Interreg North-West Europe DGE-ROLLOUT

Socio-economic potential mapping for Deep Geothermal Energy

Focus: North-West Europe

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

Introduction

Climate change is a global concern that requires regional actions. Northwest Europe aims to reduce CO_2 emissions through the transition from fossil fuels to renewable energy sources. The need for new opportunities 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 partly substituted by geothermal energy. In this project, we focus on deep geothermal energy (DGE).

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 about 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 have 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 the above mentioned reports.

The report is a brief definition of the socio-economic factors and how they were defined for this project and the workflow for data compilation and the sources used - most of them are freely available. Each factor is accompanied by a map to visualize its spatial distribution in the area of North-West Europe (NWE).

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 fossil 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.

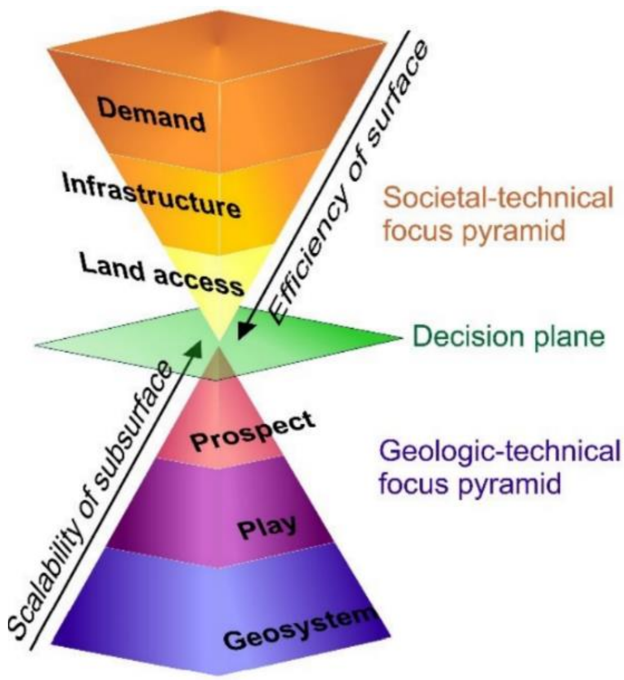

Figure 1 Decision-making factors to start a geothermal project, after (Moeck, et al., 2020).

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. Kabel ZERO (NRW.Energy4Climate, 2022) is a German project to supply part of the heat demand of the paper factory Kabel Premium Pulp & Paper GmbH with deep geothermal energy.

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 taken 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 involved 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, factors describing 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 were chosen. 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
		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 mainly from the European Commission database. The geographic data as the basis for the graphical representation of the information was used in the maximum resolution possible. In other cases, the country's values are represented.

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, 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	59	1059
Total heat demand of municipality	MWh/ha/yr	0	5000
Gross domestic product	€/cap/yr	28300	71800
Household carbon footprint	t(CO_2e)/cap	0	10

Results focusing on North-West Europe

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. The version or date of data collection is the latest available.

Social

This category encloses the population characteristics in North-West Europe. 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

The area of the DGE-ROLLOUT project focuses on the countries Belgium, France, Germany and the Netherlands with its over 120 Million citizens. The most populated areas are Ile de France, in France, North Rhine-Westphalia and Baden-Württemberg, in Germany, all regions with over 10 Million citizens. The map of population density (Figure 2) shows the distribution of the population in the area in people per km^2. In this case, regions like Brussels and the Netherlands are on the higher values due to the small areas where the people are concentrated.

