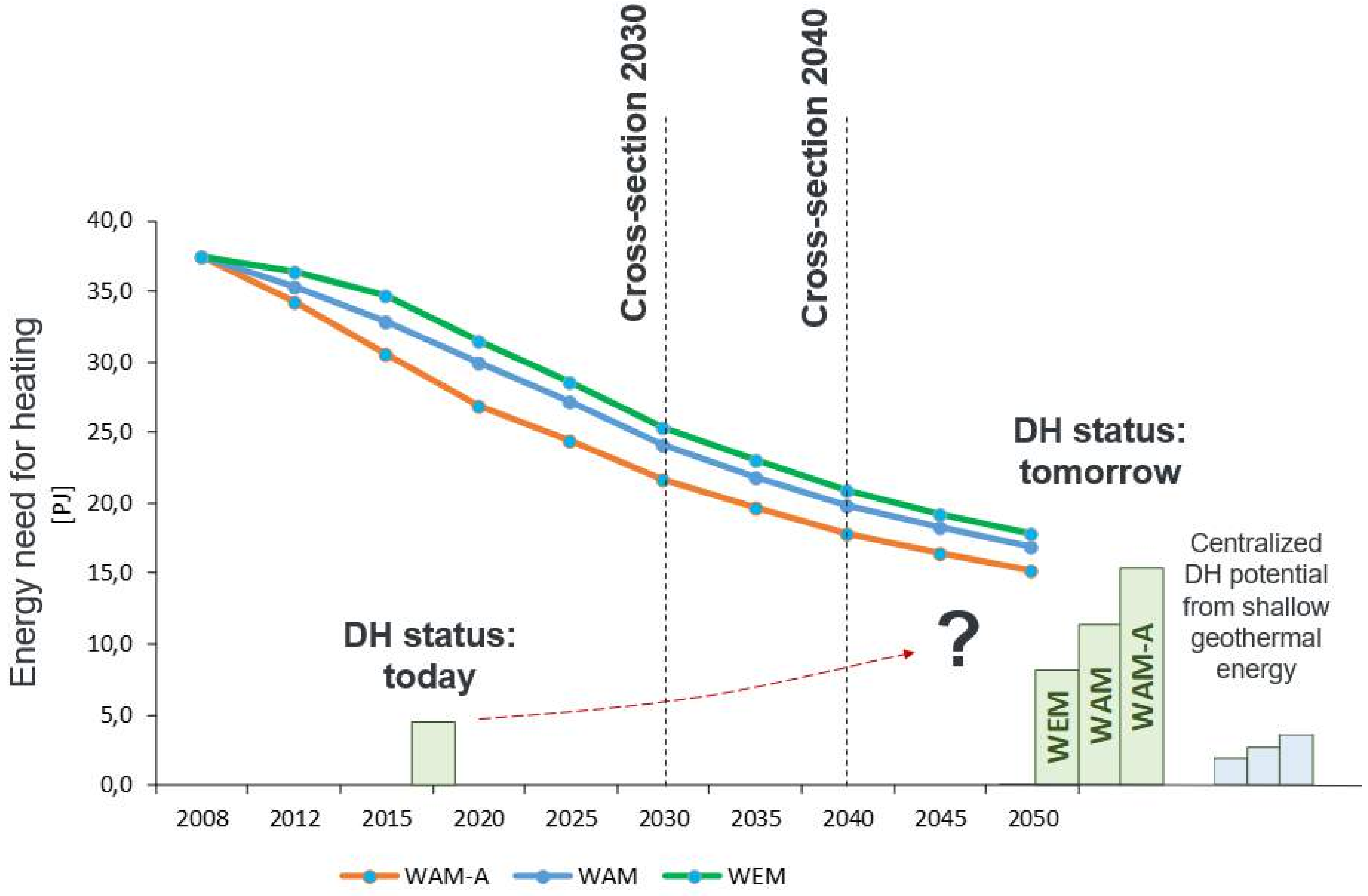
Use of model‘s results

Despite the fact aggregated energy demand will decrease in the existing buildings in due time to 2050, the approach enabled suitability analysis of DH from the economic aspect in existing and new DH areas.



