Interreg
North-West Europe
DGE-ROLLOUT

Socio-economic potential mapping for Deep Geothermal Energy

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 in Germany. 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

1. Introduction

Climate change is a global concern that requires regional action. Northwest Europe aims to reduce CO2 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 literature on geothermal projects written from a geological point of view is widely available, while the literature devoted to social aspects is limited and focuses on risk assessment. A google scholar search can show the reader this difference when a topic such as "geothermal reservoir" gives more than 350,000 results versus 800 for "geothermal socio-economics". It makes clear the need for more information on the subject.

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), WPT1 D3.2 Financial Risk Management (Taşdemir & Arndt, 2020) and WPT1 D3.3 Recommendations on legal framework and financial risk management (Petitclerc, 2022). 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 the state of Wallonia (Belgium).

2. 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 (NEW), 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, like the Balmatt energy plant in Mol (Belgium), which had investments from the Knowledge Institute and the Flemish government. 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. Proposal wells are located in the company's area associated with this project.

3. 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:

1. What information is needed to know about energy demand? e.g. population distribution and energy demand.
2. What information is needed in general within the project proposal? e.g. infrastructure and regulation.
3. 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.

Table 1 : Categories and factors defined for the socio-economic analysis of geothermal projects.

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	

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 : 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. Wallonia is composed of 5 provinces, divided into 20 arrondissements and 262 municipalities. The data is available in one of those levels of spatial resolution.

4. Data

The data collected in general are direct measurements of the selected factors. 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. The version or date of data collection is the latest available. The name of the capital of the provinces are labelled on each map.

4.1. Social

This category encloses the population characteristics in Wallonia. 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.

4.1.1. Population distribution

Figure 2 illustrates the distribution of the population of 2020 per km² by municipality. The North Wallonia is more populated than the South. Six of the eight most populated municipalities are located in the Province of Liège. This number includes the municipalities of Liège and 5 other located nearby. The municipality of Charleroi and one around the municipality of Mons are also highly populated. The origin of this popularity is the mining industry of the 20th century in the Houiller Basin, which extends East-West across Wallonia, through these communities.

Source : The data is provided by “StatBel”, the Belgian statistical office which collects, produces and disseminates reliable and relevant figures on the Belgian economy, society and territory : StatBel | Population distribution.

