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Interreg North-West Europe
DGE-ROLLOUT

Socio-economic potential mapping for Deep Geothermal Energy (Flanders)

Deliverable T1.2.3

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Disclaimer

The purpose of the following report is to give a short overview of the aspect that has been defined as a milestone in the socio/economic mapping potential inside the DGE Roll-out project. It should provide general information to local, regional, and national public authorities, project developers, politicians and enterprises with heat demand. However, this report does not replace the own independent research on this topic. Appropriate legal advice should be obtained in actual situations.

The recommendations given herein are the authors' subjective opinions based on the research which has been done for this report. It does not rely on experience during drilling or seismic exploration in the field. It mainly sums up the opinion of experienced project partners and actual goals in contributing as much as possible to stop climate change.

We cannot guarantee the accuracy, reliability, correctness or completeness of the information and materials given in this report and accept no legal responsibility. For further reading, please refer to the literature mentioned herein about the socio-economics aspect above mentioned.

Contents

Introduction

Climate change is a global concern that requires regional action. Northwest Europe aims to reduce CO_2 emissions through the transition from fossil fuels to renewable energy sources. The need for an opportunities overview is growing to meet the energy demand of the population and industry. The heat demand covers almost 50 % of the total energy demand. It can be substituted with geothermal energy. In this project, we focus on deep geothermal energy (DGE).

The success of DGE projects lies in an accurate estimation of the resources, considering geological and surface-level factors. The importance of evaluating both topics, social and reservoir factors, is described in the technical approach pyramid (Moeck, et al., 2020). It considers social and geological aspects in the exploration phase of geothermal projects and emphasizes the decisive surface and subsurface elements.

As part of the DGE-ROLLOUT project, deliverable 2.3 "Mapping of socio-economic potential for DGE" has been developed covering the decisive elements. Its aim is to inform the current socio-economic situation for new geothermal projects, considering the investor profile (van Melle, et al., 2021) and the heat demand (Fraunhofer IEG, 2021).

Inside the DGE ROLLOUT project, the economic aspects related to deep geothermal projects has been described and analysed in reports: WPT1 D3.1 Legal Framework (Van Malderen, 2020) and WPT1 D3.2 Financial Risk Management (Taşdemir & Arndt, 2020). These topics will not be covered in this report, so the reader is referred to them.

The report is a brief definition of the socio-economic factors and how they were defined for this project, the workflow for data compilation and the sources used - most of which are freely available. Each factor is accompanied by a map to visualize its spatial distribution in Flanders.

Socio-economic aspect in Geothermal Projects

The methodology for geothermal exploration is based on the existing one for hydrocarbons (Moeck & Beardsmore, 2014). The exploration phase distinguishes between geosystems, plays and prospects according size and detail of the geological model. The workflow suggested by Moeck (Moeck, et al., 2020) integrates the surfaces and subsurface parameters in groups to evaluate a geothermal project (Figure 1). The subsurface group is the geologic-technical focus pyramid with all the factors related to the reservoir. The geosystem includes the overall characterization of the reservoir rock, the play is an area of interest within the geosystem, and the prospect is the exploration target that will later be exploited. This process is called the scalability of the subsurface. The other group is the societal-technical focus pyramid, which characterizes the efficient use of these resources on the surface. Factors as demand, existing infrastructure and land access are considered. The next step is the determination of the project in the decision plane. The different possibilities of geothermal energy systems and the existing requirements, well documented, are analysed to match the best option. The socio-economic potential mapping report is a starting point, that is, a guide with the necessary information to communicate about the potential on the surface.

The difference between fossils and geothermal energy sources is at the surface, geothermal energy cannot be transported over long distances because of heat dissipation. Therefore, it becomes essential to know the surface conditions.

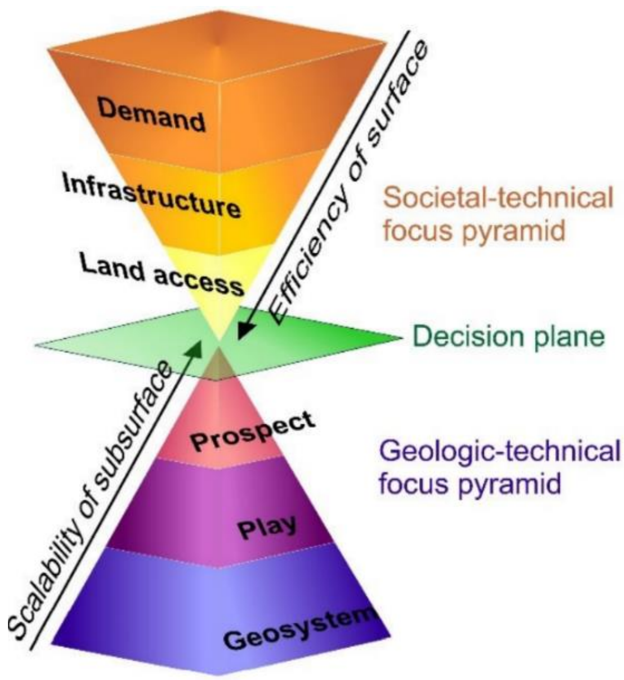

Figure 1 Decision-making factors to start a geothermal project, after (Moeck, et al., 2020).

The societal pyramid factors particularised are:

- Demand

  In the case of Northwest Europe (NWE), it can be classified in energy and heat demand, sector or end-user types, current supply and density population.

- Infrastructure

  This aspect holds the existing infrastructure to the distribution of energy or heat, for example, the district heating networks.

- Land access

  This factor includes data such as land ownership, environmental protection and culturally areas.

Additional to these considerations, the International Renewable Energy Agency (IRENA) incorporate other factors with a socio-economic focus. The Factors are related to the welfare improvements to the population and the environment such as reduction of gas emissions (International Renewable Energy Agency, 2017).

The importance is, for example, projects within regions with risk insurance or incentives could have a higher probability of investment. In the case of heat demand, it is necessary to be situated in an area with heat demand because geothermal energy is not suitable to be transported over long distances.

Methodology

The socio-economical factors to be considered in the geothermal project assessment can be established on diverse sources, based on literature, surveys and interviewing people involved in geothermal projects and policy (Chocobar, 2020). Those are methodologies widely used in social sciences to collect information and gathering the elements.

