Workshop on methods and models for the preparation of GHG emissions projections up to 2050

Modeling of district heating systems: status quo, its development and expansions

dr. Gašper Stegnar

15th September 2021

LIFE CLIMATE PATH 2050

Projekt LIFE ClimatePath2050 (LIFE16 GIC/SI/000043) je financiran iz finančnega mehanizma LIFE, ki ga upravlja Evropska komisija, in iz Sklada za podnebne spremembe Ministrstva za okolje in prostor RS.

Why do we model district heating systems?

cost efficient solution due to low investment and price

improved air quality due to replacement of old boilers

improved user comfort of system control

low carbon solution

suited to feed in locally available, renewable and low-carbon energy sources

generation of heat in one large plant can often be more efficient than production in multiple smaller ones

Projekt LIFE ClimatePath2050 (LIFE16 GIC/SI/000043) je financiran iz finančnega mehanizma LIFE, ki ga upravlja Evropska komisija, in iz Sklada za podnebne spremembe Ministrstva za okolje in prostor RS.

DH MODEL (1)

- *National Climate and Energy Action plan* and *Long term building energy renovation strategy to 2050* aim towards decarbonised building stock. This will be achieved through extensive building energy renovation and directed heating and cooling strategy towards centralized heating systems.
- 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.

Projekt LIFE ClimatePath2050 (LIFE16 GIC/SI/000043) je financiran iz finančnega mehanizma LIFE, ki ga upravlja Evropska komisija, in iz Sklada za podnebne spremembe Ministrstva za okolje in prostor RS.

DH MODEL (2)

- 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 the first model which 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.

LIFE CLIMATE PATH 2050

Projekt LIFE ClimatePath2050 (LIFE16 GIC/SI/000043) je financiran iz finančnega mehanizma LIFE, ki ga upravlja Evropska komisija, in iz Sklada za podnebne spremembe Ministrstva za okolje in prostor RS.

Modelling approach

1. **Calculation of building‘s energy performance**
2. Creation of heat maps
3. Evaluation of existing DH infrastructure
4. Evaluation of DH expansion potential today and in 2050
5. Analysis and evaluation of (local) energy potential
6. Application of DH model expansion
7. Calculation of investment‘s cost efficiency
8. Data aggregation and projections

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

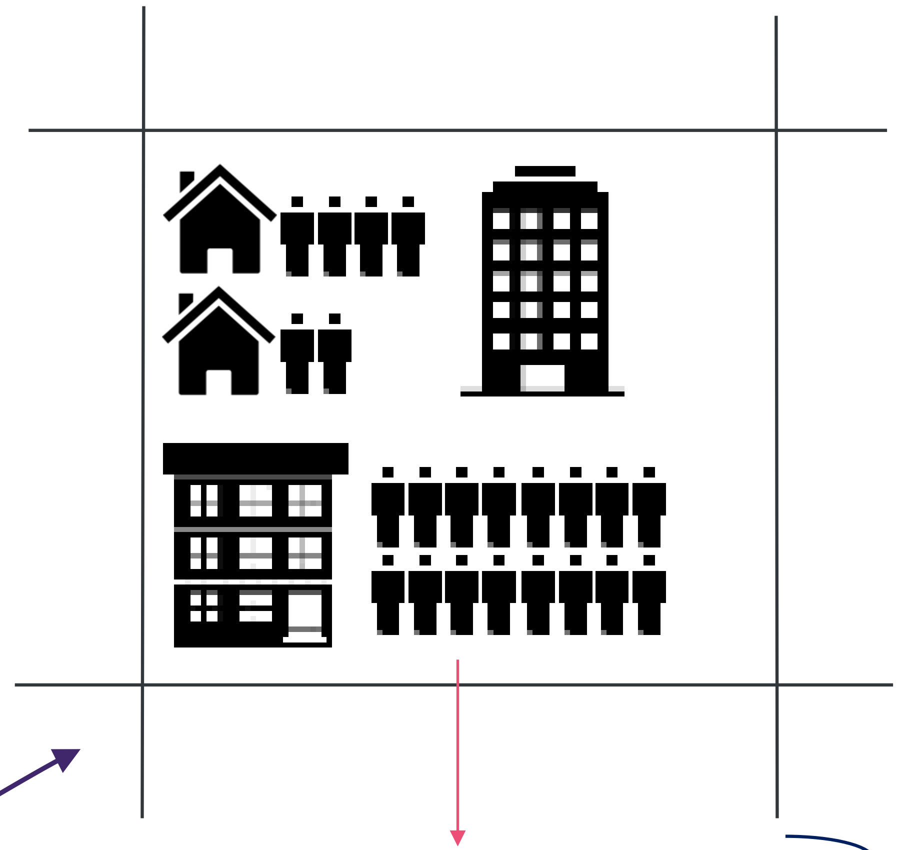
Aspects taken into account:

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

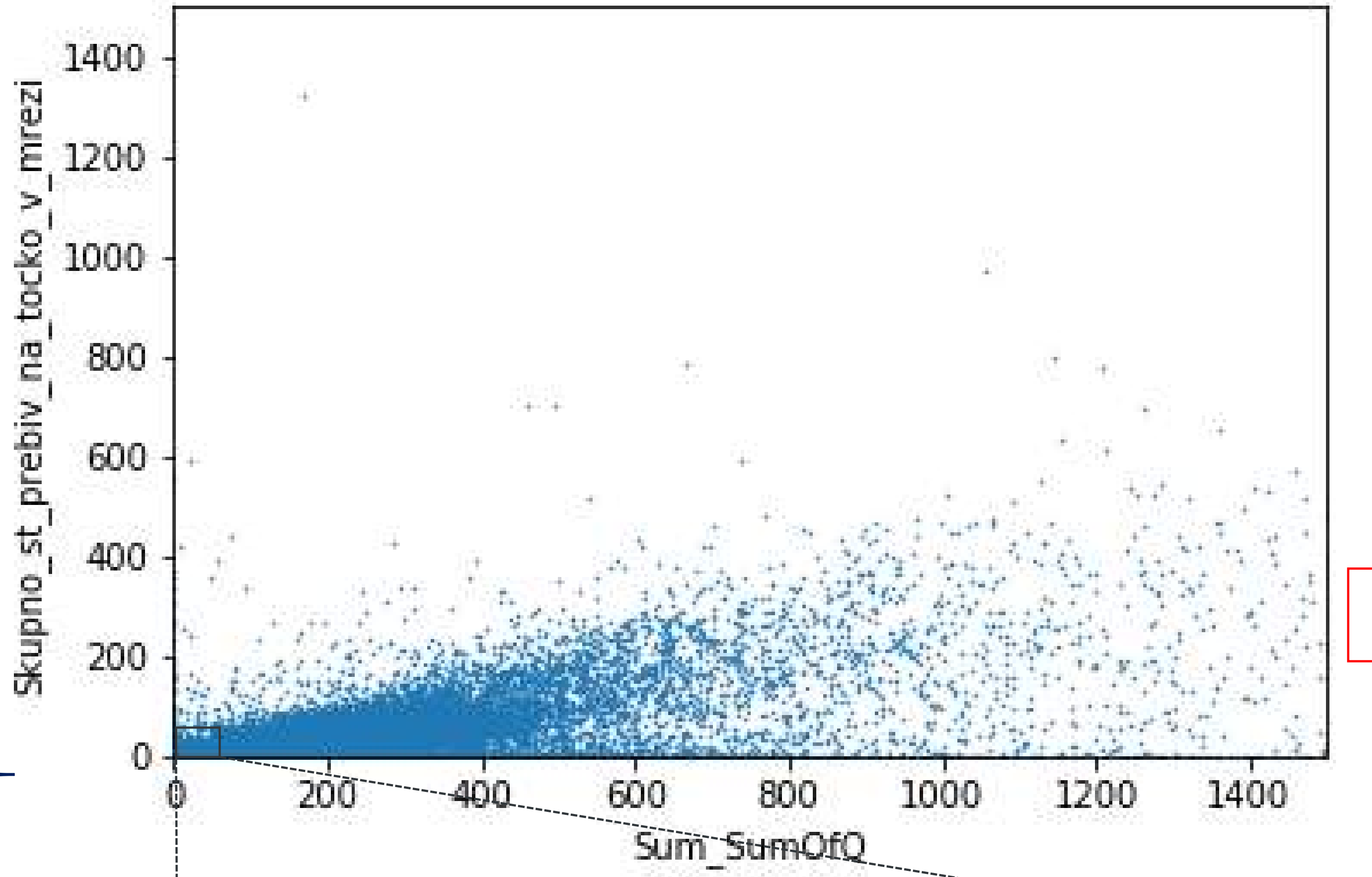
Calculation of energy indicators is executed with either results from EPC either building typology.