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Modelling approach

New DH systems

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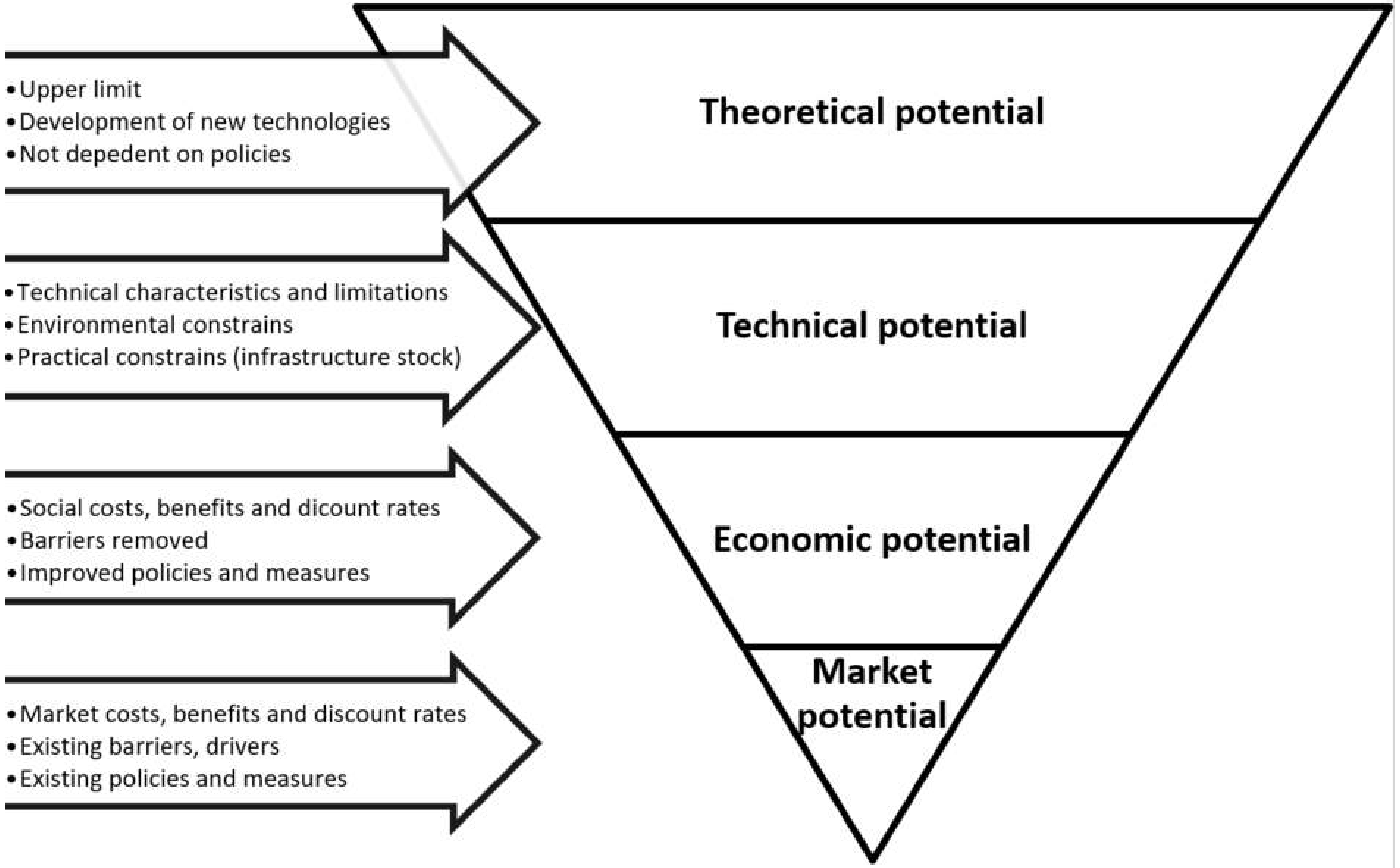

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Results: general DH potential

Larger buildings are more interesting from the point of view of cost-effectiveness of connection to DH, so an analysis of the density of annual heat needs was made only for buildings with a usable area of more than 400 m2.