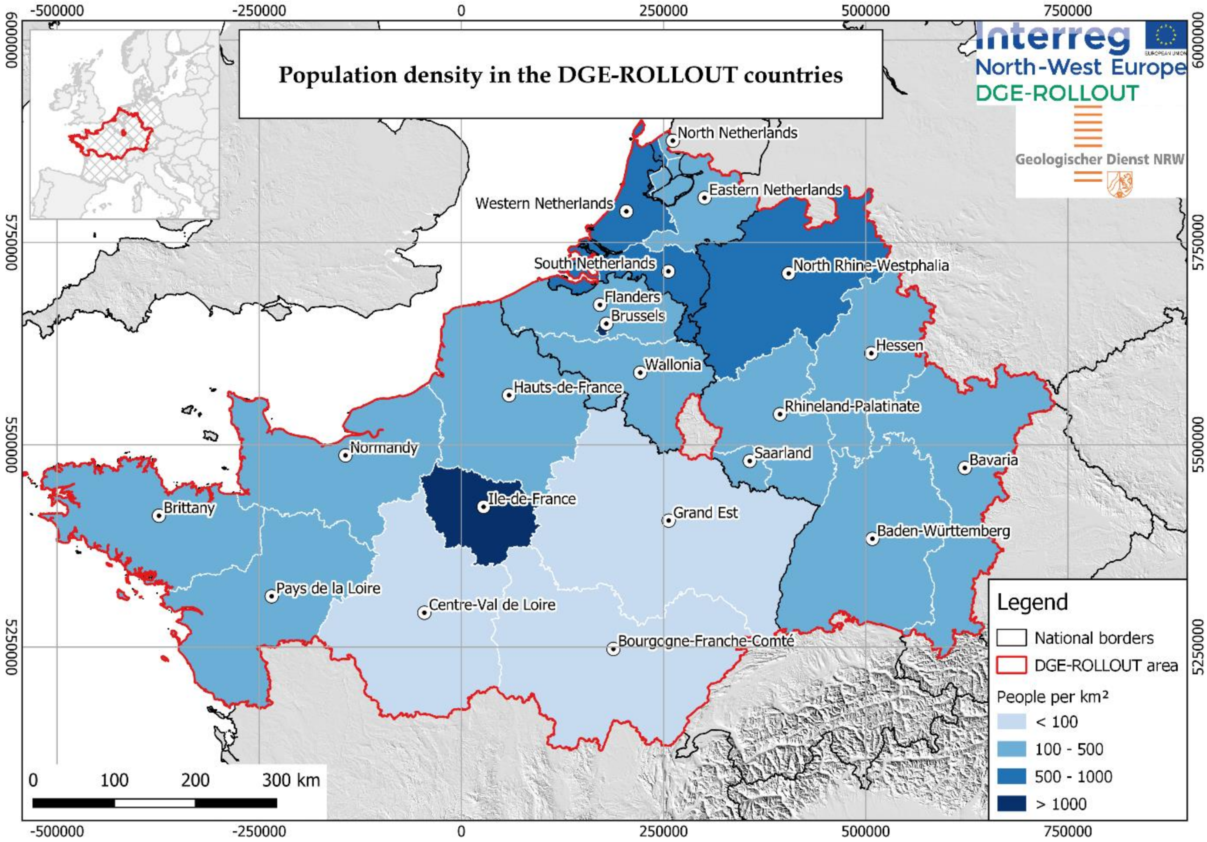

Figure 2 Population distribution in the countries part of the DGE-ROLLOUT countries.

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.

Figure 3 shows the map of residential and tertiary sector heat demand for North-West Europe. The heat demand generally follows the population distribution. It is possible to locate the capitals of the regions based on the energy demand.