The methodology of this project was based on literature and surveys. The main categories Social, Economy and Environment are took from the literature, mainly the *societal pyramid factor* (Moeck, et al., 2020), *benefits for the society* (International Renewable Energy Agency, 2017) and *Identification of socio-technical factors within the play-based geothermal exploration process: Application and considerations in Central America* (Chocobar, 2020). Those categories are the typical groups for the factors involve in socio economic studies.

Socio-economic factors have been discussed with the different project partners. Their expertise in different phases of geothermal projects, from exploration to energy supply, is essential to select the correct parameters. Factors were defined by answering three questions:

- What information is needed to know about energy demand? e.g. population distribution and energy demand.
- What information is needed in general within the project proposal? e.g. infrastructure and regulation.
- What other factors could be related to the success of a DGE project? e.g. acceptance and investment.

In the social category were chosen factors that describe the community, the distribution of the population in the state, the heat demand, the percentage of employment-related to renewable energies, and the acceptance of renewable energies among the society. The economic category englobes the factors like income per capita, infrastructure (the existence of heating districts), the existence of investments in renewable energies or the existing regulations that promote or encourage the use of renewable energies. Finally, the environment category considers the current situation of factors that could be beneficial, such as greenhouse gas emissions reduction. Also, factors could limit the development of projects such as protected areas. The crucial factors defined in the DGE ROLLOUT project are summarized in Table 1. Not all of them were used for Flanders.

*Table 1 Categories and factors defined for the socio-economic analysis of geothermal projects. Factors used in this report (for Flanders) are indicated by *.*

Social	*Country information*	Population distribution*
		Heat demand*
		Employment / Forecast
		Social level map*
	Acceptance	Political parties map / Election maps
Economic	*Infrastructure*	District heating*
	Finance	Income*
		Level of debt of municipalities*
		Investment
Environmental	*Land access*	Land ownership
		Assigned land usage
		Environmentally sensitive areas*
	Greenhouse gas emissions	*

Collecting data

The data collection has been carried out through different official databases, such as those of the state statistical institutes, the official database or directly on the website of the mentioned institutions. The sources of information are divided into four groups that will be exposed below, three correspond to the categories (social, economic and environmental), and the fourth is the geographic data. It is the basis for the graphical representation of the information.

Social data

In this category are enclosed the aspects related to the population, including basic information of the region as population distribution and income. No data were collected on the impact of the geothermal energy projects (employment generation). The data come from databases managed by the Flemish authorities and available online at websites www.statistiekvlaanderen.be and gemeente-stadsmonitor.vlaanderen.be.

Economic data

The debt of the municipalities was considered important for the investment in renewable energies. Data can be found at www.statistiekvlaanderen.be.

Environmental data

On the environmental side, protected areas were taken from the Natura 2000 list, information which is available from another website from the Flemish authorities www.geopunt.be.

Geographic data

Flanders is divided into 5 provinces, subdivided into 22 arrondissements (35 districts), and counts 308 municipalities. These numbers exclude Brussels. The data, in general, is available in one of those levels of spatial resolution.

Socio-Economic Index

The different quantifiable factors of the socio-economic potential for deep geothermal energy were combined into a joint index. The factors population density, heat demand, social progress index, acceptance of renewable energies, availability of district heating networks, gross domestic product, public debt, environmentally sensitive areas and greenhouse gas emissions were considered. For the other components, a harmonized and spatially resolved data set is not available, which is why they are not included in the calculation of the index.

Detailed discussions of aggregation of various indicators is given e.g. in Lustig (2011), Decancq and Lugo (2013) and Annoni and Bolsi (2020). Following this, a simplistic approach is adopted in this report, where the composite index I is calculated via an unweighted generalized mean:

$$I = \left(\frac{1}{n}\sum_{i=1}^{n} x_i^{\beta}\right)^{\frac{1}{\beta}}$$

Where n is the total number of components, x_i is the i-th component of the socioeconomic potential, and the constant β describes the compensability between the individual components. A β of 1 corresponds to the arithmetic mean. In accordance with Annoni and Bolsi (2020), a β of 0.5 was used, being between the arithmetic and geometric means.

Before the factors can be combined, a normalization is necessary to scale the parameters between 0 and 100 (for some parameters, like the social progress indices or the acceptance, this is already the case). For this purpose, a min-max transformation was performed:

$$x_{norm} = \frac{100 * (x - x_{min})}{(x_{max} - x_{min})}$$

Respectively for the parameter public debt (high debt corresponds to low potential):

$$x_{norm} = 100 - \frac{100 * (x - x_{min})}{(x_{max} - x_{min})}$$

The minimum and maximum values are either based on the database or were defined individually. They are summarized in Table 2.

Table 2: Min/max values of some components for the normalization.

Factor	Unit	Minimum	Maximum
Population density	Ppl/km²	0	3352
Total heat demand of municipality	MWh/ha/yr	0	5200
Gross domestic product	€/cap/yr	23800	50600
Public debt per capita	€/cap	0	3587
Household carbon footprint	t(CO_2e)/cap	0	25

Results

The data collected in general are direct measurements of the selected factors. Sections are formed by the definition of the factor and its characteristics in Flanders. Maps have been created in QGIS, an open-source software dedicated to geospatial analysis. Some data are available in various sources at the Europe Union, country or state level. Preference was given to state sources as they have the highest spatial resolution of information. The version or date of data collection is the latest available.

Social

This category encloses the population characteristics in Flanders. Knowing the number of inhabitants or energy demand makes it possible to identify zones with potential for DGE projects due to the corresponding customer structures.

Population distribution

Flanders is a densely populated region, with over 6 Million citizens and an average population density of 492 people per km². The biggest cities are Antwerpen and Gent. The most densely populated part of Flanders is located in the center, covering the area between Antwerpen, Gent, Brussels and Leuven. This is where the main economic activity is located, with the ports of Antwerpen and Gent, Brussels Airport, and with lots of company offices, administrations and universities in Brussels, Antwerpen, Gent and Leuven. Hence a majority of people lives within these cities or within commuting distance. Population density is lower towards the West and East (provinces of West-Vlaanderen and Limburg), which are more rural or agricultural areas. The higher population density in Limburg (North and East of Hasselt) coincides with the former coal mining districts.