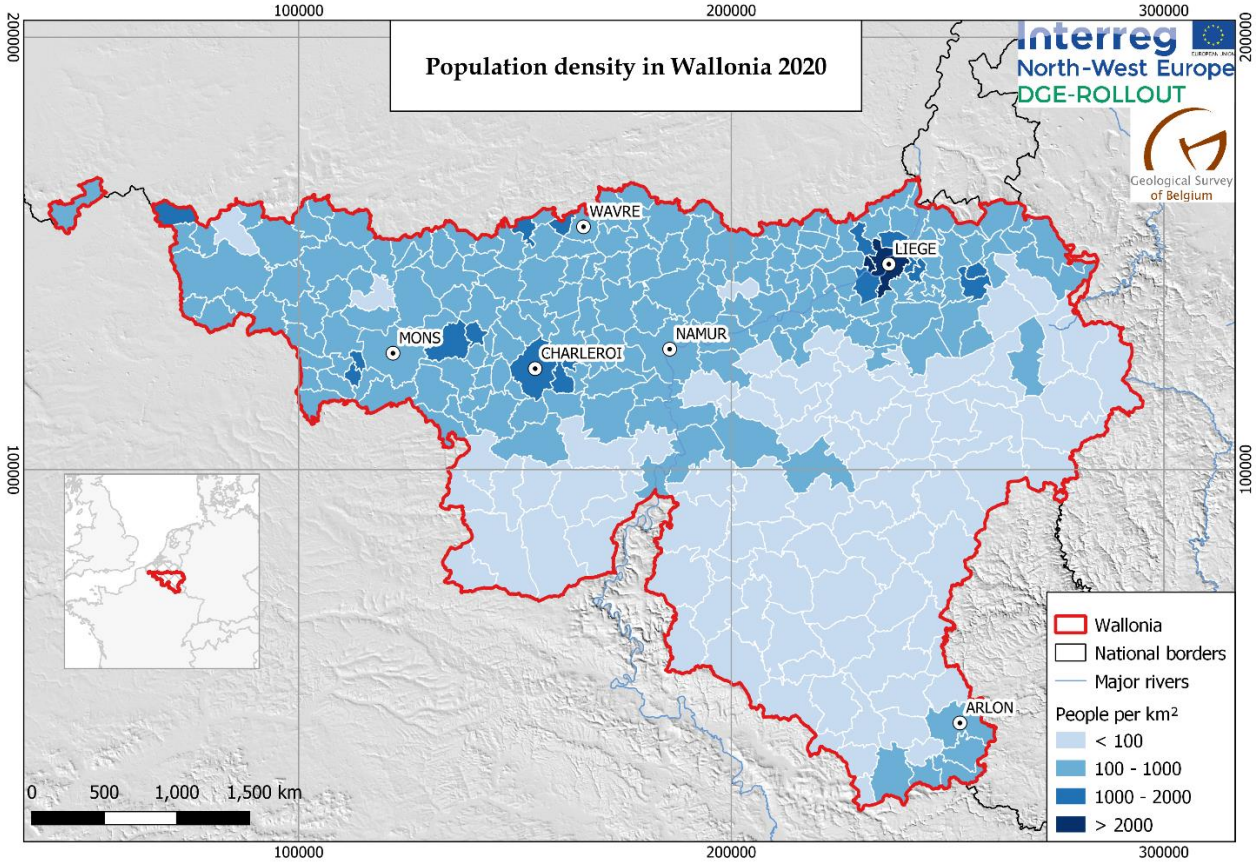

Figure 2 : Population distribution in 2020 of Wallonia (Belgium)

4.1.2. Heat demand

The heat demand in Northwest Europe was described and analysed 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.

Figure 3 shows the map of residential and tertiary sector heat demand for Wallonia. The heat demand generally follows the population distribution. The highest demand is found in and around the capital of the provinces.

Source : DGE-ROLLOUT report : "WP T1 - 2.1 Map of the spatial distribution of the heat demand at the surface" (Strozyk et al. 2021).