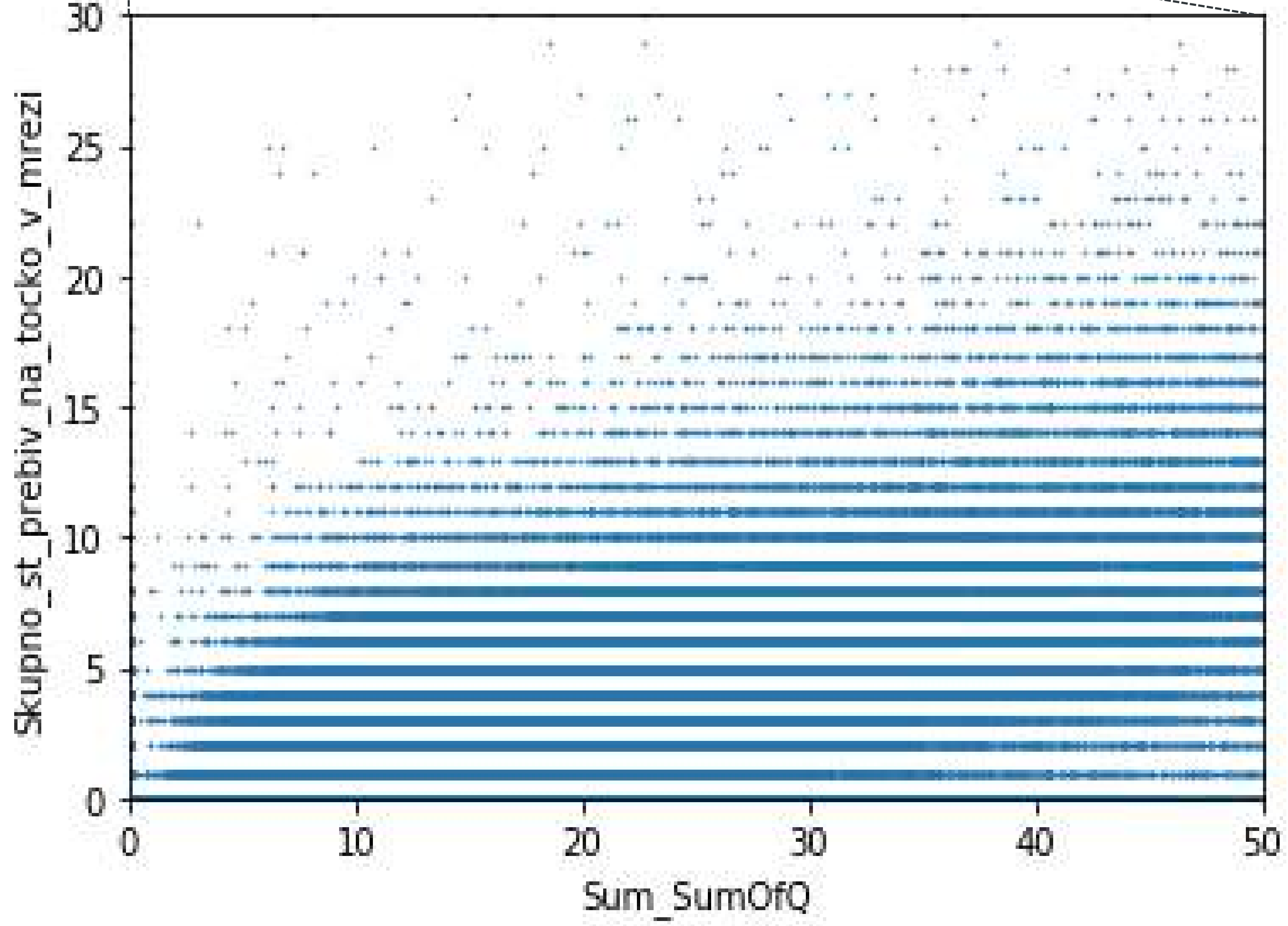
Projekt LIFE ClimatePath2050 (LIFE16 GIC/SI/000043) je financiran iz finančnega mehanizma LIFE, ki ga upravlja Evropska komisija, in iz Sklada za podnebne spremembe Ministrstva za okolje in prostor RS.

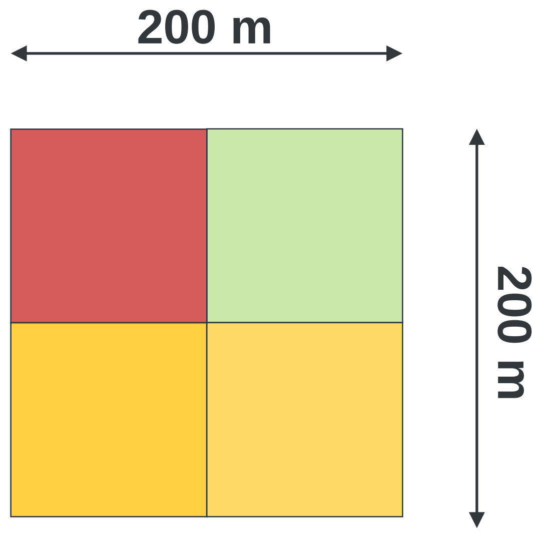
"Bottom-up" approach



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)
čnega mehanizma LIFE, ki ga
;ija, in iz Sklada za podnebne
rstva za okolje in prostor RS.

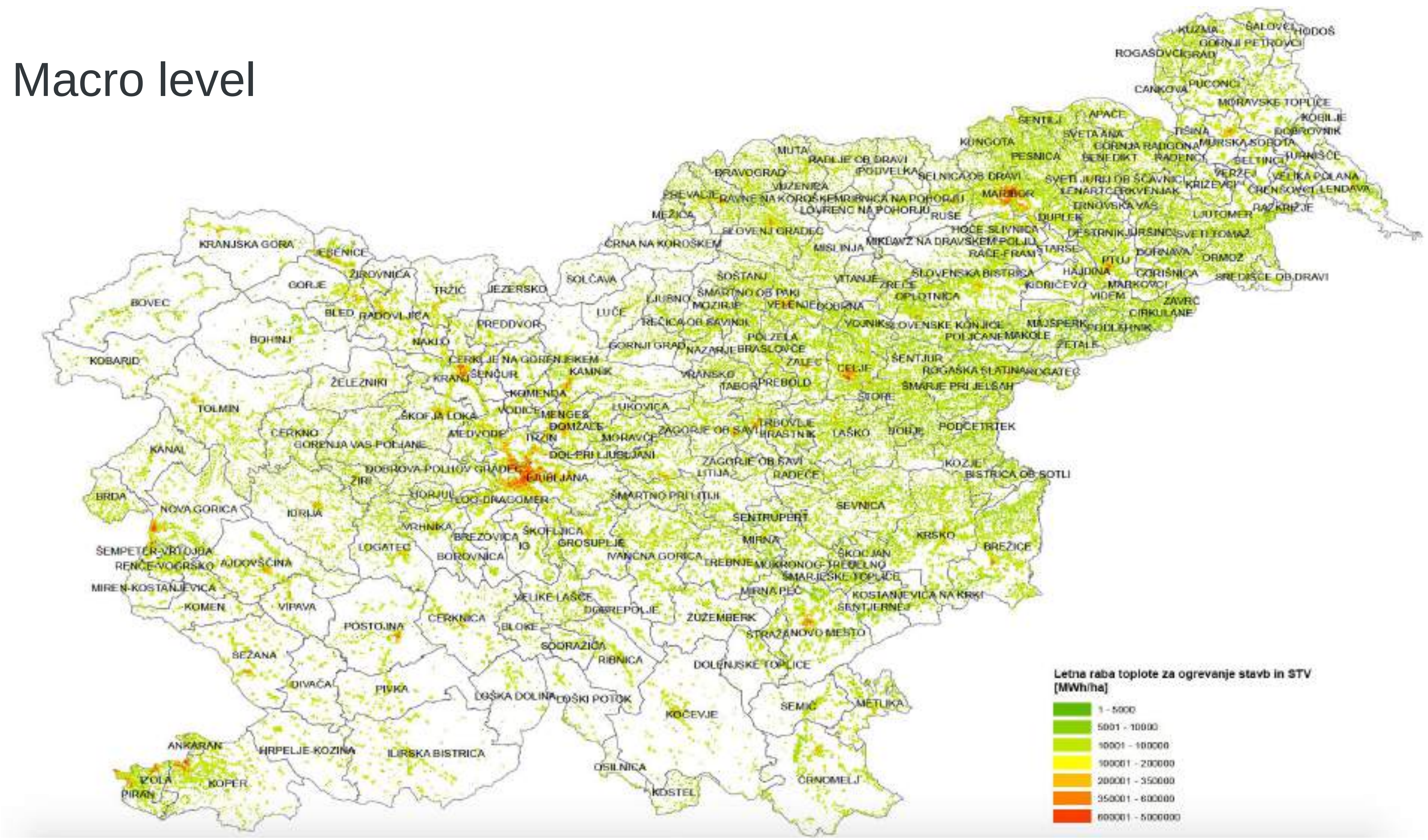
Modelling approach

1. Calculation of building‘s energy performance
2. **Creation of heat maps**
3. Evaluation of existing DH infrastructure
4. Evaluation of DH expansion potential today and in 2050
5. Analysis and evaluation of (local) energy potential
6. Application of DH model expansion
7. Calculation of investment‘s cost efficiency
8. Data aggregation and projections

Heat map of Slovenia

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

Macro level



Projekt LIFE ClimatePath2050 (LIFE16 GIC/SI/000043) je financiran iz finančnega mehanizma LIFE, ki ga upravlja Evropska komisija, in iz Sklada za podnebne spremembe Ministrstva za okolje in prostor RS.