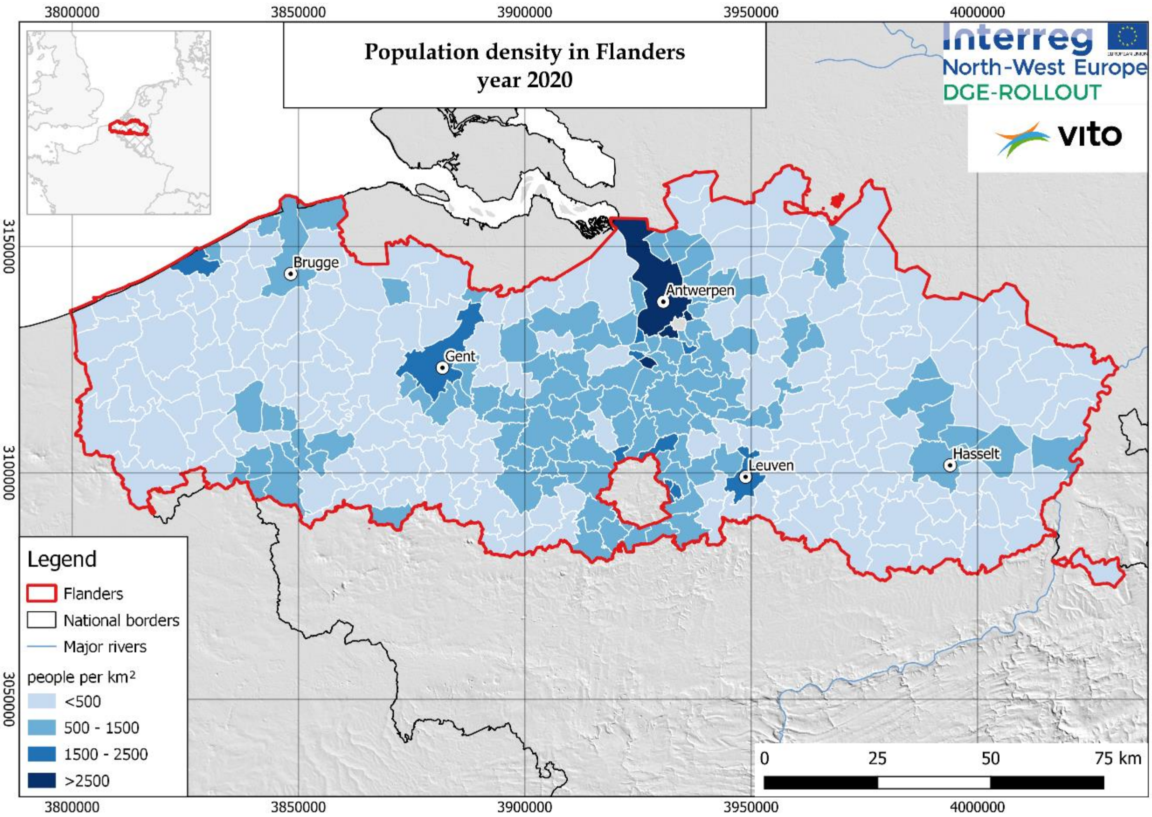

Figure 2 Population distribution in Flanders

Heat demand

The heat demand in Northwest Europe was described and analyzed in the DGE-ROLLOUT report "WP T1 - 2.1 Map of the spatial distribution of the heat demand at the surface" (Strozyk et al. 2021). The map was generated from heat demand (HD) data measured or calculated by each project region in North-West Europe and has a spatial resolution of 100 x 100 m². Input for Strozyk et al. (2021) comes from the Warmte in Vlaanderen report published by the Vlaamse Energie & Klimaatagentschap (2020).

Figure 3 shows the map of residential and tertiary sector heat demand for Flanders. The heat demand generally follows the population distribution.

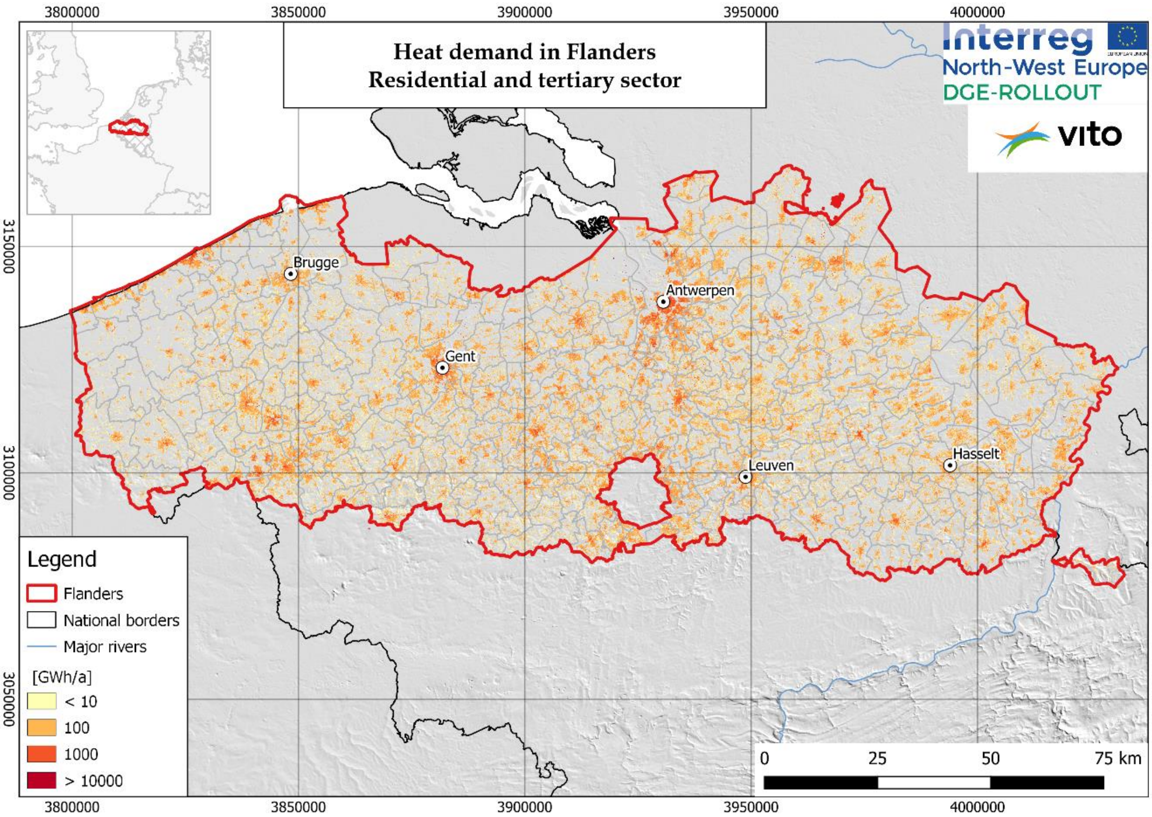

Figure 3 Map of residential and tertiary sector heat demand in Flanders, the most populated cities are named.