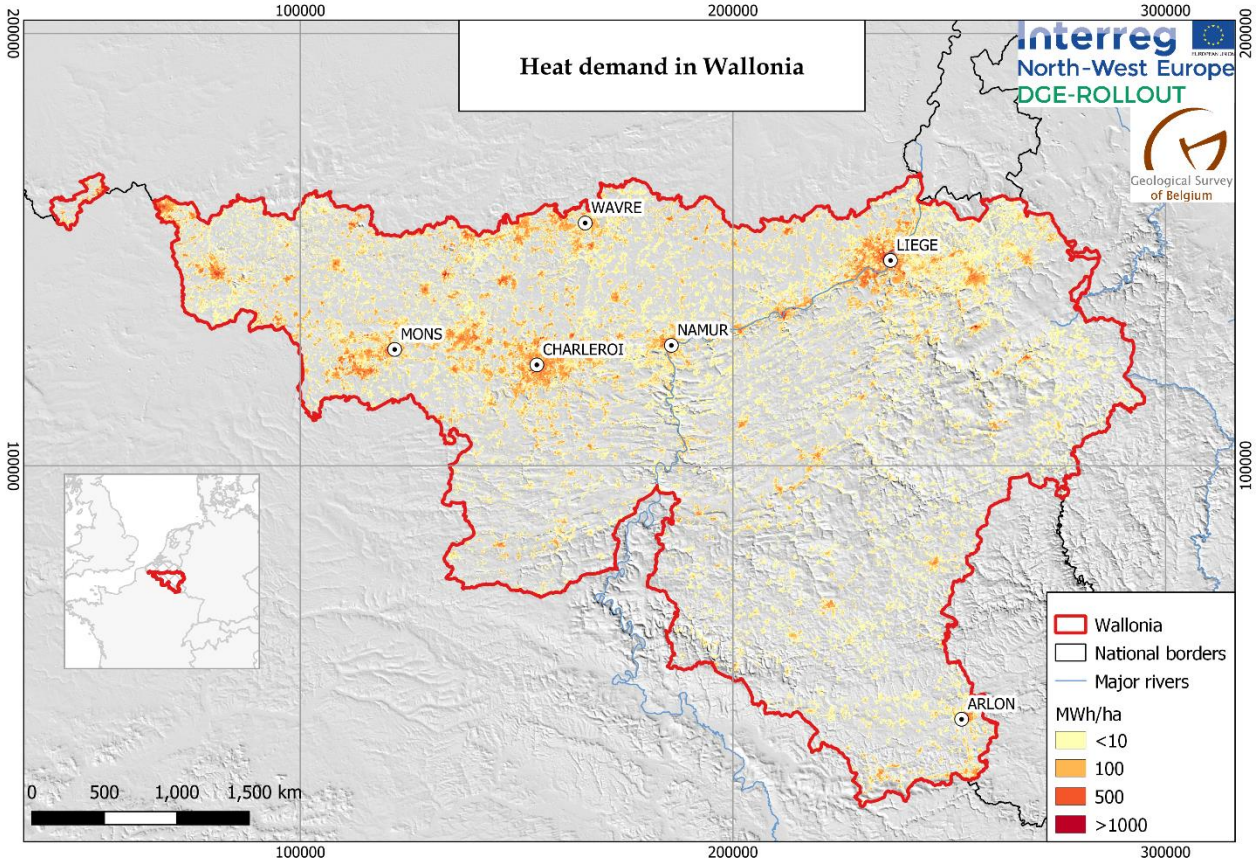

Figure 3 : Heat demand of 2021 in Wallonia (Belgium)

4.1.3. 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 per province of Wallonia at the NUTS 2 level. The provinces of Mons and Charleroi have the lower EU-SPI index. They are followed by the province of Liège. The highest values if the index can be fond in the provinces of the Walloon Brabant, Namur and Luxemburg.

Source: EU-SPI is provided by the European Commission for the regions of the EU : European Commission | Social Progress Index.