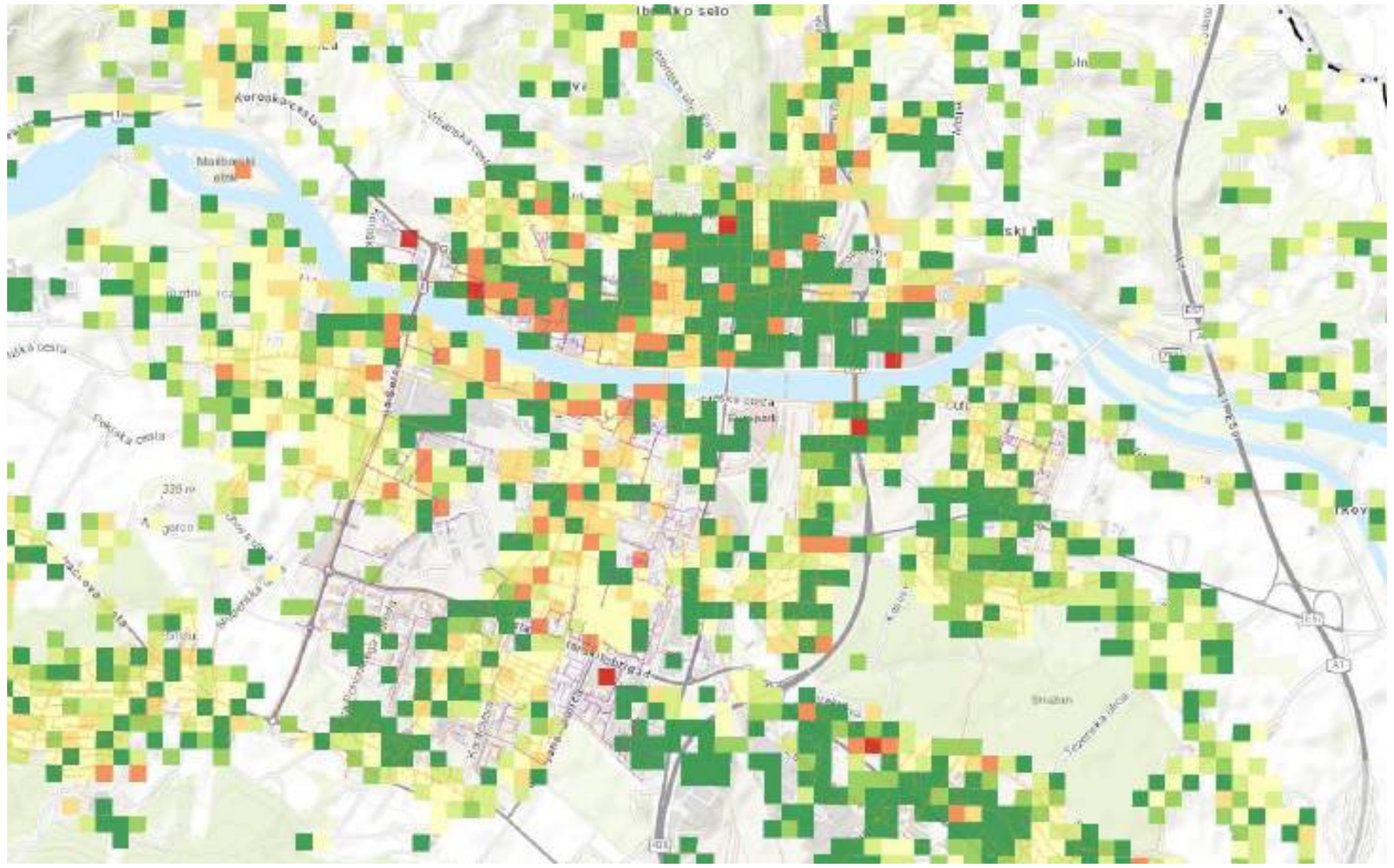
Modelling approach

1. Calculation of building's energy performance
2. **Creation of heat maps**
3. Evaluation of existing DH infrastructure
4. Evaluation of DH expansion potential today and in 2050
5. Analysis and evaluation of (local) energy potential
6. Application of DH model expansion
7. Calculation of investment's cost efficiency
8. Data aggregation and projections

Heat map of Slovenia

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

Micro level



Projekt LIFE ClimatePath2050 (LIFE16 GIC/SI/000043) je financiran iz finančnega mehanizma LIFE, ki ga upravlja Evropska komisija, in iz Sklada za podnebne spremembe Ministrstva za okolje in prostor RS.

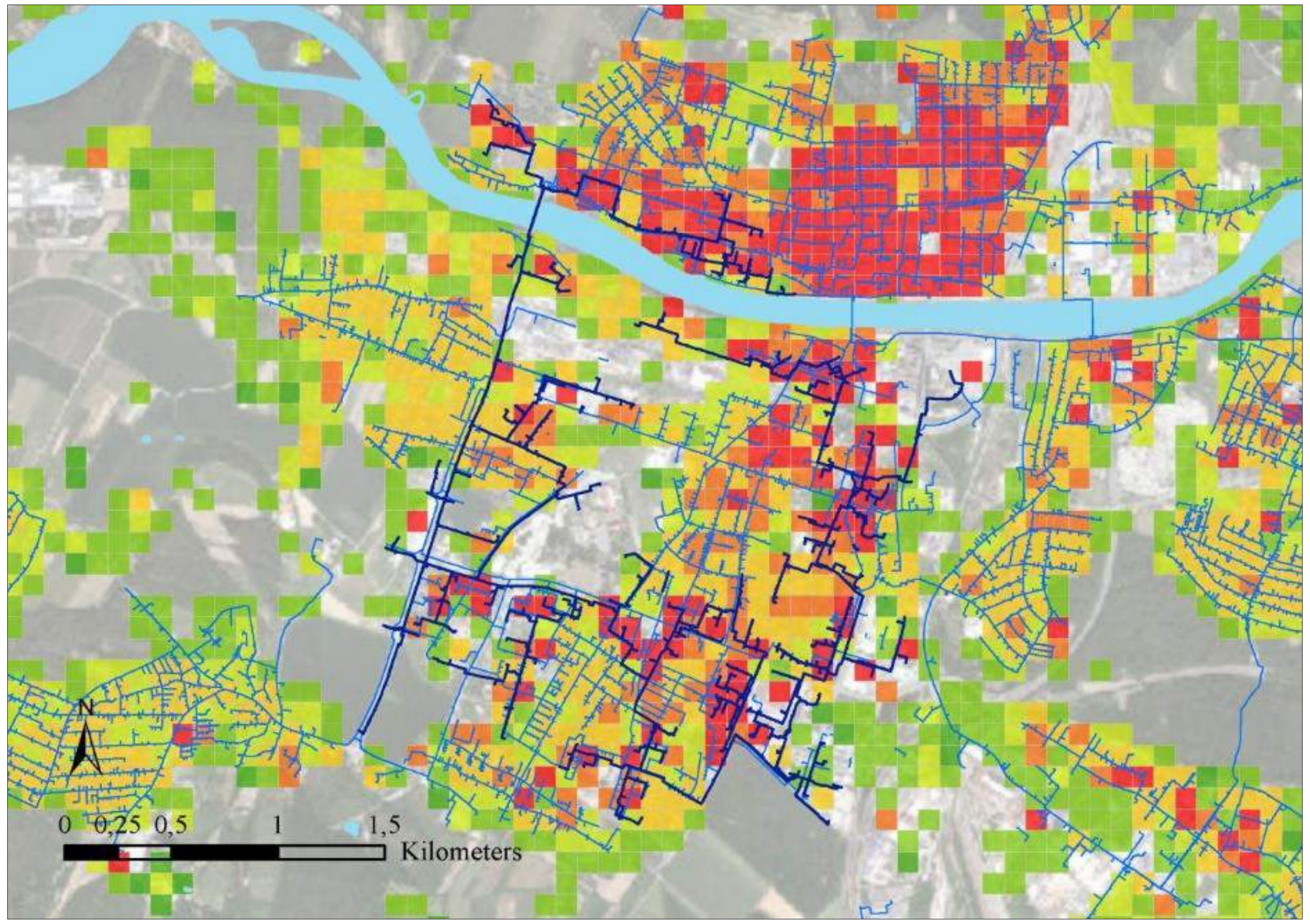
Modelling approach

1. Calculation of building‘s energy performance
2. Creation of heat maps
3. **Evaluation of existing DH infrastructure**
4. Evaluation of DH expansion potential today and in 2050
5. Analysis and evaluation of (local) energy potential
6. Application of DH model expansion
7. Calculation of investment‘s cost efficiency
8. Data aggregation and projections

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



Projekt LIFE ClimatePath2050 (LIFE16 GIC/SI/000043) je financiran iz finančnega mehanizma LIFE, ki ga upravlja Evropska komisija, in iz Sklada za podnebne spremembe Ministrstva za okolje in prostor RS.