Total heating needs for larger buildings represent only 1/3 of the total needs of all buildings (2.9 TWh), 90% of these needs or. 2.6 TWh is in cells with a density greater than 100 MWh/ha, more than 75% or 2.2 TWh in areas with a density of more than 200 MWh/ha

Density class	1	2	3	4	5	6	7	SUM
Heat demand density [MWh/ha]	< 20	20 - 50	50 - 100	100 - 200	200 - 350	350 - 600	> 600	
Heat demand [GWh]								
All buildings	**3**	**90**	**202**	**420**	**535**	**619**	**1.075**	**2.945**
City municipalities with DH	1	27	65	164	250	367	840	**1.714**
Other municipalities with DH	1	25	56	103	136	121	114	**557**
Other municipalities without DH	1	39	81	152	148	131	122	**675**
Class proportion [%]	**0,1%**	**3,1%**	**6,9%**	**14,3%**	**18,2%**	**21,0%**	**36,5%**	**100%**

Structure of annual heat needs for heating buildings larger than 400 m2 by density classes

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Results: existing DH systems

Taking into account the criterion of annual heat demand density as a criterion for economic potential, and the expansion of existing SDOs mainly by connecting larger buildings, we estimate the economic potential for expansion of existing DHs between 150 GWh (density more than 350 MWh/ha) and 500 GWh in dense areas above 200 MWh / ha (more suitable for low-temperature 4DH).

Despite a conservative estimate of the economic potential, this is an increase from 12 to 40% of today's heat sales for heating buildings.

[GWh]	Heat density [MWh/ha]	
	>100	>200
All buildings in municipalties with DH	3.523	2.517
Buildings > 400 m^2 in municipalties with DH	2.096	1.828
Heat supply (2017)	1.290	
DH expansion with a model approach of«uniform expansion«	**1.870**	
Extra potential	**580**	

Results for modelling approach 1

[GWh]	Heat density [MWh/ha]		
	>100	>200	>350
All buildings in municipalties with DH	3.523	2.517	1.740
Buildings > 400 m^2 in municipalties with DH	**2.096**	**1.828**	**1.442**
Heat supply (2017)	1.290		
DH expansion with a model approach of«areas connectivity«	**3.300**	**2.560**	**1.652**
Extra potential	**2.010**	**1.270**	**362**

Results for modelling approach 2

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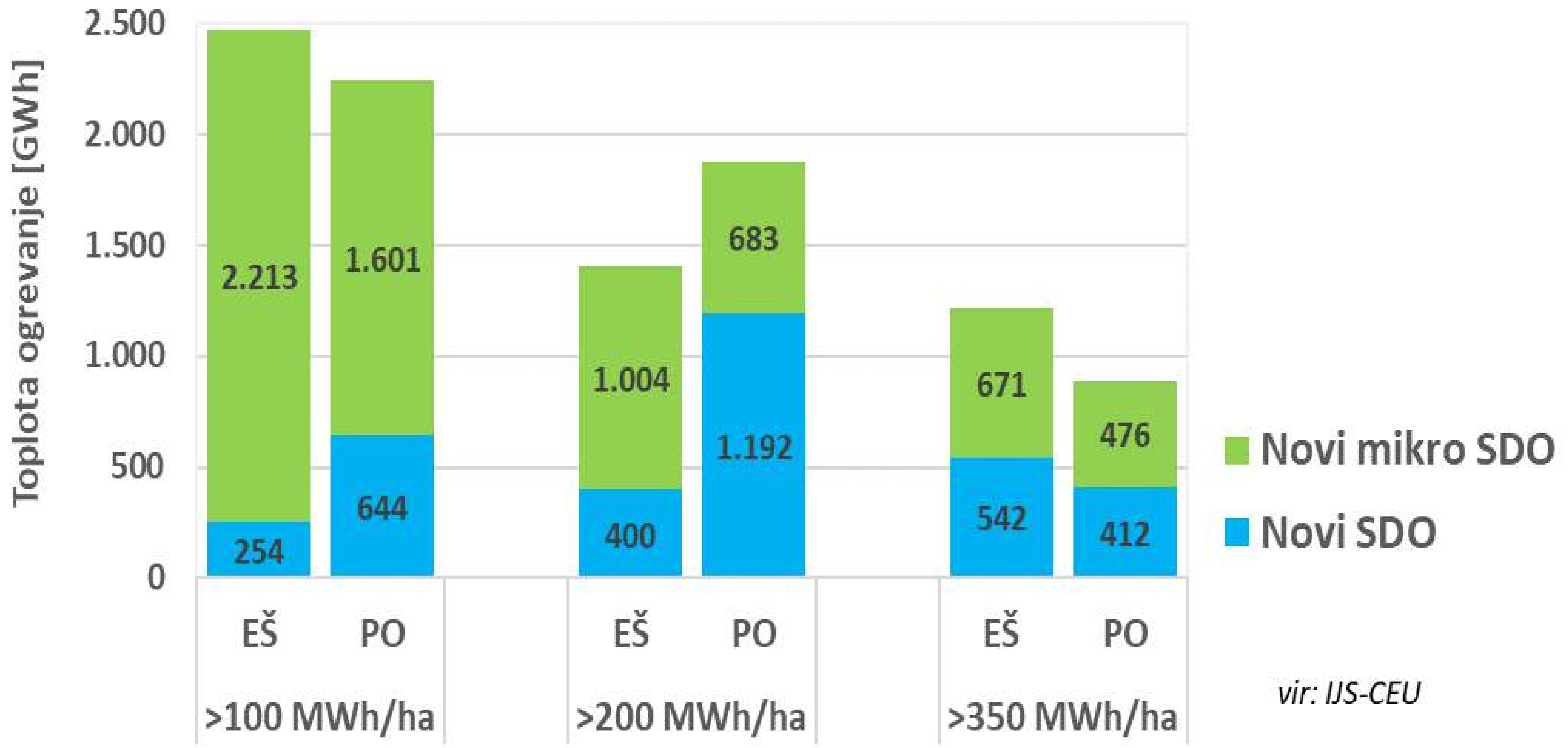
Results: new DH systems