Social level map

The social level has been described through different indexes, for example, the Human Development Index or the European Social Progress Index. The first encloses three dimensions, each with one indicator: life, education and income to evaluate a decent standard of living. The second has three dimensions, each with four indicators: Basic human needs, Foundations of well-being and opportunity, excluding the economic indicators. Every indicator group defines components, 55 in total.

The European Social Progress Index (EU-SPI) was selected to create the map because of the factor "environmental quality". It has eight components air, noise and general pollution, plus nature protection areas.

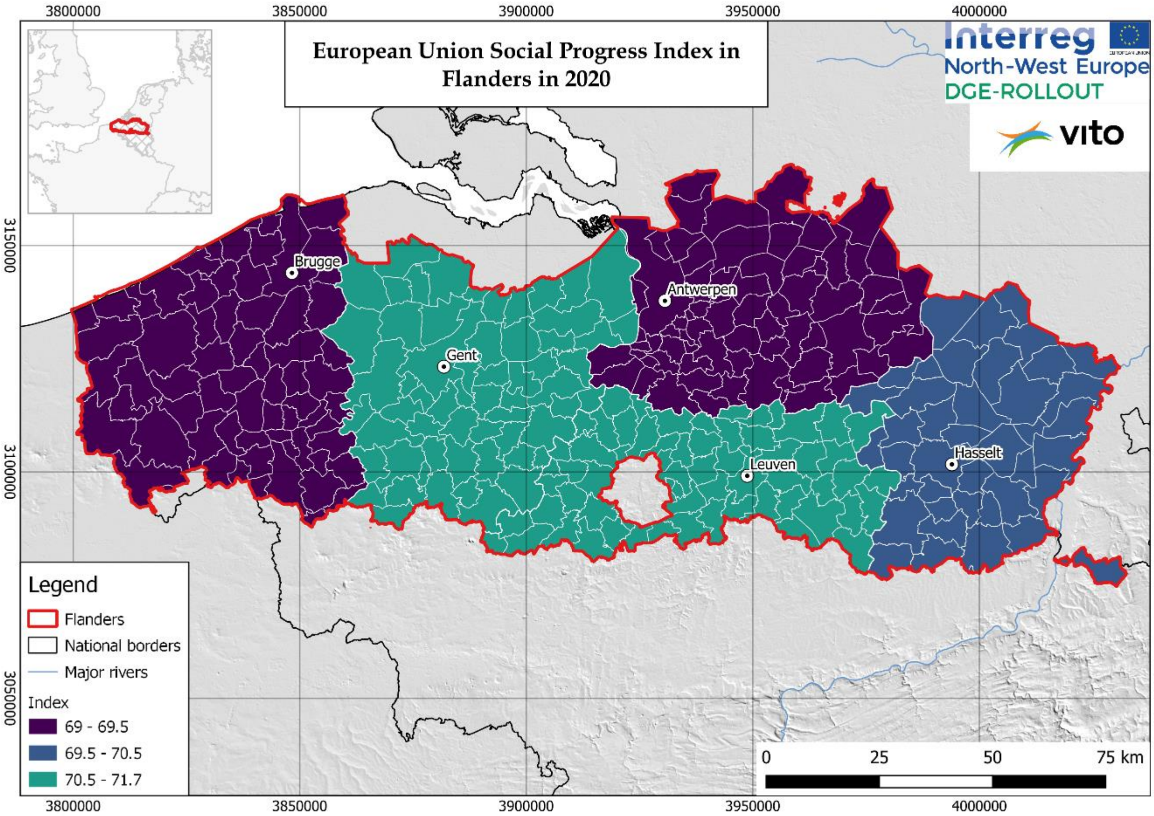

Figure *4* shows the EU-SPI in 2020 for the five provinces, all over 67, the average of the EU.