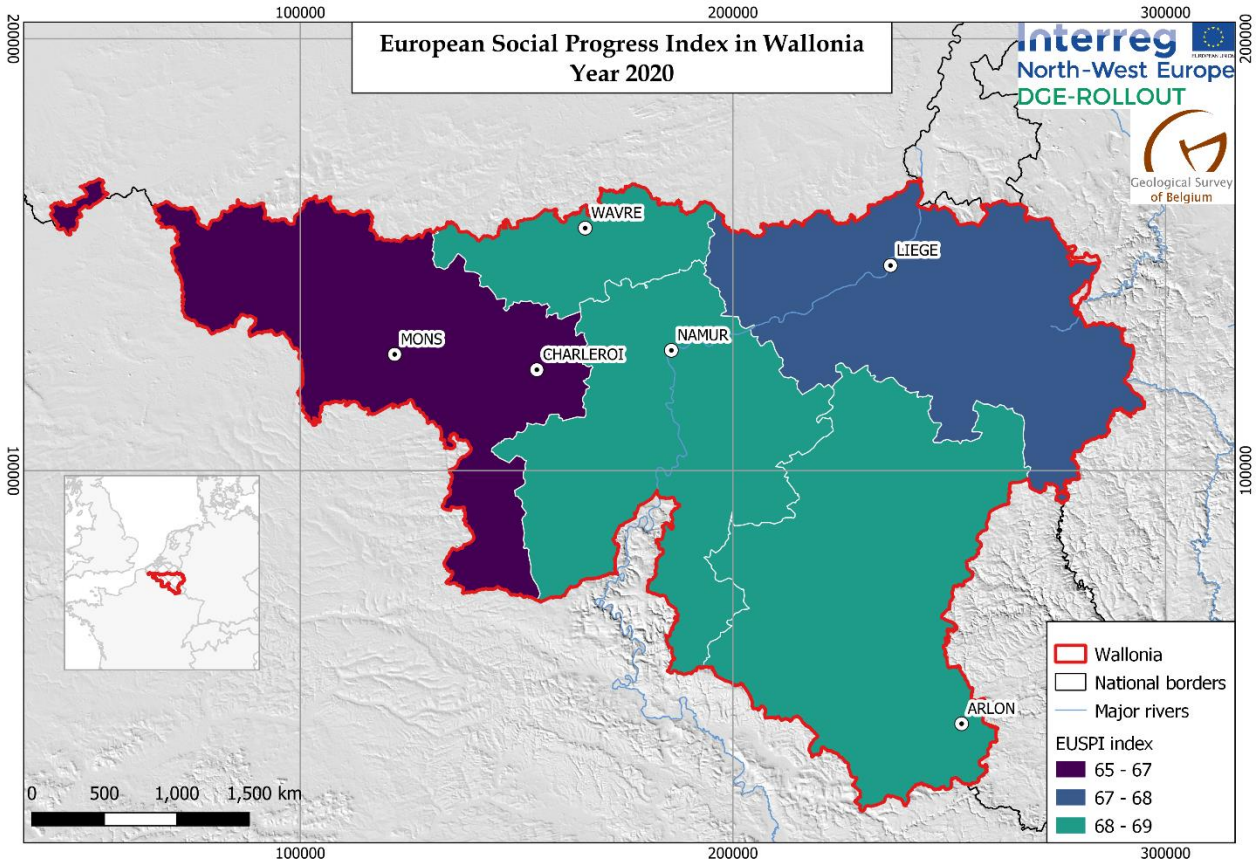

Figure 4 : Social level map of 2020 per province of Wallonia (Belgium).

4.2. Economic

4.2.1. 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 per arrondissement in 2019. The highest numbers are located in the arrondissement of Wavre.

Source: The dataset is available on the website of Eurostat, the statistical offices of the European Union, under "Regional Economic accounts" with the code "nama_10r_3gdp". Data is available for the NUTS 3 level regions in Europe : [Eurostat | Gross Domestic Product].