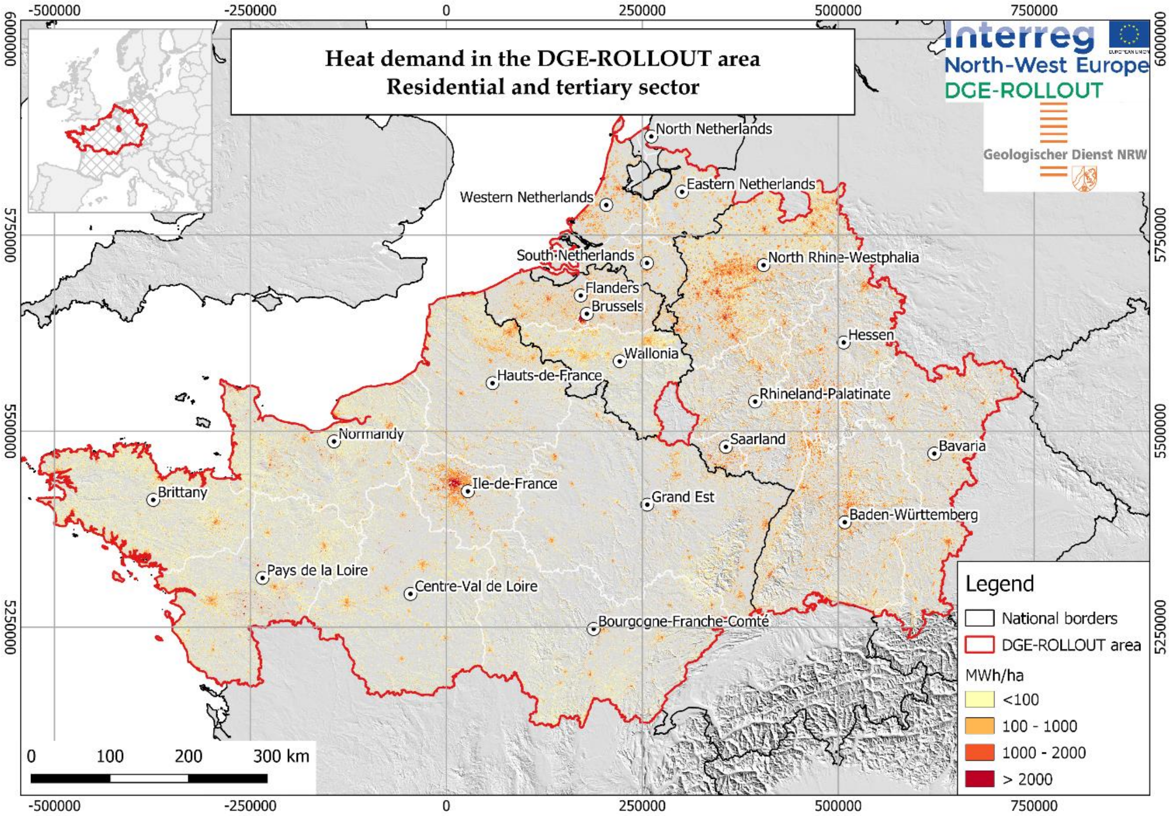

Figure 3 Map of residential and tertiary sector heat demand in North-West Europe, the concentration of population is reflected in this factor in regions for example Ile de France or North Rhine-Westphalia.

Employment

The number of jobs related to Renewable energy are published every year by the International Renewable Energy Agency (IRENA), the number of jobs is given by country and consider shallow and deep geothermal energy.

Figure 4 shows the distribution in the countries in the region. Germany is leading the sector, with a number of jobs over 20, 000 in the sector. Followed by France and the Netherlands with over thousand jobs. IRENA proposes a forecast with scenarios for employment in the transition to clean energy. For Europe in the case of Geothermal energy, the increase is 10 % for the “planned energy scenario” in the year 2030 and remains the same value until the year 2050, in case of applying the “transforming energy scenario” the employment increases 30% for the year 2030 and 50 for the year 2050 (International Renewable Energy Agency, 2020).

The current employment is not considered in the index calculation. It is showed as one of the benefits for the population related to geothermal projects.

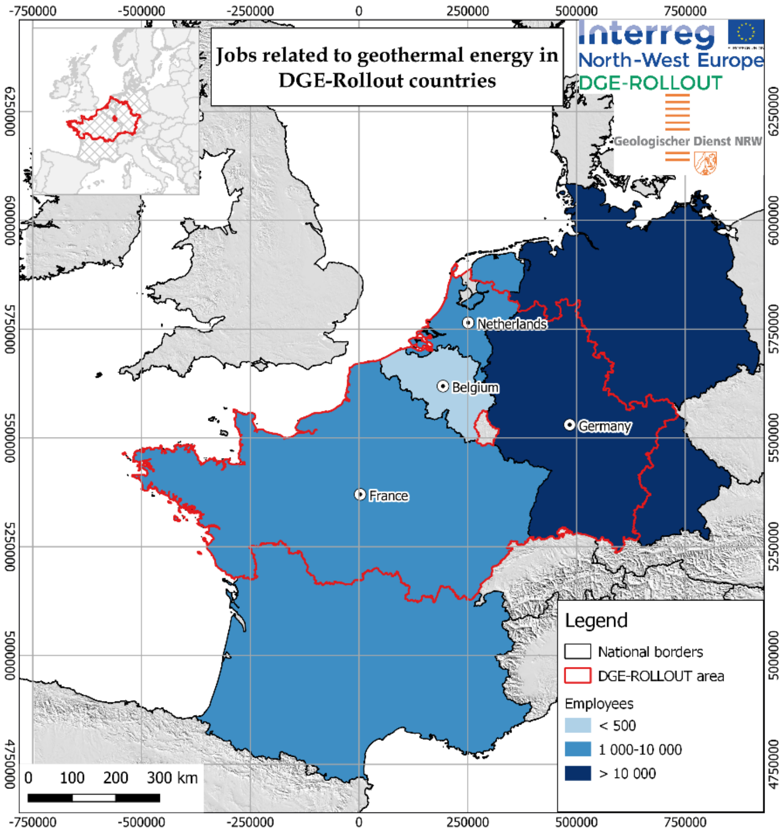

Figure 4 Jobs related to Geothermal energy in North-West Europe.