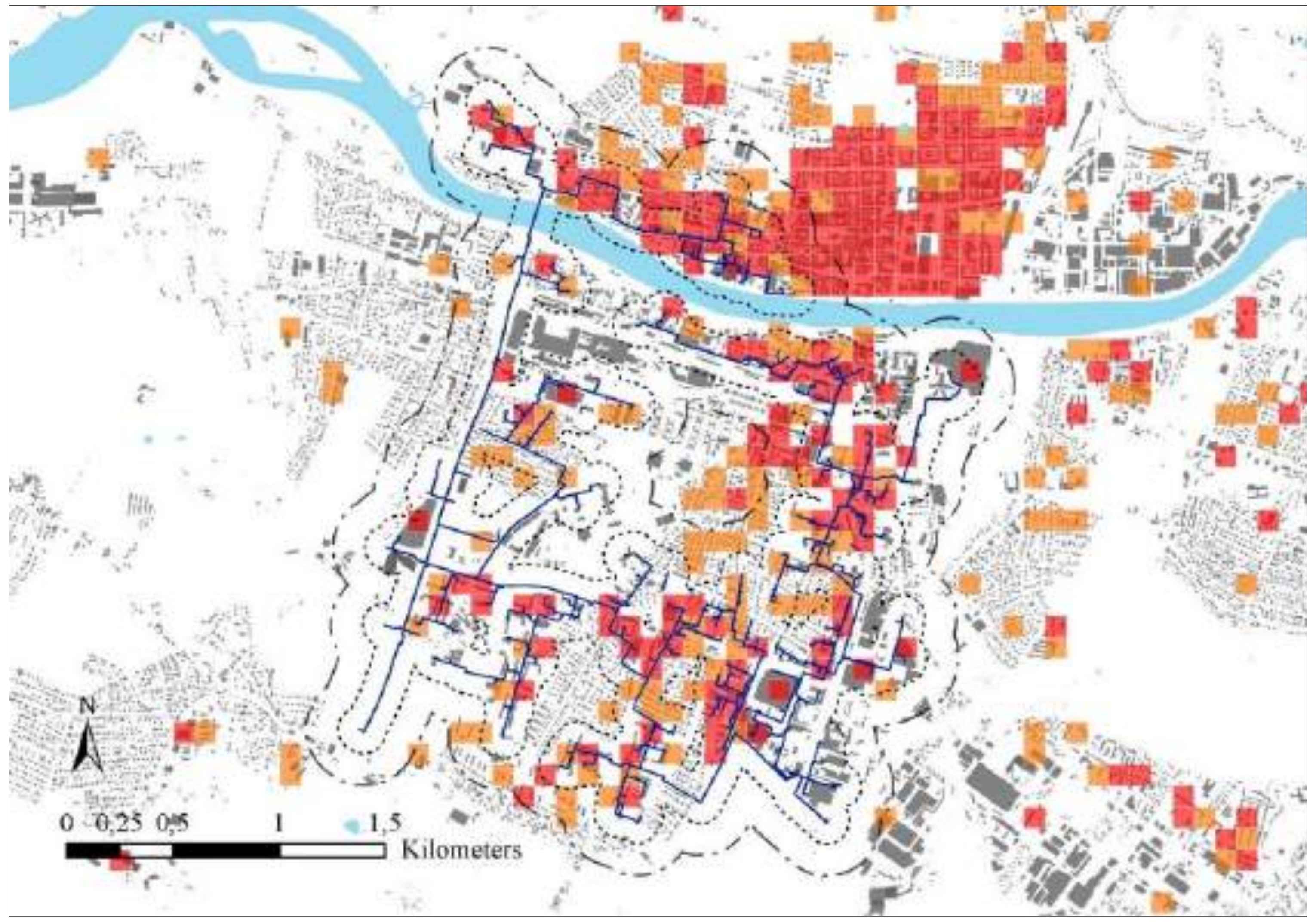
Modelling approach

1. Calculation of building‘s energy performance
2. Creation of heat maps
3. Evaluation of existing DH infrastructure
4. **Evaluation of DH expansion potential today and in 2050**
5. Analysis and evaluation of (local) energy potential
6. Application of DH model expansion
7. Calculation of investment‘s cost efficiency
8. Data aggregation and projections

Expanding the network

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

Expansion of DH infrastructure in Maribor and Kranj



Projekt LIFE ClimatePath2050 (LIFE16 GIC/SI/000043) je financiran iz finančnega mehanizma LIFE, ki ga upravlja Evropska komisija, in iz Sklada za podnebne spremembe Ministrstva za okolje in prostor RS.

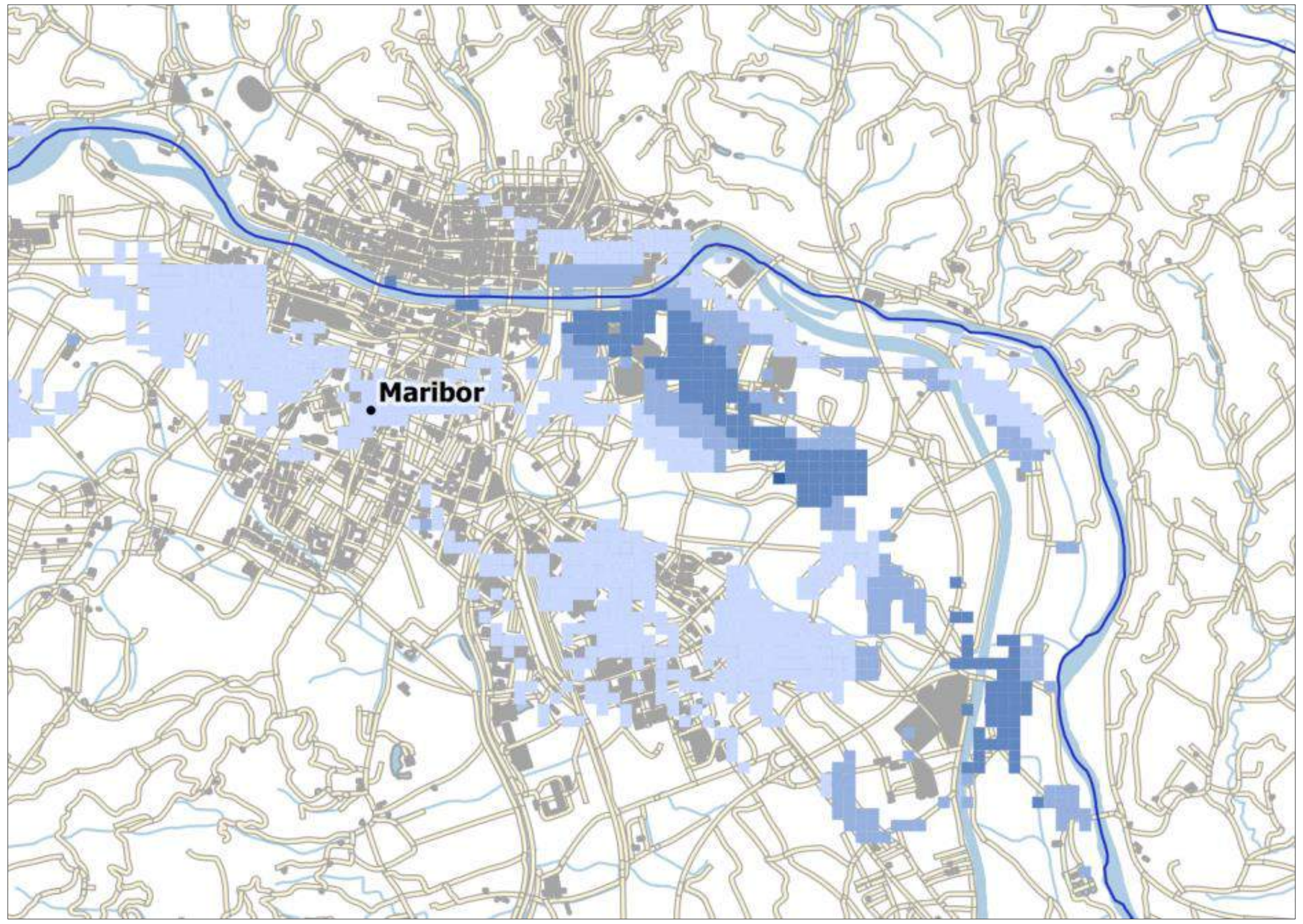
Modelling approach

1. Calculation of building‘s energy performance
2. Creation of heat maps
3. Evaluation of existing DH infrastructure
4. Evaluation of DH expansion potential today and in 2050
5. **Analysis and evaluation of (local) energy potential**
6. Application of DH model expansion
7. Calculation of investment‘s cost efficiency
8. Data aggregation and projections

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



Projekt LIFE ClimatePath2050 (LIFE16 GIC/SI/000043) je financiran iz finančnega mehanizma LIFE, ki ga upravlja Evropska komisija, in iz Sklada za podnebne spremembe Ministrstva za okolje in prostor RS.