According to the proposed methodology, **95 new potential areas were identified**, covering a total area of **32 km2** (average 34 ha), the estimated total annual **heat demand potential in these areas is 540 GWh**, and the estimated **cooling potential in these buildings is 138 GWh**.

We estimate the economic potential for new DHs between 200 and 400 GWh (areas with a higher density than 350 MWh/ha).

The estimated economic potential for new low-temperature micro DHs, which connect only a few buildings in areas with a higher consumption density, is between 400 and 600 GWh, depending mainly on the economics of implementation in densely populated residential areas.



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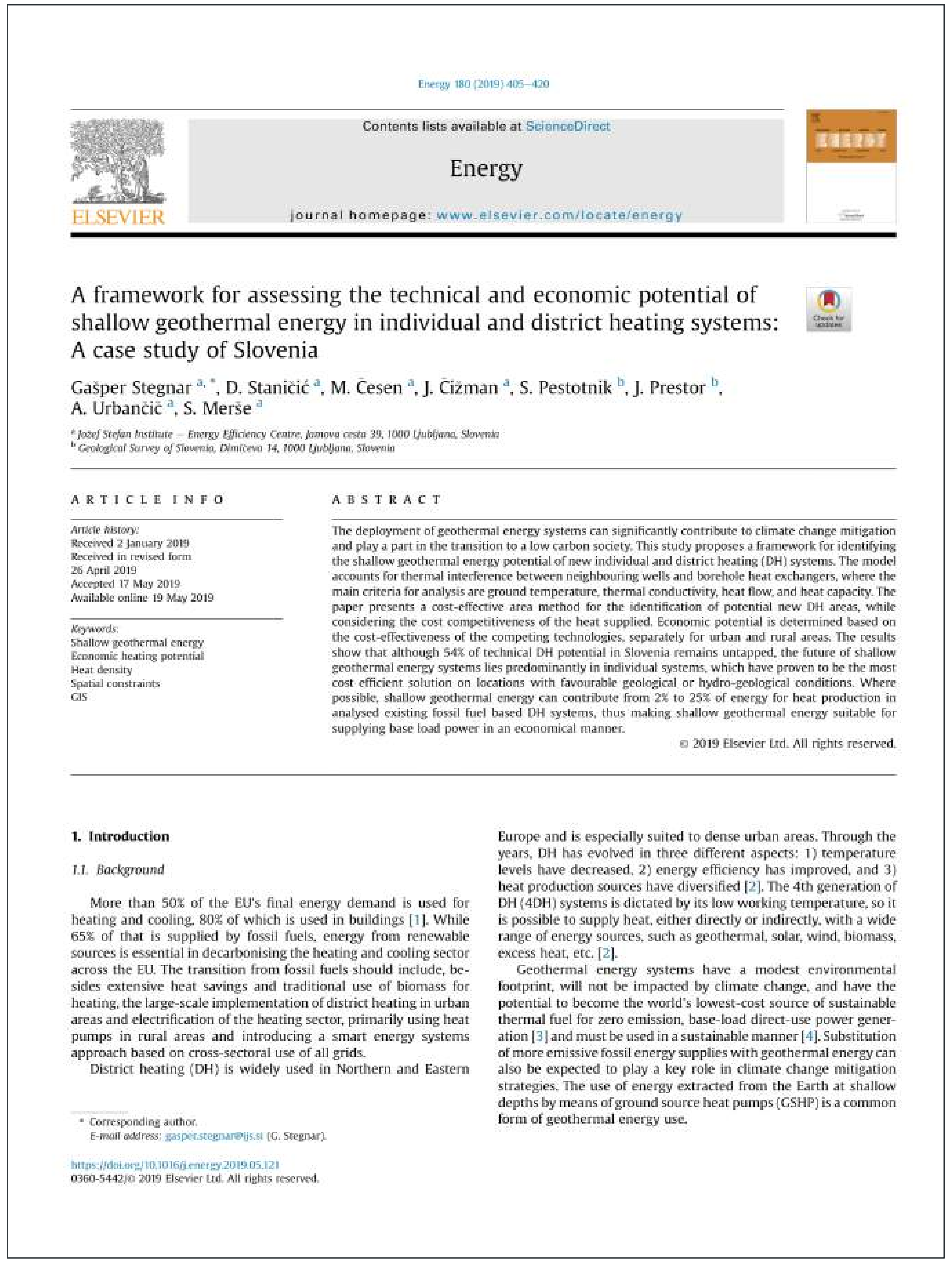
DH MODEL – exploitation of results