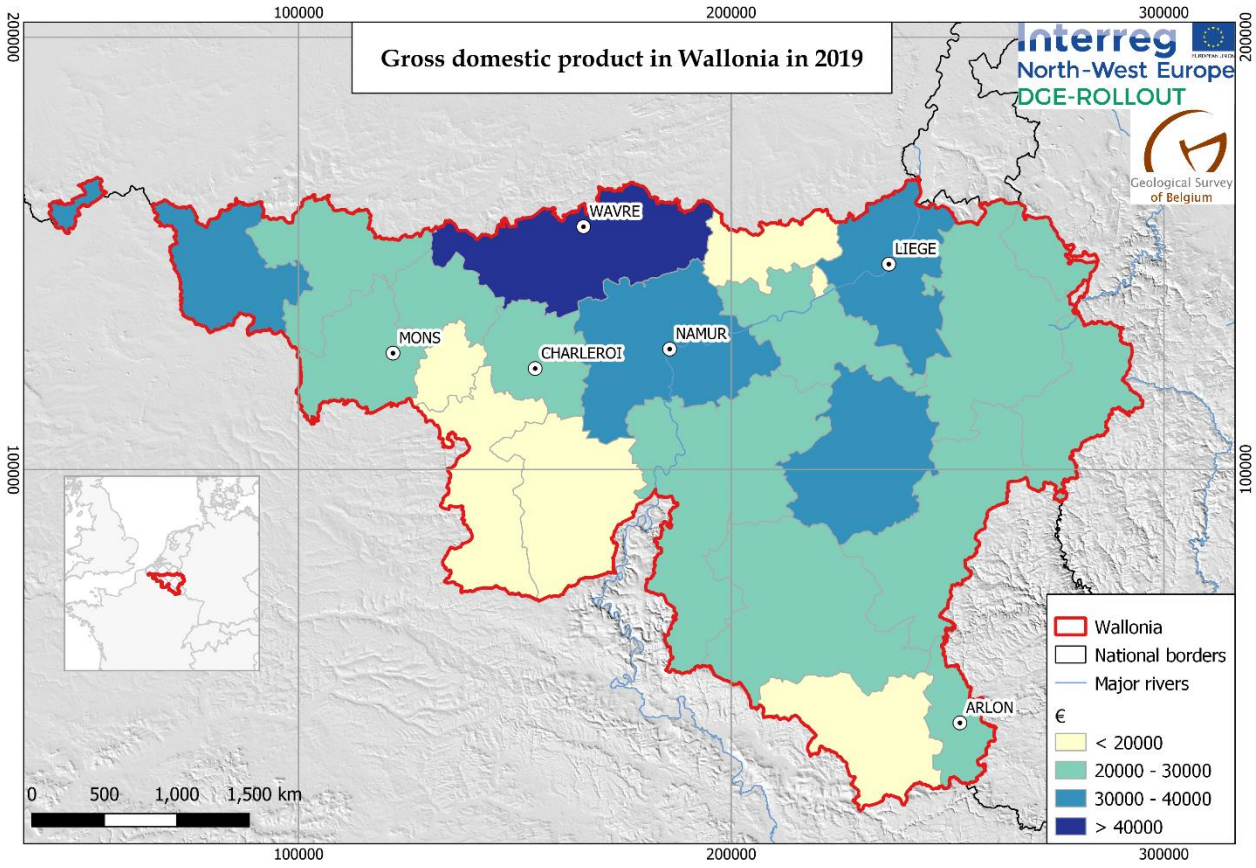

Figure 5 : Gross domestic product in 2019 per arrondissement of Wallonia (Belgium)

4.2.2. Level of debt of municipalities

The possible funding at the municipality level is highly dependent on the public debt. In Figure 6, the public debt of 2019 per municipality is shown. The city with the largest public debt is Liège.

Source : The data is provided by WalStat, the portal for local statistical information on Wallonia : [Walstat | Level of debt of municipalities]

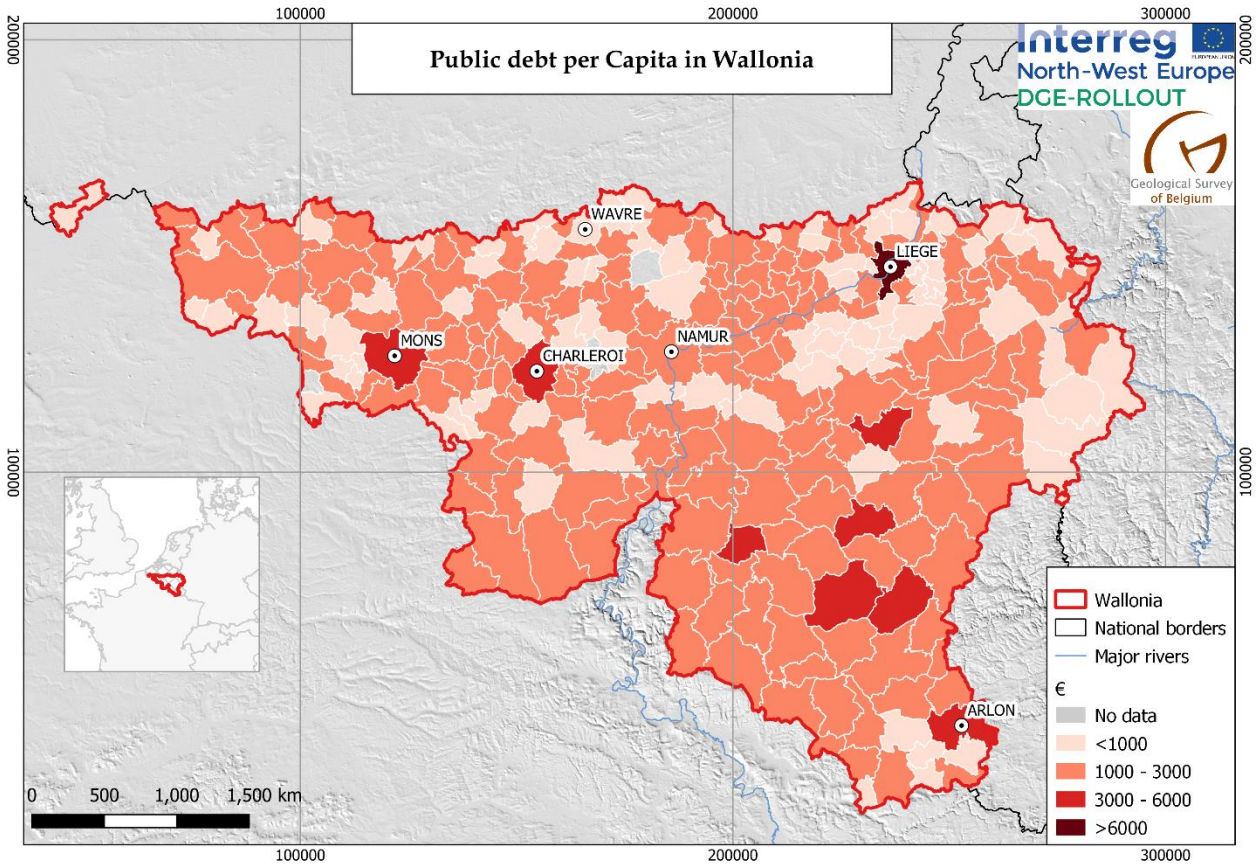

Figure 6 : Public debt per capita in Wallonia (Belgium)

4.2.3. 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 illustrates the final consumption related to fossil fuel sources per municipality in 2018. The fossil fuel sources included in the data are natural gas, oil products and others in the industrial, residential, tertiary, transport and agriculture sectors.