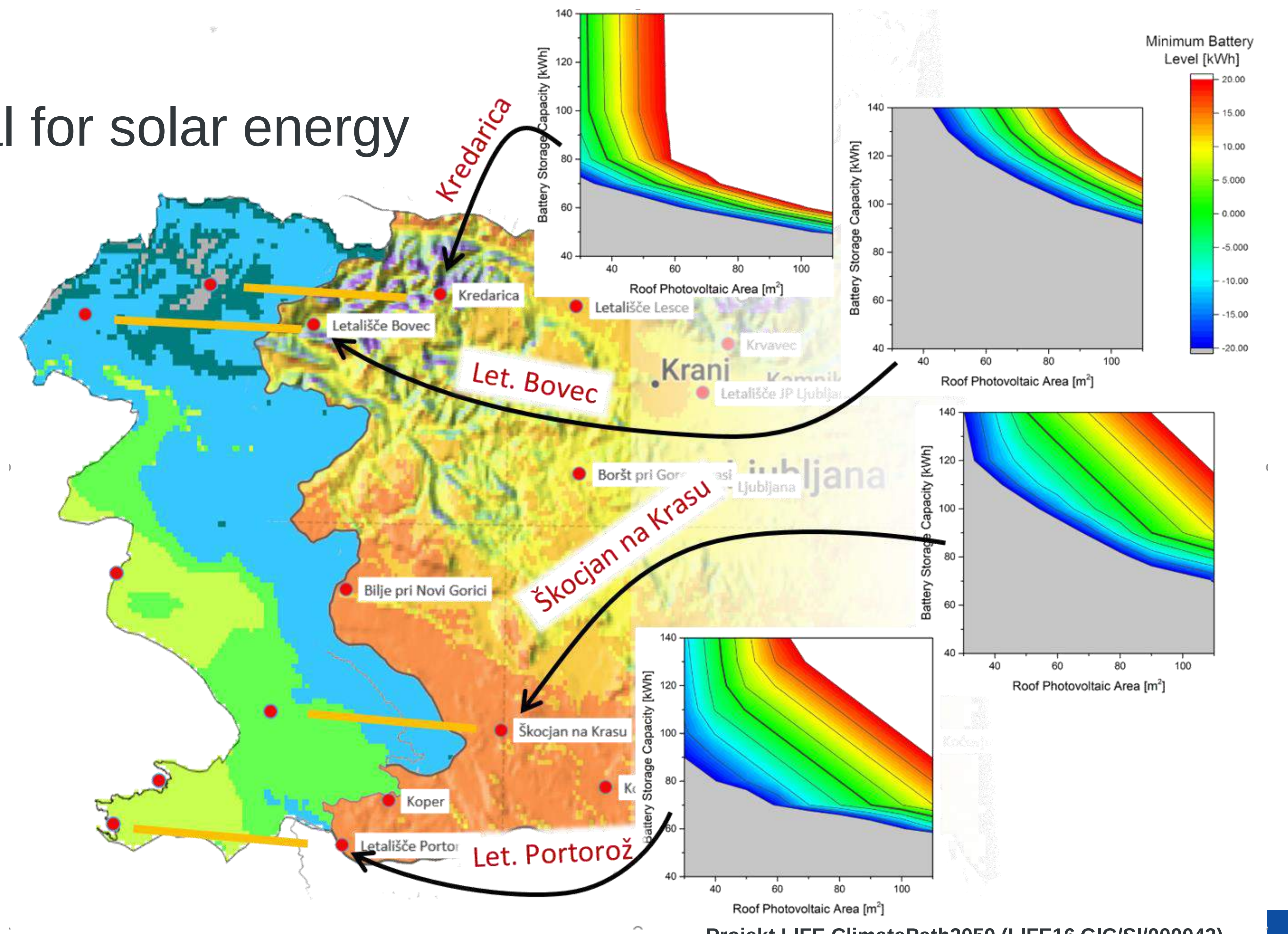
Modelling approach

1. Calculation of building‘s energy performance
2. Creation of heat maps
3. Evaluation of existing DH infrastructure
4. Evaluation of DH expansion potential today and in 2050
5. **Analysis and evaluation of (local) energy potential**
6. Application of DH model expansion
7. Calculation of investment‘s cost efficiency
8. Data aggregation and projections

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 solar energy



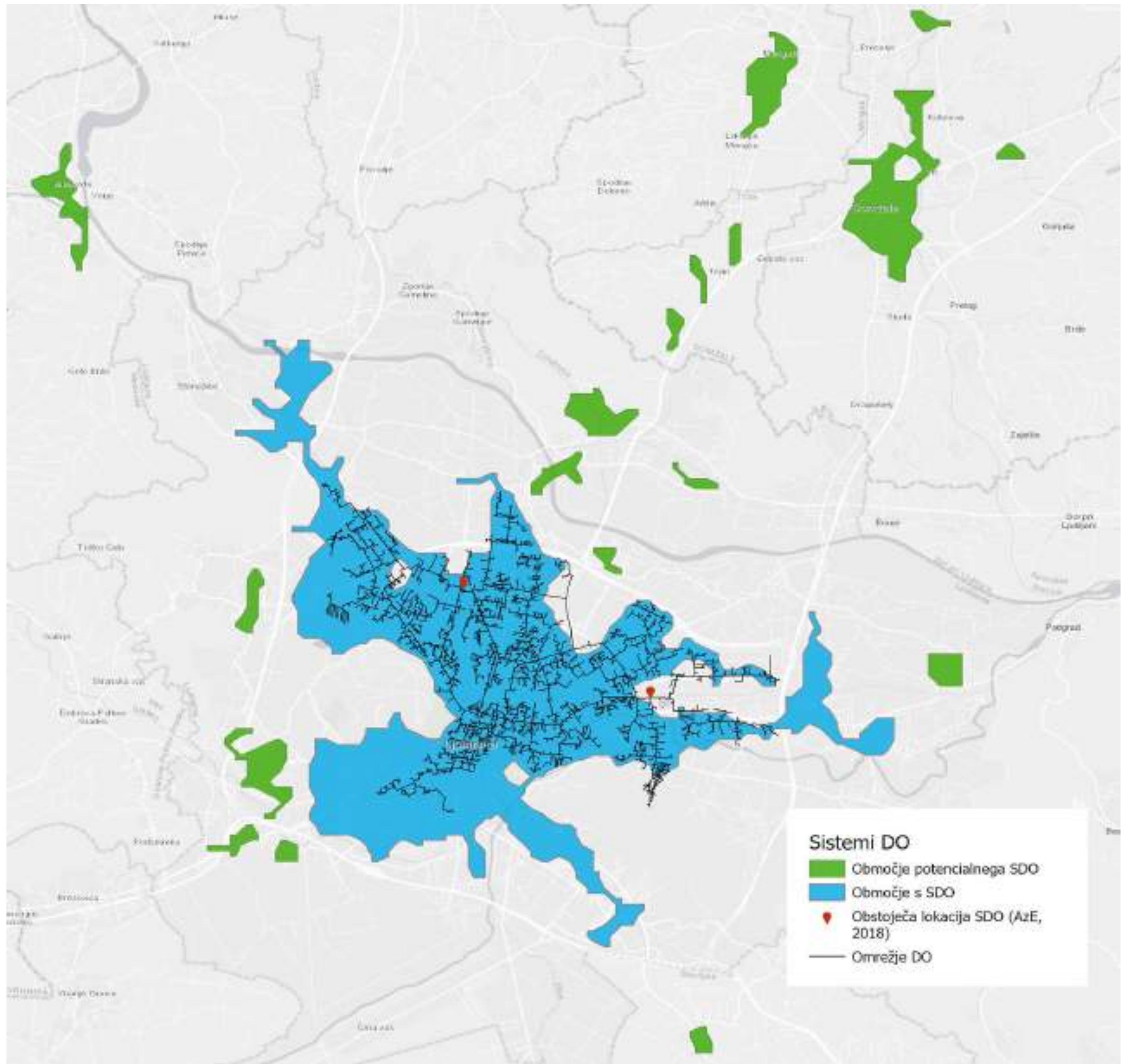
Projekt LIFE ClimatePath2050 (LIFE16 GIC/SI/000043) je financiran iz finančnega mehanizma LIFE, ki ga upravlja Evropska komisija, in iz Sklada za podnebne spremembe Ministrstva za okolje in prostor RS.

Modelling approach

1. Calculation of building‘s energy performance
2. Creation of heat maps
3. Evaluation of existing DH infrastructure
4. Evaluation of DH expansion potential today and in 2050
5. Analysis and evaluation of (local) energy potential
6. **Application of DH model expansion**
7. Calculation of investment‘s cost efficiency
8. Data aggregation and projections

Step 1: Technical potential

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



Projekt LIFE ClimatePath2050 (LIFE16 GIC/SI/000043) je financiran iz finančnega mehanizma LIFE, ki ga upravlja Evropska komisija, in iz Sklada za podnebne spremembe Ministrstva za okolje in prostor RS.

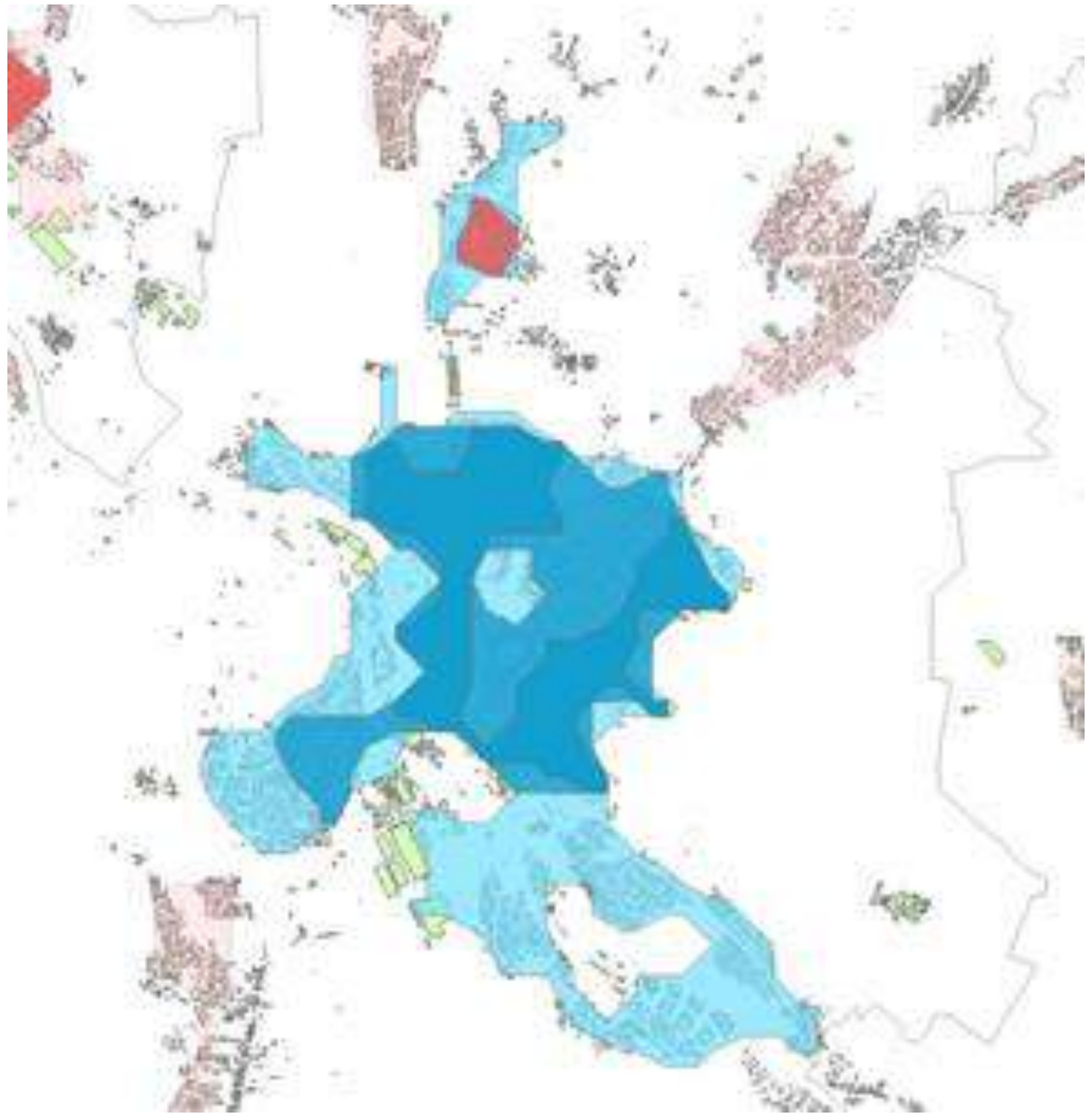
Modelling approach

1. Calculation of building‘s energy performance
2. Creation of heat maps
3. Evaluation of existing DH infrastructure
4. Evaluation of DH expansion potential today and in 2050
5. Analysis and evaluation of (local) energy potential
6. **Application of DH model expansion**
7. Calculation of investment‘s cost efficiency
8. Data aggregation and projections

Step 1: Technical potential

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

But, is it cost efficient?