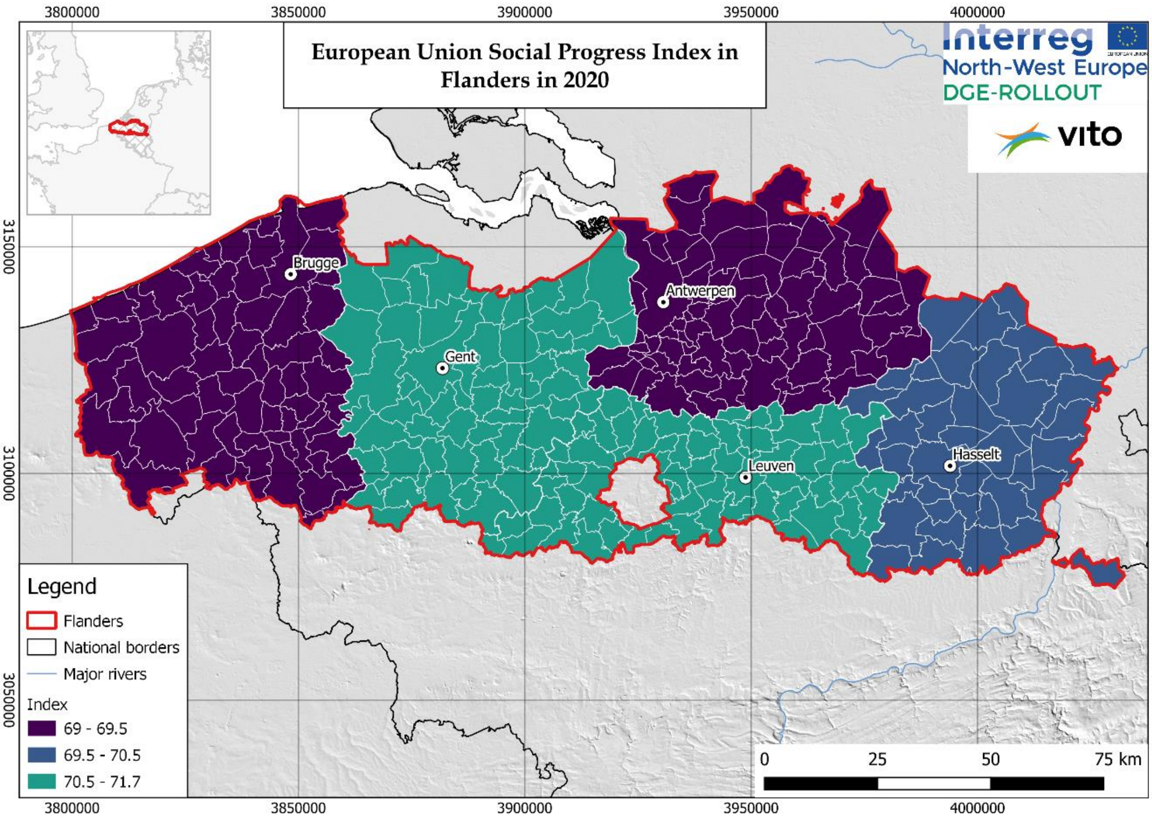

Figure 4 European Social Index in Flanders

Economic

Income

The Gross Domestic Product (GDP) at the market is an indicator of the national economic situation. This number is the total value of all goods and services produced in a region minus the ones consumed in their intermediate production (European Commission, 2022).

Figure 5 shows the distribution in Flanders. In the regions of and around the main cities, values are above € 40,000 per inhabitant in 2019. Values are lower in ore rural areas.

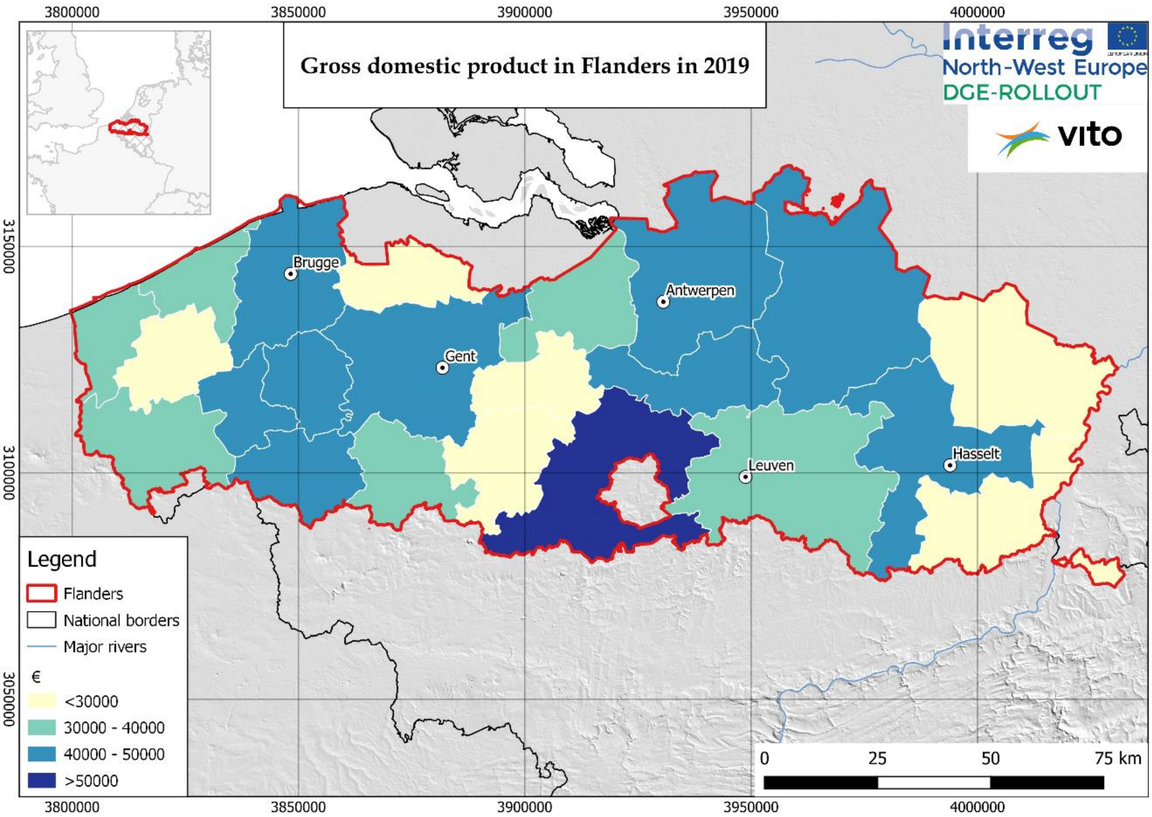

Figure 5 GDP in Flanders with data updated in 2019

Level of debt of municipalities

In Figure 6, the public debt of the municipalities of Flanders is shown per capita. The municipalities with the largest public debt are located mostly in the west and central part of Flanders.

The initial phases of geothermal projects are funded by the government (section Financial Risk Management). Public debt is acquired to pay for municipalities' expenses and new investments, therefore can not be directly correlated with the opportunity to promote new projects or vice versa.