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 5 shows the EU-SPI in 2020 for the regions, all of which are over 67, the EU average. The regions with the highest values are in the Netherlands and France. Some of the factors with the biggest differences are the personal security, in Belgium it is evaluated around 51 percent compared to 70 % evaluated in the Netherlands regions. The factor about “environment quality”, related with the targets of the present report, has the best values in Brittany, France, while the lowest values belong to Belgium.

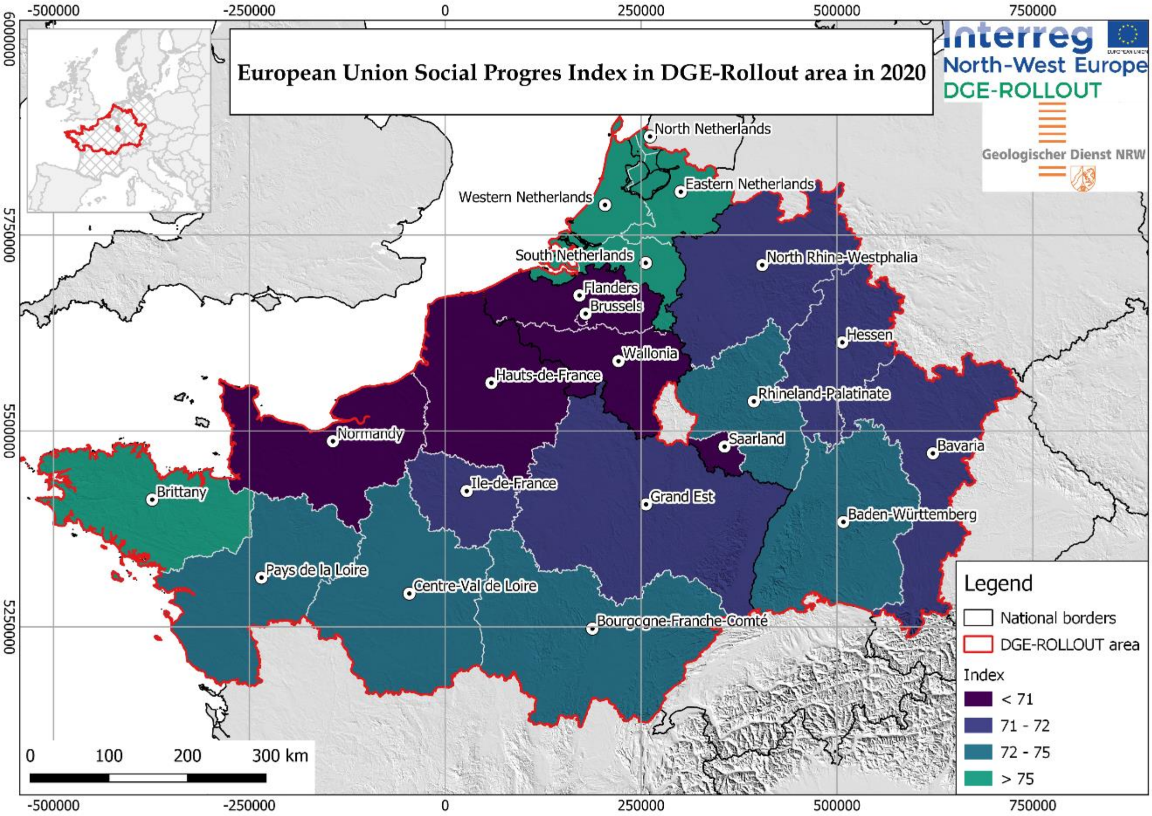

Figure 5 European Social Index in NUTS 01 resolution, DGE-Rollout countries.

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 6 shows the GDP distribution in the regions. The inequality observed in France is due to the population, with a GDP over € 50,000 in Ile de France compare to the zones around below $ 30, 000 per inhabitant in 2018. In the case of German regions, the values are more equative, the same for Belgium.