Projekt LIFE ClimatePath2050 (LIFE16 GIC/SI/000043) je financiran iz finančnega mehanizma LIFE, ki ga upravlja Evropska komisija, in iz Sklada za podnebne spremembe Ministrstva za okolje in prostor RS.

Modelling approach

1. Calculation of building's energy performance
2. Creation of heat maps
3. Evaluation of existing DH infrastructure
4. Evaluation of DH expansion potential today and in 2050
5. Analysis and evaluation of (local) energy potential
6. Application of DH model expansion
7. **Calculation of cost efficiency for new DH systems**
8. Data aggregation and projections

Cost efficiency

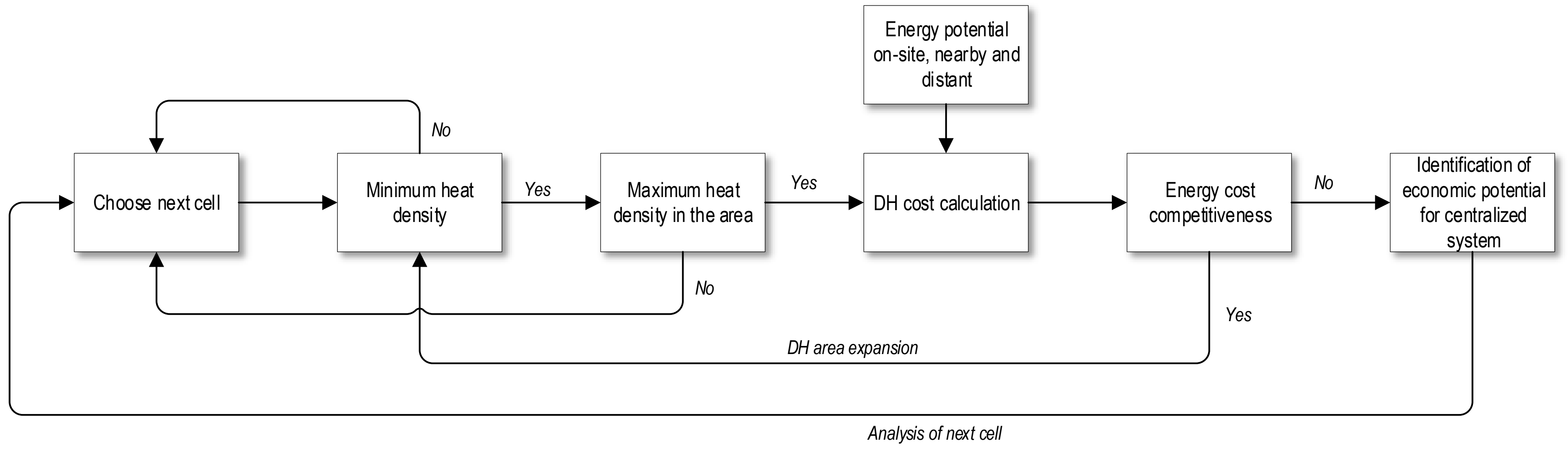
Areas with potential:
HEAT DENSITY > 100 – 200 – 350 MWh/ha

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)

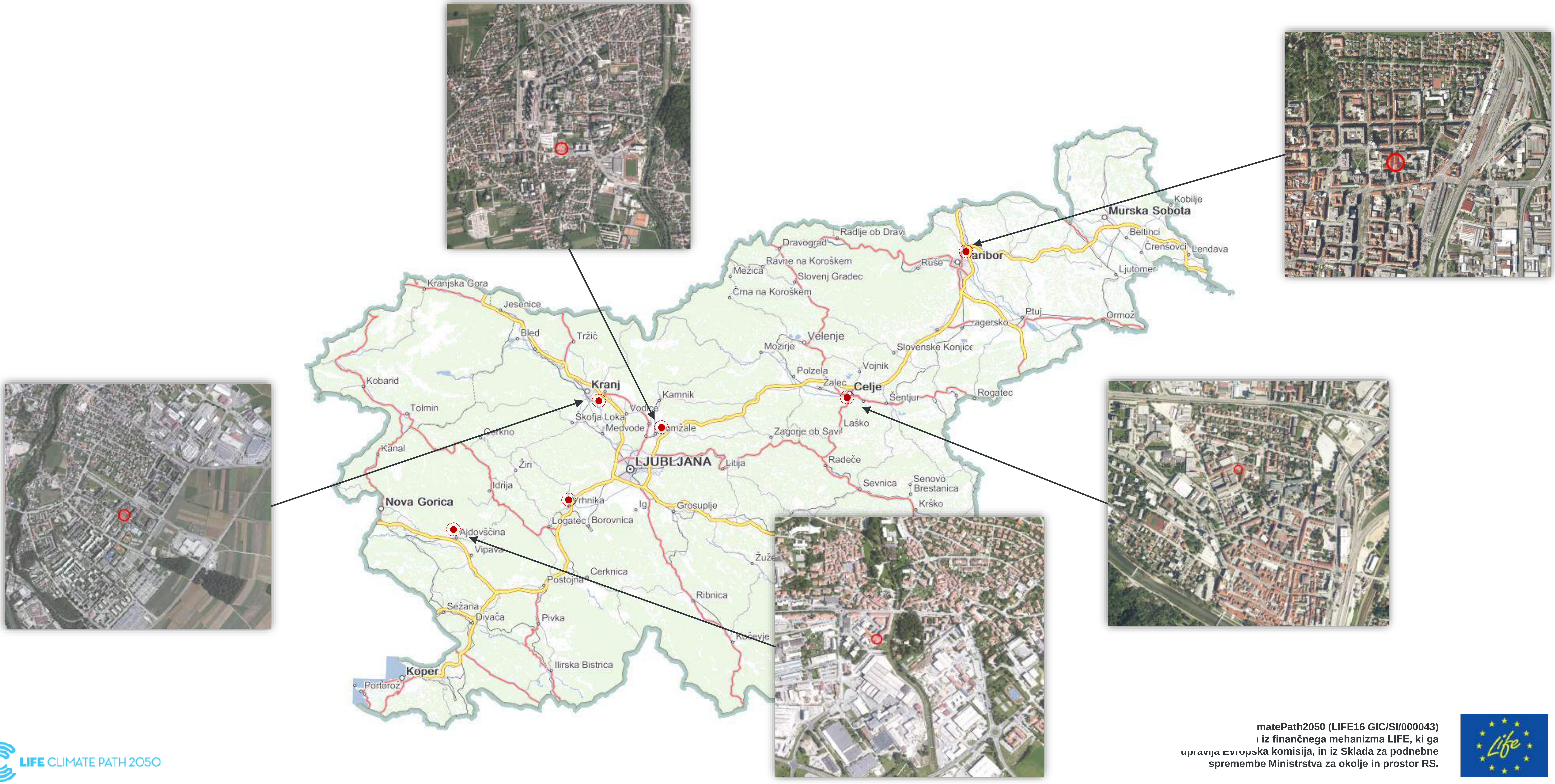
Competitiveness: LCC comparison with the cheapest and "clean" technology available in dense (HP air-water) and sparsely (HP air-water and biomass boiler) populated areas