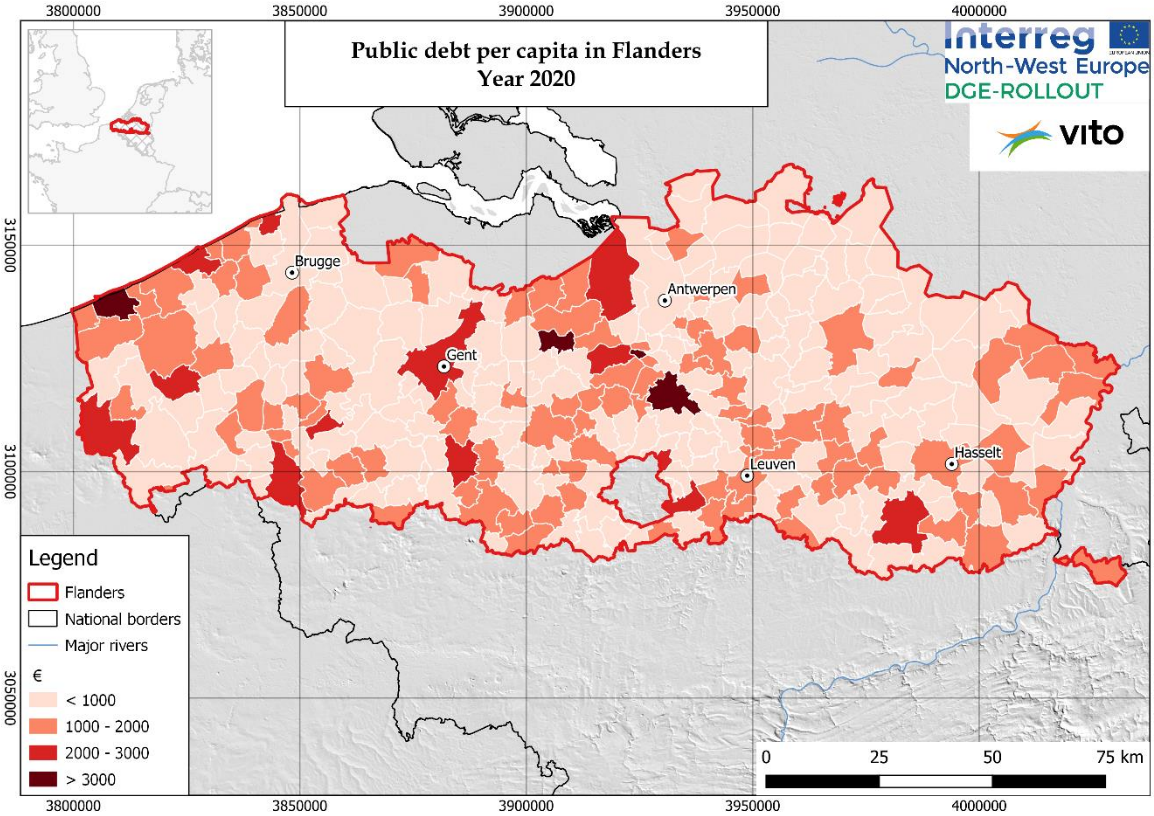

Figure 6 Public debt in Flanders

District heating

The importance of the District Heating (DH) lies in the potential of the heat that these can generate, the capacity of heat distribution with the existence infrastructure with different level of costumers. The costumers can be small- local companies, public services and end users. Figure 7 shows the municipalities with existing district heating networks, the cities with the highest heat demand are named.

The GeoDH project (European Geothermal Energy Council, 2014) mentions among the strengths of the heating districts the adaptation of existing infrastructure with renewable sources to replace fossil fuels.

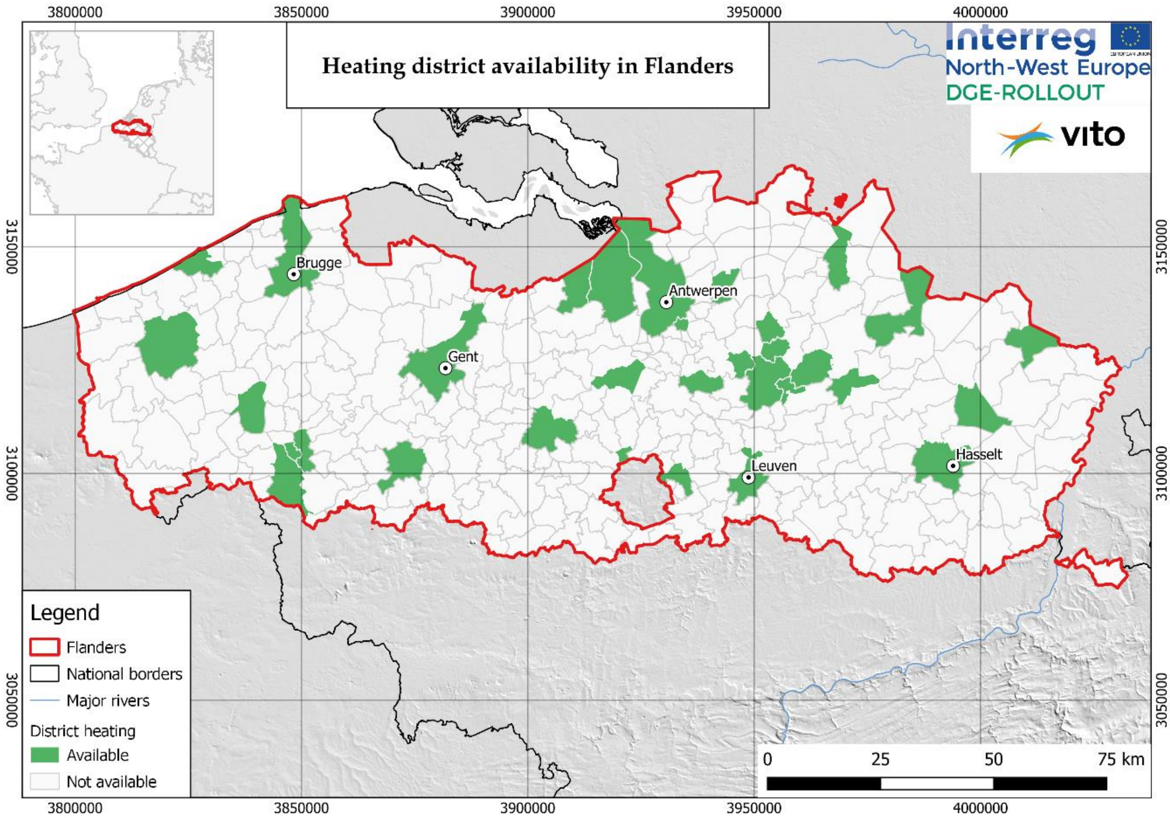

Figure 7 Municipalities with existence of (a) district heating network(s) in Flanders.

Environmental

Land access

Environmentally sensitive areas are mapped and categorized in different ways. Below, Figure 8 shows the distribution of Natura 2000 areas in Flanders. The environmental assessment in a geothermal project will offer a detailed evaluation of the areas around the project.