Source : The data is provided by WalStat, the portal for local statistical information on Wallonia : [Walstat | District Heating]

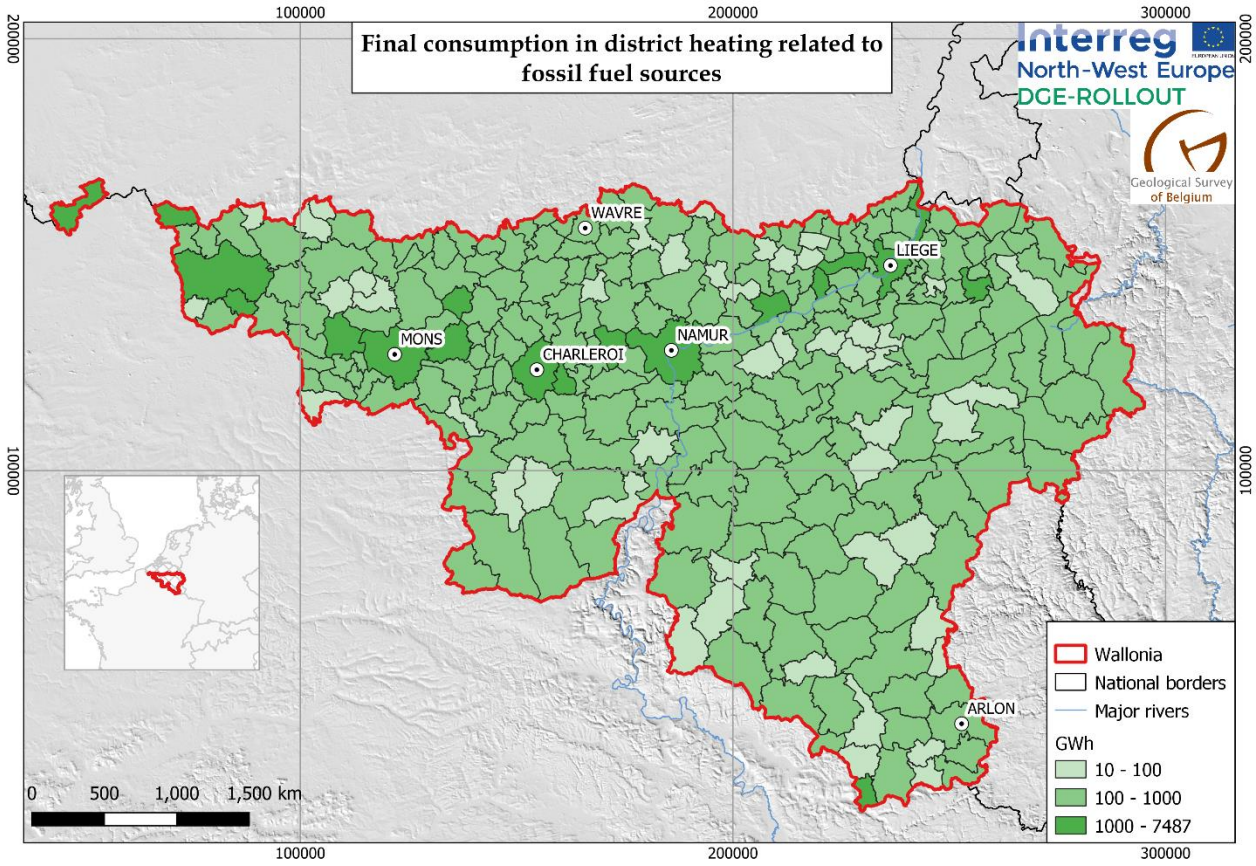

Figure 7 : Final consumption in district heating related to fossil fuel sources per capita in Wallonia (Belgium)

4.3. Environmental

Environmentally sensitive areas

Figure 8 illustrates the localization of the environmentally sensitive areas of Wallonia in 2017. These areas belong to the Natura 2000 network, an European ecological network of natural zones (peat bogs, forests, rivers, rocks, caves), semi-natural areas (flowering meadows, dry grasslands, moors, etc.) or zones serving as habitat for certain animal or plant species. Natura 2000 areas are not "closed" reserves. Human activities remain authorized as long as they do not compromise the maintenance of a favorable conservation status of habitats and species in the area.