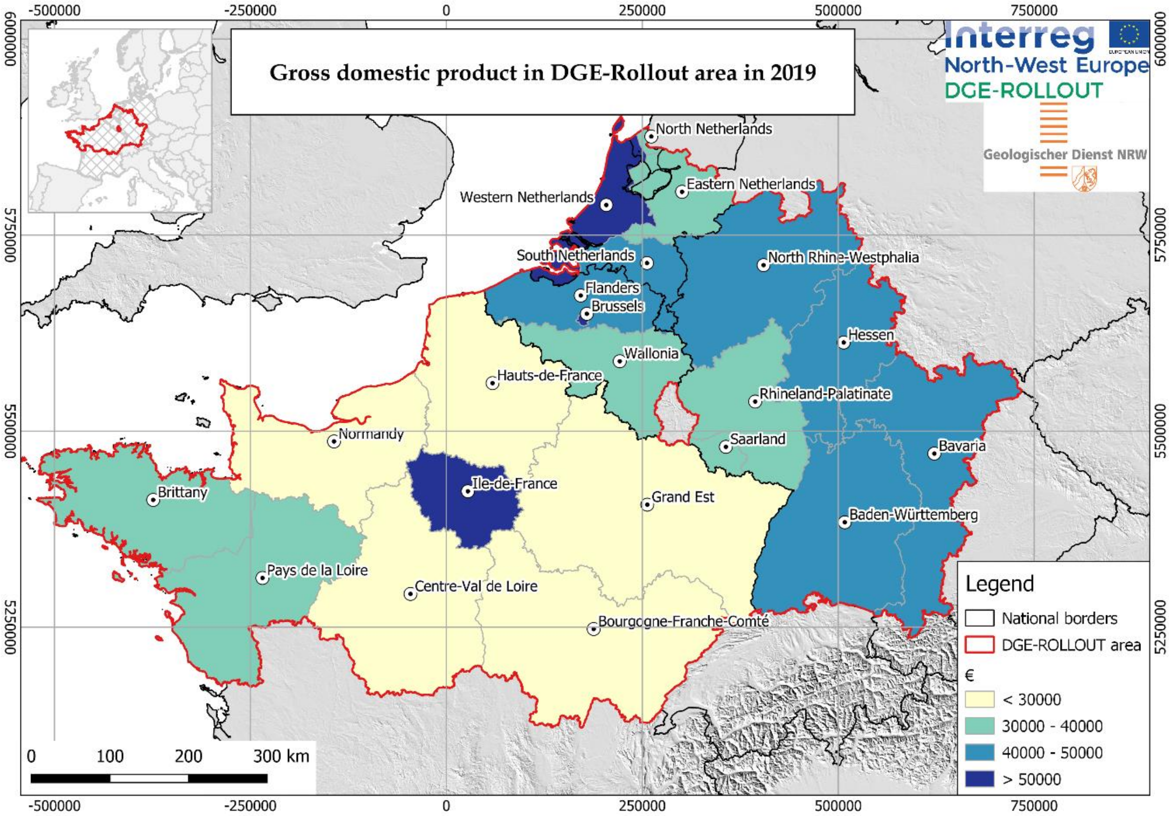

Figure 6 GDP in the DGE-Rollout countries with data updated in 2018

District heating

The importance of the District Heating (DH) lies in the potential of the heat that these can distribute, 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.

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. The current renewable energy sources used are the biogenic fraction of waste, biofuels (solid, liquid and gaseous), biomethane, solar and geothermal energies. Figure 7 shows the values of total installed district heating capacity in Belgium, France, Germany and Netherlands. Germany has the highest capacity with 49,475 MWth from which 12% are linked to a renewable source.