Level of detail: 100 x 100m area



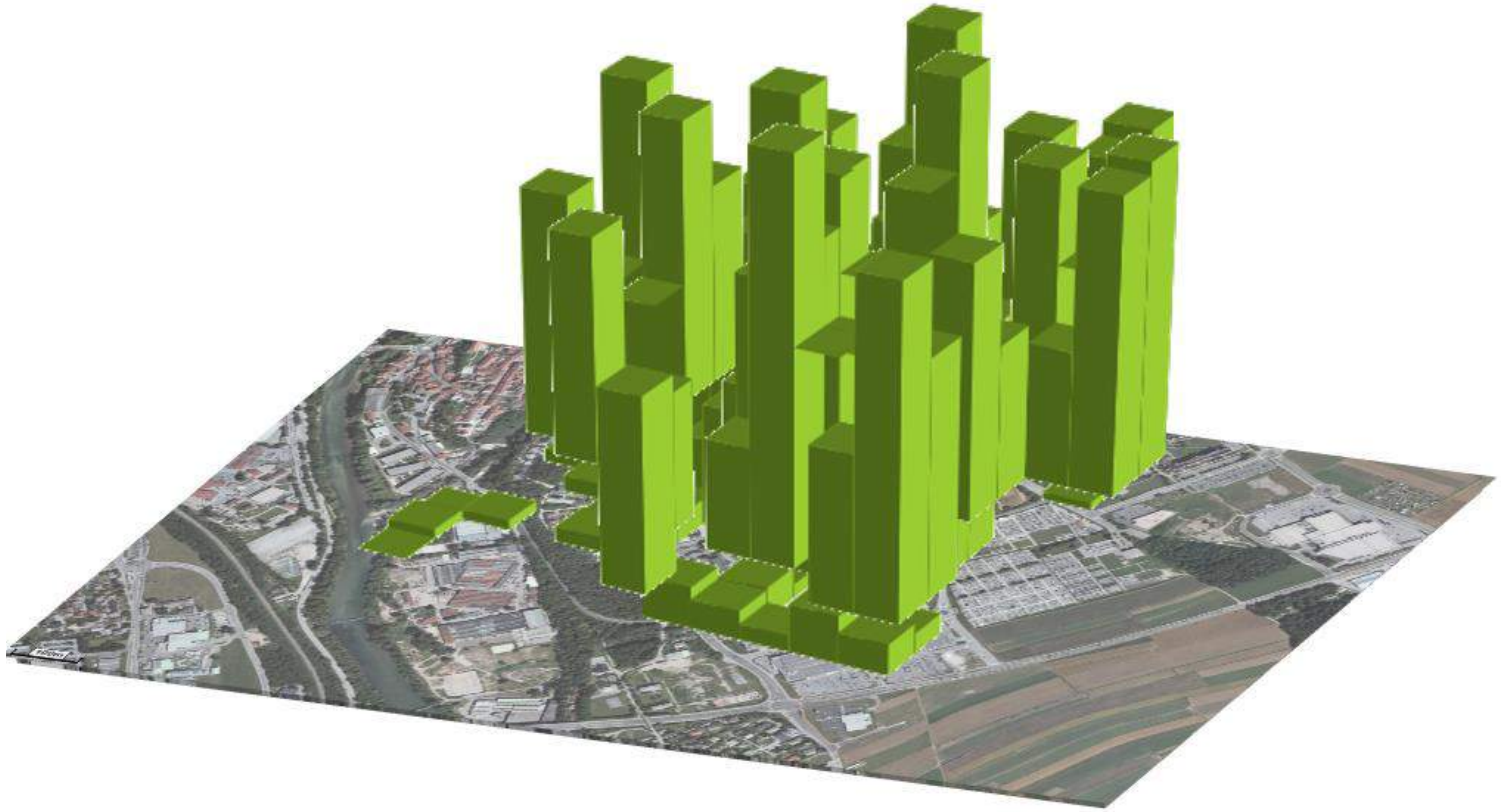
Projekt LIFE ClimatePath2050 (LIFE16 GIC/SI/000043) je financiran iz finančnega mehanizma LIFE, ki ga upravlja Evropska komisija, in iz Sklada za podnebne spremembe Ministrstva za okolje in prostor RS.

DH potential for new DH systems in Slovenia



matePath2050 (LIFE16 GIC/SI/000043)
ı iz finančnega mehanizma LIFE, ki ga
upravlja Evropska komisija, in iz Sklada za podnebne
spremembe Ministrstva za okolje in prostor RS.

Mapping for advanced local planning



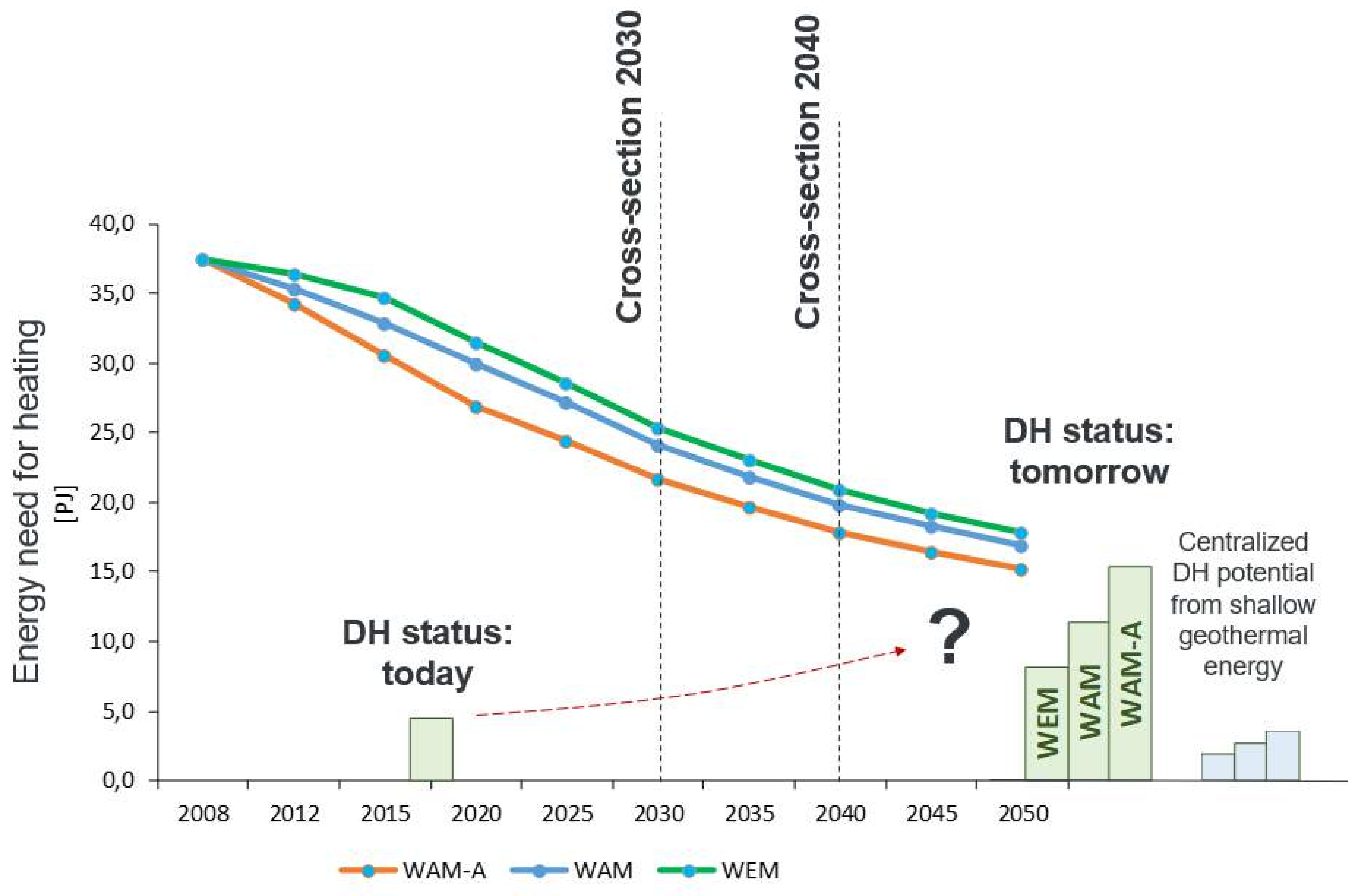
Projekt LIFE ClimatePath2050 (LIFE16 GIC/SI/000043)
je financiran iz finančnega mehanizma LIFE, ki ga
upravlja Evropska komisija, in iz Sklada za podnebne
spremembe Ministrstva za okolje in prostor RS.

Modelling approach

1. Calculation of building‘s energy performance
2. Creation of heat maps
3. Evaluation of existing DH infrastructure
4. Evaluation of DH expansion potential today and in 2050
5. Analysis and evaluation of (local) energy potential
6. Application of DH model expansion
7. Calculation of investment‘s cost efficiency
8. **Data aggregation and projections**

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.



LIFE CLIMATE PATH 2050

Projekt LIFE ClimatePath2050 (LIFE16 GIC/SI/000043) je financiran iz finančnega mehanizma LIFE, ki ga upravlja Evropska komisija, in iz Sklada za podnebne spremembe Ministrstva za okolje in prostor RS.

Modelling approach

1. Calculation of building's energy performance
2. Creation of heat maps
3. Evaluation of existing DH infrastructure
4. Evaluation of DH expansion potential today and in 2050
5. Analysis and evaluation of (local) energy potential
6. Application of DH model expansion
7. Calculation of investment's cost efficiency
8. **Data aggregation and projections**

New DH systems

Potential for **new** DH and micro DH areas in Slovenia with focus on exploitation of shallow geothermal potential.