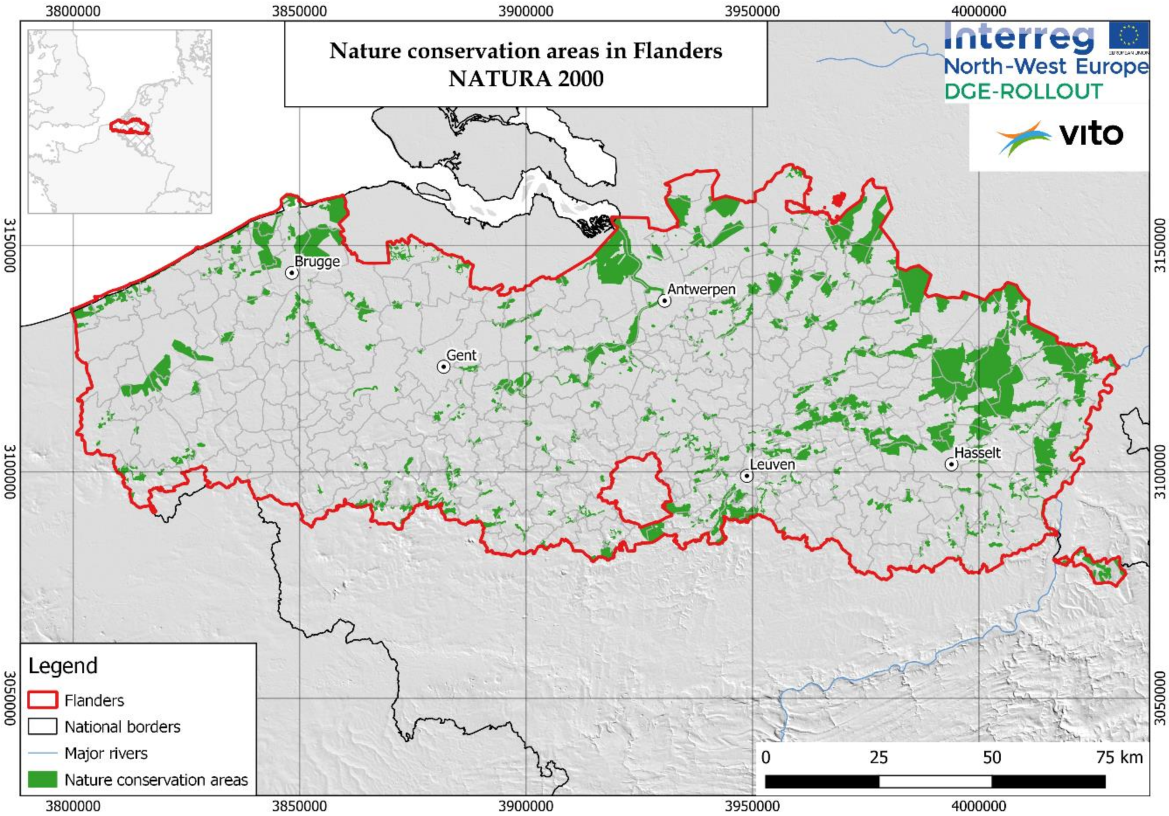

Figure 8 Nature and Landscape conservation areas in Flanders (Natura 2000).

Greenhouse gas emissions

The three major Greenhouse Gases are Carbon Dioxide (CO_2), Methane (CH_4) and Nitrous Oxide (N_2O), reaching 98% of the gases related to the Greenhouse effect. The other 2 per cent correspond to Fluorinated gases. The sources of the CO_2 emissions are the heat and electricity production by fossil fuels combustion, among others. The production of greenhouses gases due to energy production can reach one-quarter of the human-driven emissions. (Natural Resources Defense Council, 2022).

Figure 9 shows the emissions per capita in the municipalities in the year 2020. Municipalities with the highest emissions rate are Ardooie, Wielsbeke, and Merksplas. Whereas the highest total emissions are observed for the major cities and industrial areas (e.g. part of port of Antwerp located in Beveren), these three municipalities have a rather low population. Their high emission rate per capita is related by slightly higher industrial and/or agricultural activity in combination with a lower population count.

Lower emissions per capita are observed in the province of Limburg, the southern and eastern part of Oost-Vlaanderen and western part of Vlaams-Brabant, the eastern part of Vlaams-Brabant and the border area between Vlaams-Brabant and Antwerpen (north of Leuven).

Deep geothermal developments in Flanders are currently concentrated in the Campine Basin covering most of the provinces of Antwerpen and Limburg.

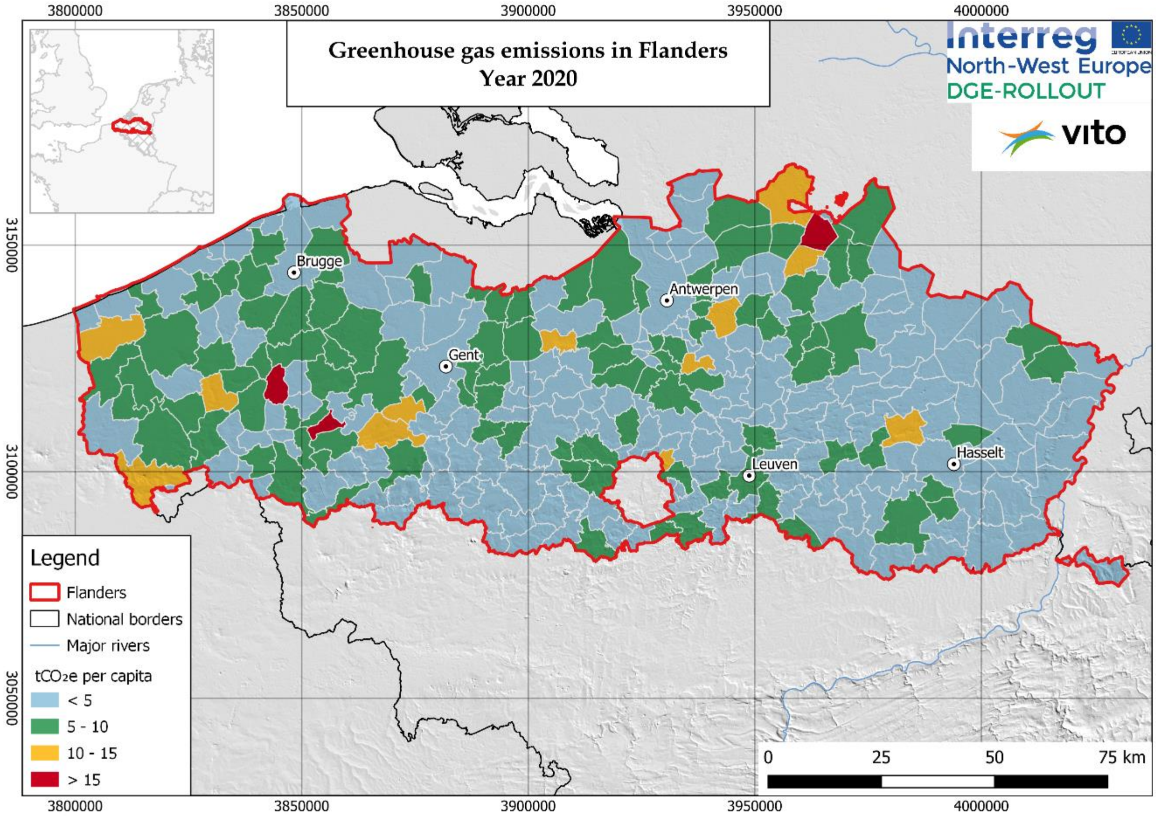

Figure 9 Greenhouse gas emissions in Flanders (ton CO_2 per capita).