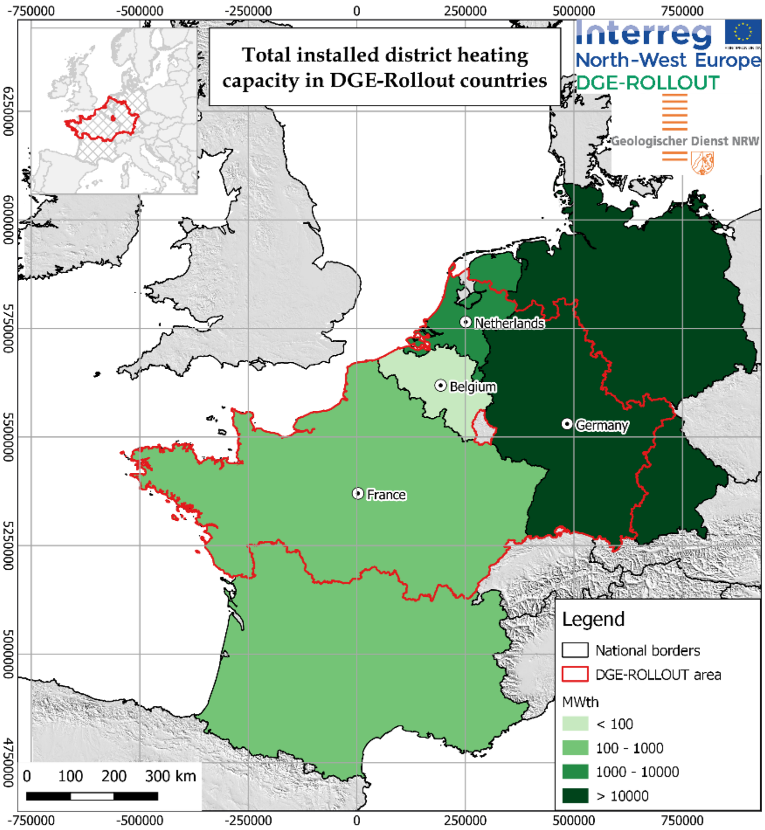

Figure 7 Total installed capacity of district heating in DGE-Rollout countries.

Environmental

Conservation areas

Natura 2000 is a network of conservation areas in the European Union. The site designation encloses 3 types of sites, protected areas under habitat directive, bird directive, and sites under both directives. Human activity is not excluded in these zones, but it is looking to manage it in a sustainable manner. For this reason, is contemplated a minor restriction in the geothermal projects, and special regulations must be considered a difference in areas outside the conservation areas.

In each country exist different classifications, for this reason the nature protected zones could be underestimated. In the case of France, some restricted zones exist due to deep drilling (Durst, et al., 2022).