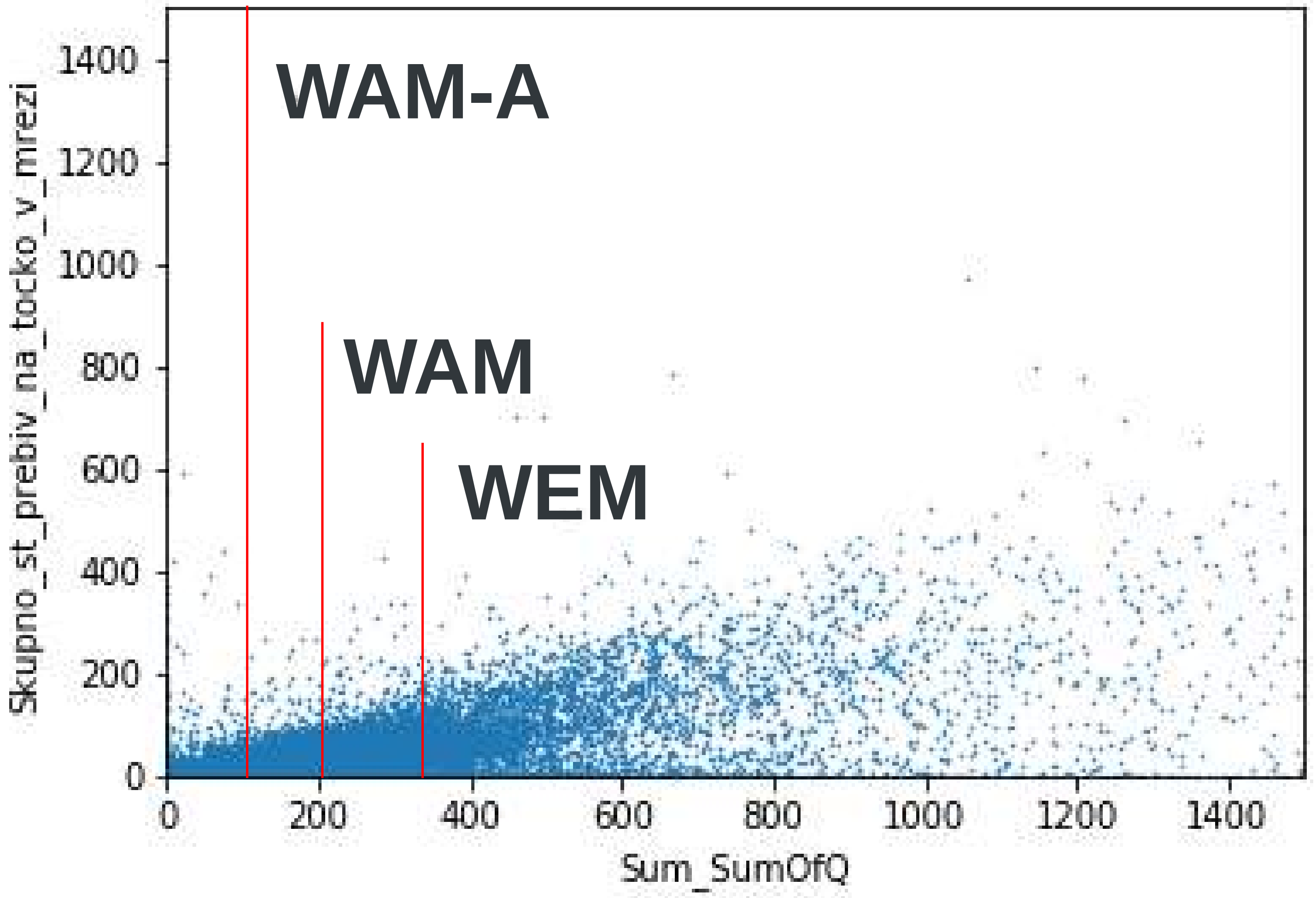
Area	Unit	Technical potential	Economic potential for shallow geothermal systems	Heat demand
DH	TWh/a	45.17	0.1	2.6
Micro DH	TWh/a	4.36	0.9	2.4

Projekt LIFE ClimatePath2050 (LIFE16 GIC/SI/000043) je financiran iz finančnega mehanizma LIFE, ki ga upravlja Evropska komisija, in iz Sklada za podnebne spremembe Ministrstva za okolje in prostor RS.

DH expansion potential

Tip stavbe	D/S	Stanje DO	WEM	WAM	WAM-A
Single family buildings	D	OS	18%		
		OS + nVS	19%	20%	25%
		OS + nVS + nMS	19%	21%	35%
Multi family buildings	D	OS	56%		
		OS + nVS	64%	73%	78%
		OS + nVS + nMS	66%	78%	87%
Public buildings	D	OS	48%		
		OS + nVS	49%	51%	52%
		OS + nVS + nMS	51%	53%	56%
Commercial buildings	D	OS	43%		
		OS + nVS	45%	49%	50%
		OS + nVS + nMS	47%	52%	59%

OS - Existing DH + expansions
nVS - New DH systems
nMS - New micro DH systems

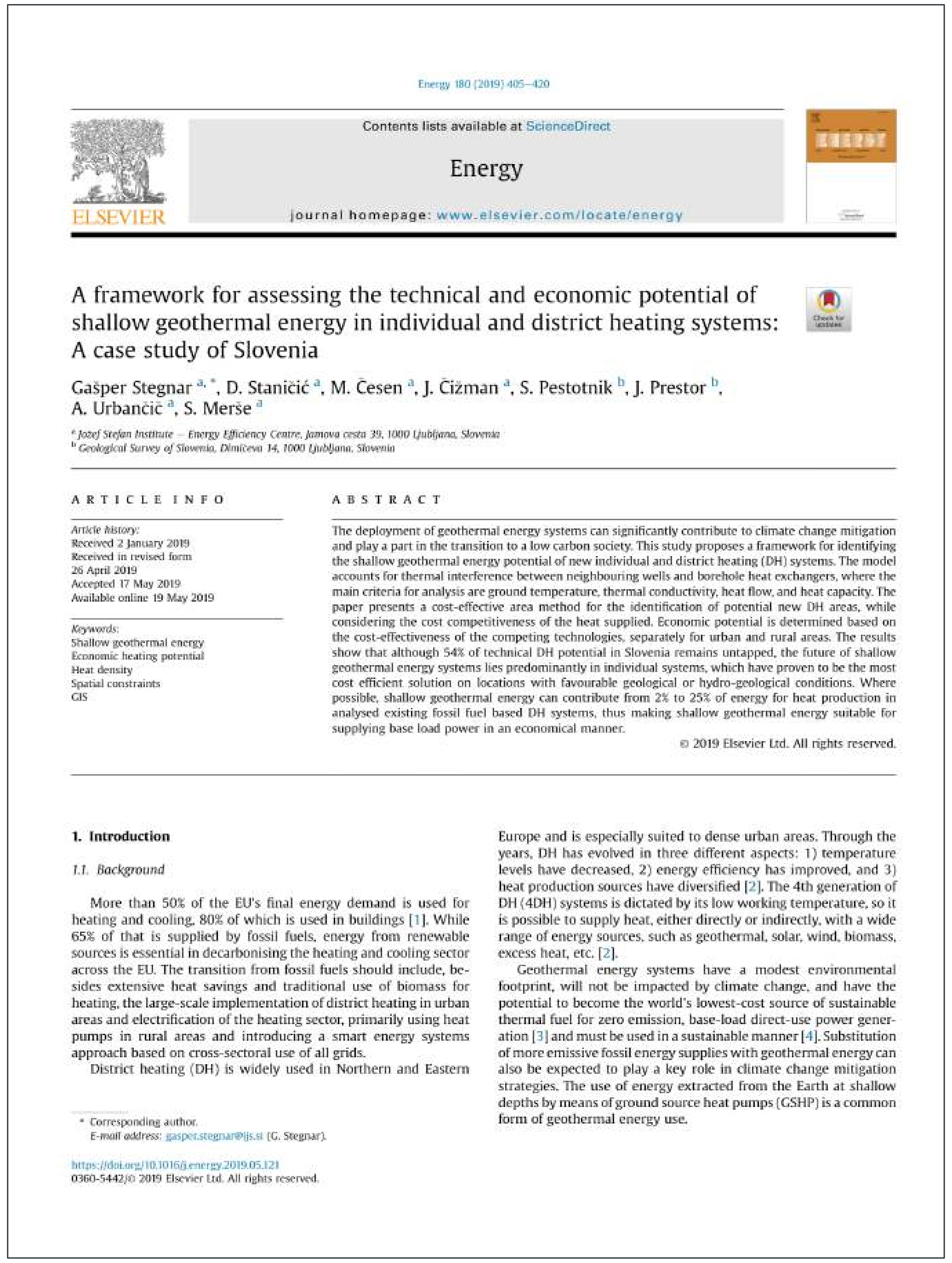


Projekt LIFE ClimatePath2050 (LIFE16 GIC/SI/000043) je financiran iz finančnega mehanizma LIFE, ki ga upravlja Evropska komisija, in iz Sklada za podnebne spremembe Ministrstva za okolje in prostor RS.

DH MODEL – exploitation of results

The DH model and its methodology main results:

- were presented 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.*
- won a 3rd place at „DHC+ PhD Student Awards highlight for outstanding and original contributions to District Heating and Cooling related research“ and presented in Nantes, France at Euroheat & Power congress in 2019.


Energy 180 (2019) 405–420

Contents lists available at ScienceDirect

Energy

journal homepage: www.elsevier.com/locate/energy

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

Gašper Stegnar [a,*], D. Staničić [a], M. Česen [a], J. Čižman [a], S. Pestotnik [b], J. Prestor [b], A. Urbančič [a], S. Merše [a]

[a] Jožef Stefan Institute – Energy Efficiency Centre, Jamova cesta 39, 1000 Ljubljana, Slovenia
[b] Geological Survey of Slovenia, Dimičeva 14, 1000 Ljubljana, Slovenia

ARTICLE INFO

Article history:
Received 2 January 2019
Received in revised form 26 April 2019
Accepted 17 May 2019
Available online 19 May 2019

Keywords:
Shallow geothermal energy
Economic heating potential
Heat density
Spatial constraints
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.

* Corresponding author.
E-mail address: gasper.stegnar@ijs.si (G. Stegnar).

https://doi.org/10.1016/j.energy.2019.05.121
0360-5442/© 2019 Elsevier Ltd. All rights reserved.

Projekt LIFE ClimatePath2050 (LIFE16 GIC/SI/000043) je financiran iz finančnega mehanizma LIFE, ki ga upravlja Evropska komisija, in iz Sklada za podnebne spremembe Ministrstva za okolje in prostor RS.

Thank you!

Contact: gasper.stegnar@ijs.si

Projekt LIFE ClimatePath2050 (LIFE16 GIC/SI/000043)
je financiran iz finančnega mehanizma LIFE, ki ga
upravlja Evropska komisija, in iz Sklada za podnebne
spremembe Ministrstva za okolje in prostor RS.