Source : The data is provided by the “Géoportail de la Wallonie”, the portal the Walloon geographical information : [Géoportail de la Wallonie | Environmentally sensitive areas]

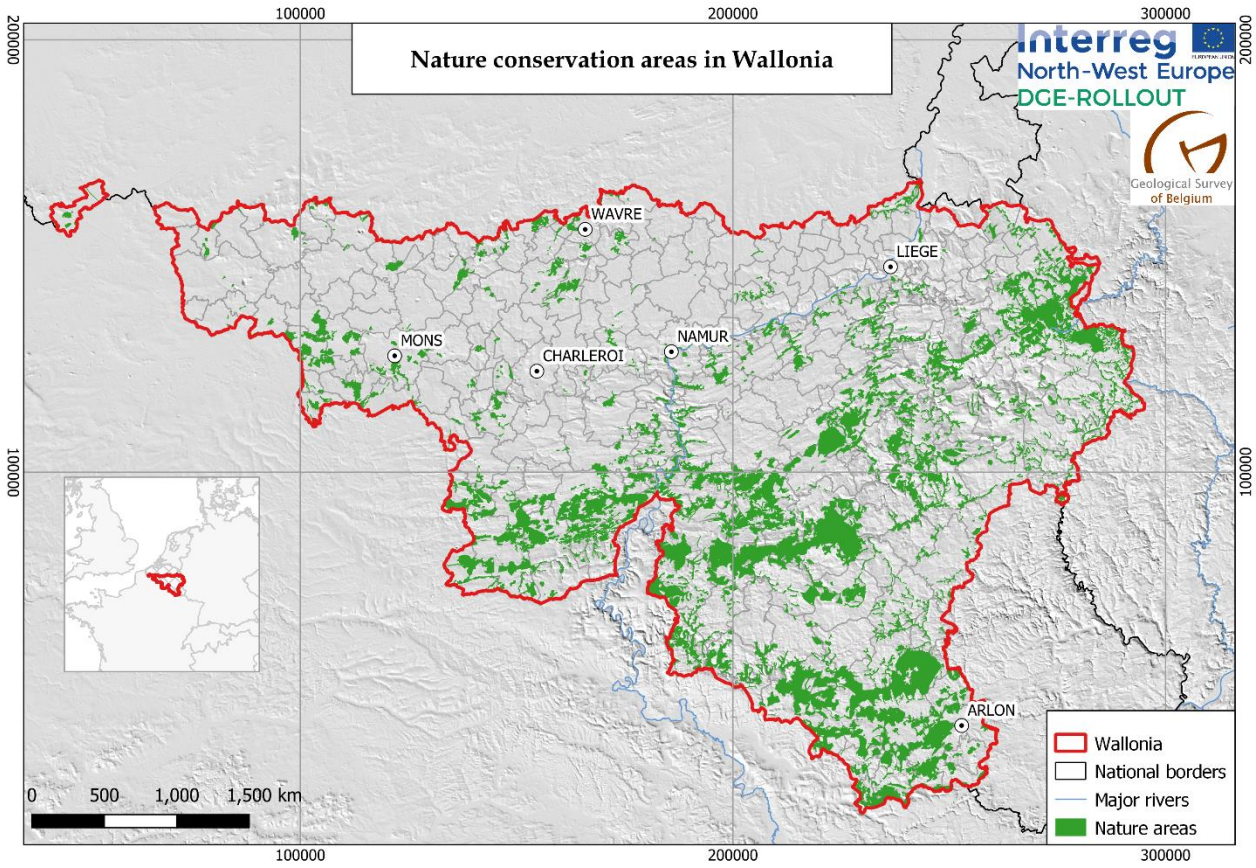

Figure 8 : Nature conservation areas in Wallonia (Belgium)