The DH model and its methodology main results were presented at **Euro heat & Power congress** in 2019 and **published in Energy** journal in 2019, entitled

A framework for assessing the technical and economic potential of shallow geothermal energy in individual and district heating systems: A case study of Slovenia.

https://doi.org/10.1016/j.energy.2019.05.121



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A framework for assessing the technical and economic potential of shallow geothermal energy in individual and district heating systems: A case study of Slovenia

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GIS

ABSTRACT

The deployment of geothermal energy systems can significantly contribute to climate change mitigation and play a part in the transition to a low carbon society. This study proposes a framework for identifying the shallow geothermal energy potential of new individual and district heating (DH) systems. The model accounts for thermal interference between neighbouring wells and borehole heat exchangers, where the main criteria for analysis are ground temperature, thermal conductivity, heat flow, and heat capacity. The paper presents a cost-effective area method for the identification of potential new DH areas, while considering the cost competitiveness of the heat supplied. Economic potential is determined based on the cost-effectiveness of the competing technologies, separately for urban and rural areas. The results show that although 54% of technical DH potential in Slovenia remains untapped, the future of shallow geothermal energy systems lies predominantly in individual systems, which have proven to be the most cost efficient solution on locations with favourable geological or hydro-geological conditions. Where possible, shallow geothermal energy can contribute from 2% to 25% of energy for heat production in analysed existing fossil fuel based DH systems, thus making shallow geothermal energy suitable for supplying base load power in an economical manner.

1. Introduction

1.1. Background

More than 50% of the EU's final energy demand is used for heating and cooling, 80% of which is used in buildings [1]. While 65% of that is supplied by fossil fuels, energy from renewable sources is essential in decarbonising the heating and cooling sector across the EU. The transition from fossil fuels should include, besides extensive heat savings and traditional use of biomass for heating, the large-scale implementation of district heating in urban areas and electrification of the heating sector, primarily using heat pumps in rural areas and introducing a smart energy systems approach based on cross-sectoral use of all grids.

District heating (DH) is widely used in Northern and Eastern Europe and is especially suited to dense urban areas. Through the years, DH has evolved in three different aspects: 1) temperature levels have decreased, 2) energy efficiency has improved, and 3) heat production sources have diversified [2]. The 4th generation of DH (4DH) systems is dictated by its low working temperature, so it is possible to supply heat, either directly or indirectly, with a wide range of energy sources, such as geothermal, solar, wind, biomass, excess heat, etc. [2].

Geothermal energy systems have a modest environmental footprint, will not be impacted by climate change, and have the potential to become the world's lowest-cost source of sustainable thermal fuel for zero emission, base-load direct-use power generation [3] and must be used in a sustainable manner [4]. Substitution of more emissive fossil energy supplies with geothermal energy can also be expected to play a key role in climate change mitigation strategies. The use of energy extracted from the Earth at shallow depths by means of ground source heat pumps (GSHP) is a common form of geothermal energy use.

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Thank you!

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