Socio-Economic Potential

Based on the data described above, a composite index for the socio-economic potential for deep geothermal energy in Flanders was calculated (Figure 10). The absolute values are strongly dependent on the calculation approach, which is why the map is mainly suitable for a qualitative interpretation of the potential. In general, the results agree with the population density which is higher in the central part (Antwerpen-Gent-Brussels-Leuven). In addition, other populated areas show up as the cities and towns of Brugge, Roeselare, Kortrijk and Hasselt. The southern part of the province of Antwerpen also scores higher (SE of the city of Antwerpen, N of Leuven). Interesting to mention is that the municipalities of Mol and Turnhout also have a higher score. There already is a geothermal site in Mol (Balmatt), whereas an exploration permit has been granted for a geothermal project in Turnhout. Overall, the rural/agricultural areas in West-Vlaanderen and Limburg receive lower scores.

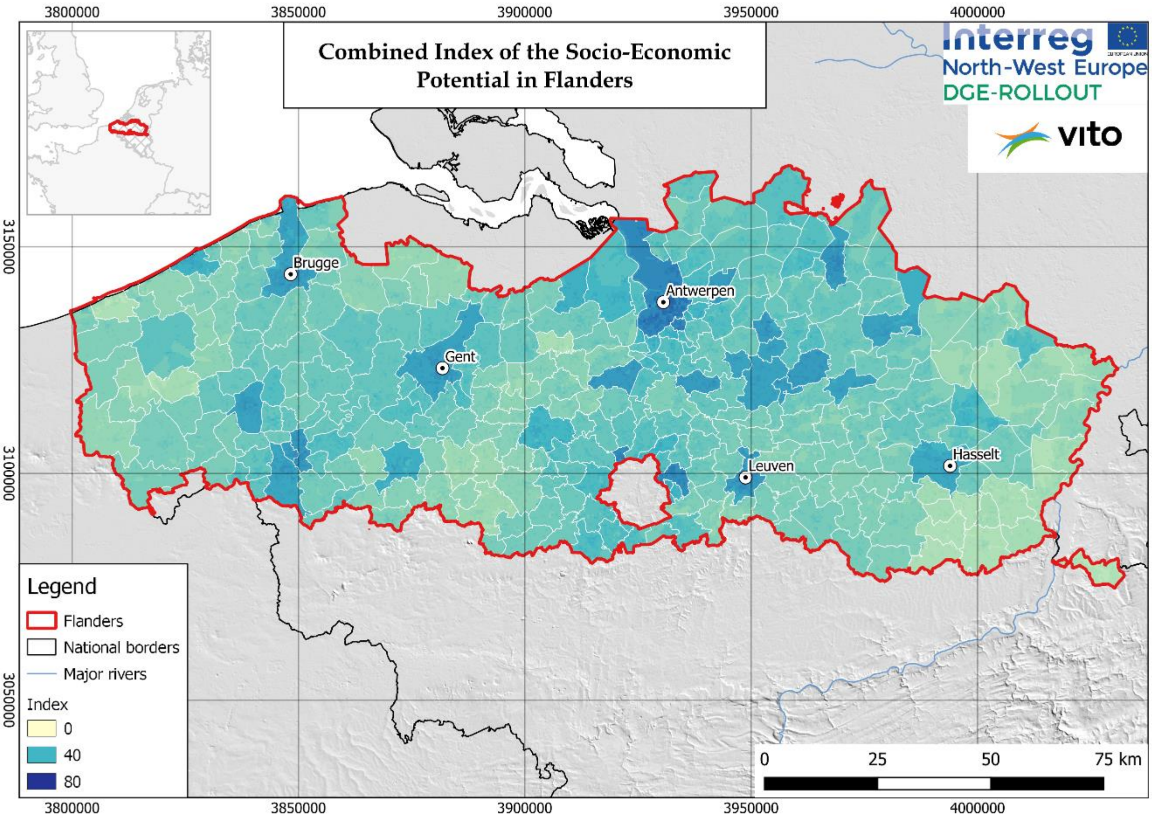

Figure 10 Composite index for the socio-economic potential for deep geothermal energy in Flanders

Conclusion

This analysis reaffirms that the heat demand, infrastructure and environmentally sensitive areas are critical for developing geothermal projects from the socio-economic point of view. As is proposed in the societal-technical focus pyramid (Moeck, et al., 2020). Although the analysis must consider the three levels of the decision pyramid, the potential zones for DGE projects clearly show similarity with the areas with infrastructure and heat demand, where heating districts exist, and the residential heat demand is high.

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Appendix A

Factor	Database
Population distribution	https://www.statistiekvlaanderen.be/nl/bevolking-omvang-en-groei#bevolkingsdichtheid
Heat demand	WPT1 D2.1_Map of the spatial distribution of the heat demand at the surface https://www.vlaanderen.be/publicaties/warmte-in-vlaanderen-rapport-2020
Income	https://gemeente-stadsmonitor.vlaanderen.be/indicators/gemiddeld-inkomen-inwoner
Social level map	EU Social Progress Index - 2020 | Data | European Structural and Investment Funds (europa.eu)
Political parties map / Election maps	https://www.vlaanderenkiest.be/verkiezingen2018/#/ Not used in the report
District heating	WPT1 D2.1_Map of the spatial distribution of the heat demand at the surface https://www.vlaanderen.be/publicaties/warmte-in-vlaanderen-rapport-2020
Level of debt of municipalities	https://www.statistiekvlaanderen.be/nl/geconsolideerde-schuld#schuld_vlaamse_gemeentebesturen_bedraagt_bijna_6,7_miljard_euro
Legal framework	legal-framework-with-contributors_dge-rollout.pdf (nweurope.eu)
Financial risk management (funding/investment)	Financial Risk Management Report (nweurope.eu)
Environmentally sensitive areas	https://www.geopunt.be/kaart
Greenhouse gas emissions	https://gemeente-stadsmonitor.vlaanderen.be/download

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