5. Socio-economic potential index

The different quantifiable factors of the socio-economic potential for deep geothermal energy were combined into a joint index. The factors population density, 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	3550
Total heat demand of municipality	MWh/ha/yr.	0	1350
Gross domestic product	€/cap/yr.	15000	56100
Public debt per capita	€/cap	0	6225

Based on the data described above, a composite index for the socio-economic potential for deep geothermal energy in Wallonia was calculated, which is illustrated in Figure 9. The Walloon Brabant Province has a high socio-economic potential index, as the areas around the capital of the provinces. The rest of Wallonia has middle to low values.

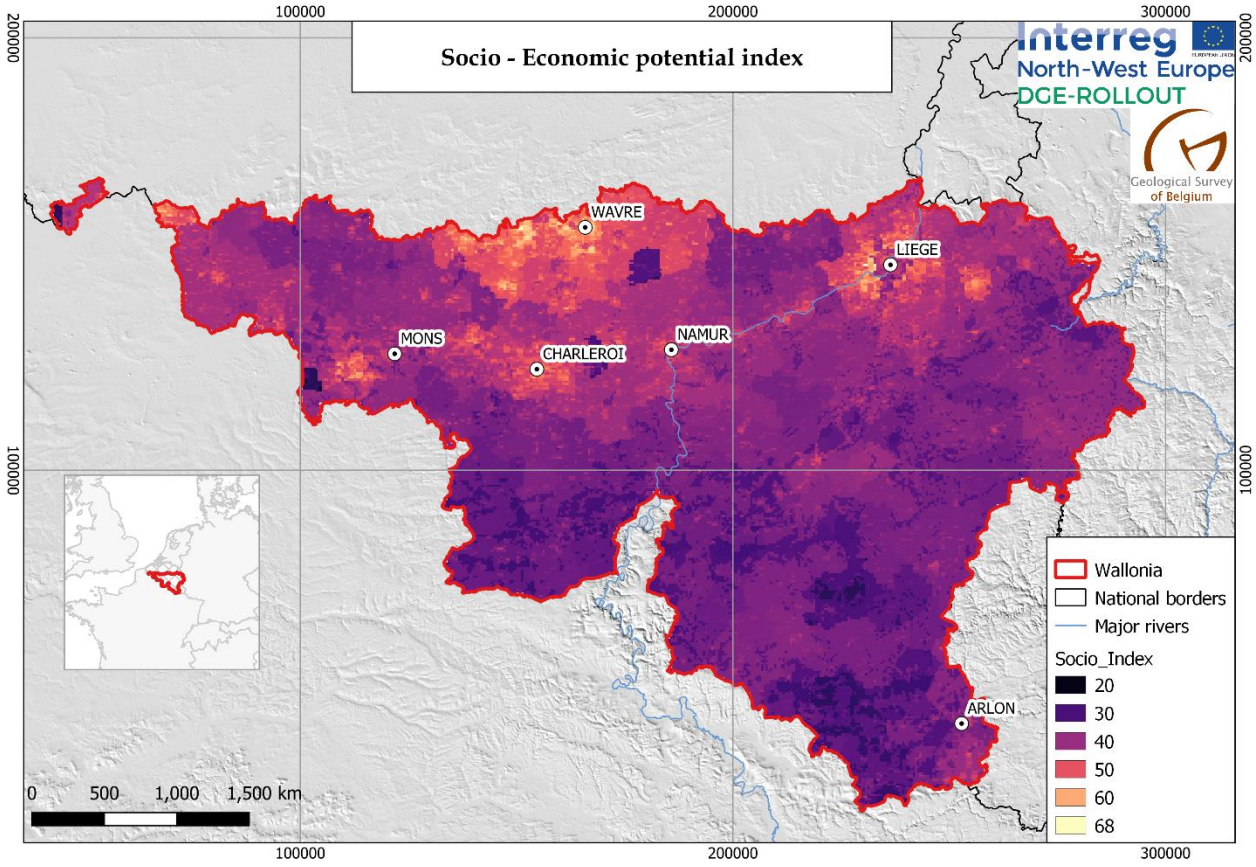

Figure 9 : Socio-economic potential index of Wallonia.

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