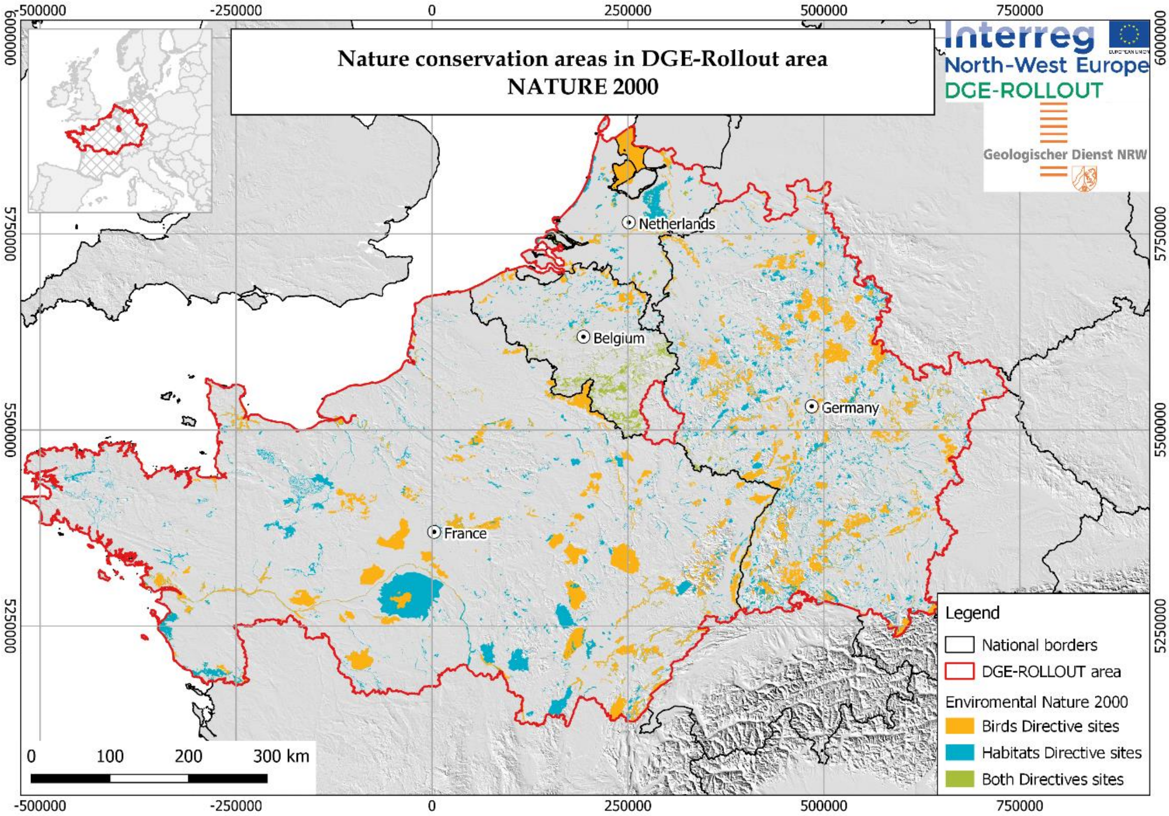

Figure 8 Nature conservation areas in North-West Europe.

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 $C0_2$ 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) Germany has the national target to reduce the Greenhouse gas emission to 65 % by 2030 and reach the neutrality in 2050.

Figure 9 shows the air pollutants and greenhouse gases emissions per capita in Belgium, France, Germany and the Netherlands. The Greenhouse gases considered are CO_2, N_2O in CO_2 equivalent, CH_4 in CO_2 equivalent, HFC in CO_2 equivalent, PFC in CO_2 equivalent, SF_6 in CO_2 equivalent, NF_3 in CO_2 equivalent)

The Netherlands has the largest emissions rate per capita around 11.3 tonnes of CO_2, it is over the average of 8.4 for Europe. In the last year the high number has been related to the transport, residential and agriculture sector.

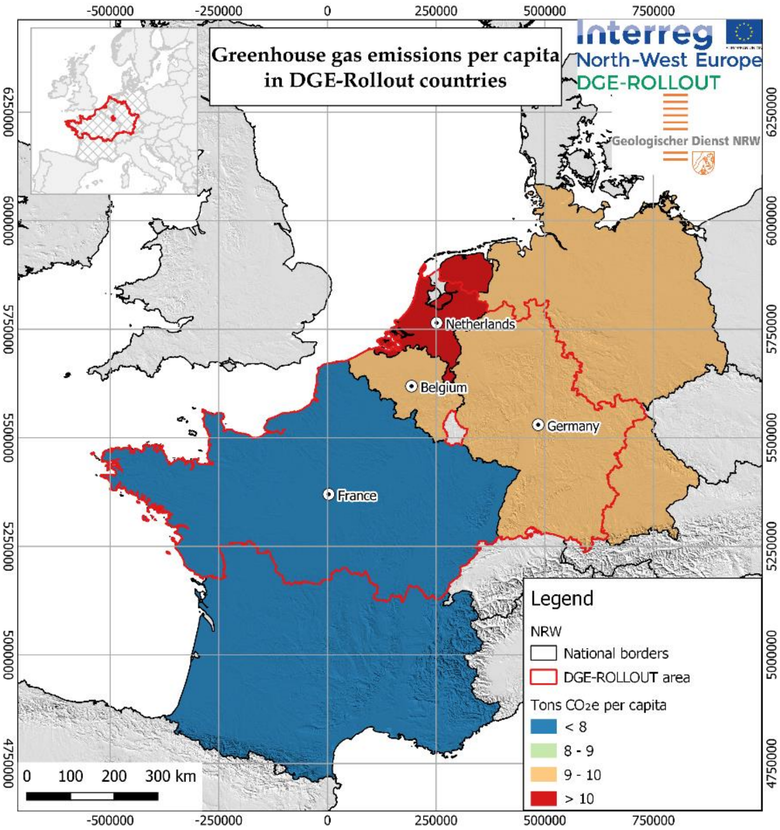

Figure 9 Air pollutants and greenhouse gases emissions in North-West Europe in 2020.

Socio-Economic Potential

Based on the data described above, a composite index for the socio-economic potential for deep geothermal energy in North-West Europe 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 some factors a maximum limit was fixed due to the variance of the data like the density population.

Based on this calculation the regions belonging to Germany and the Netherlands have a higher potential based on the socio-economic factors for the development of deep geothermal projects. In general, a clear urban-rural trend is observed, like in the case of France, where the best values of the index are located in Ile de France.

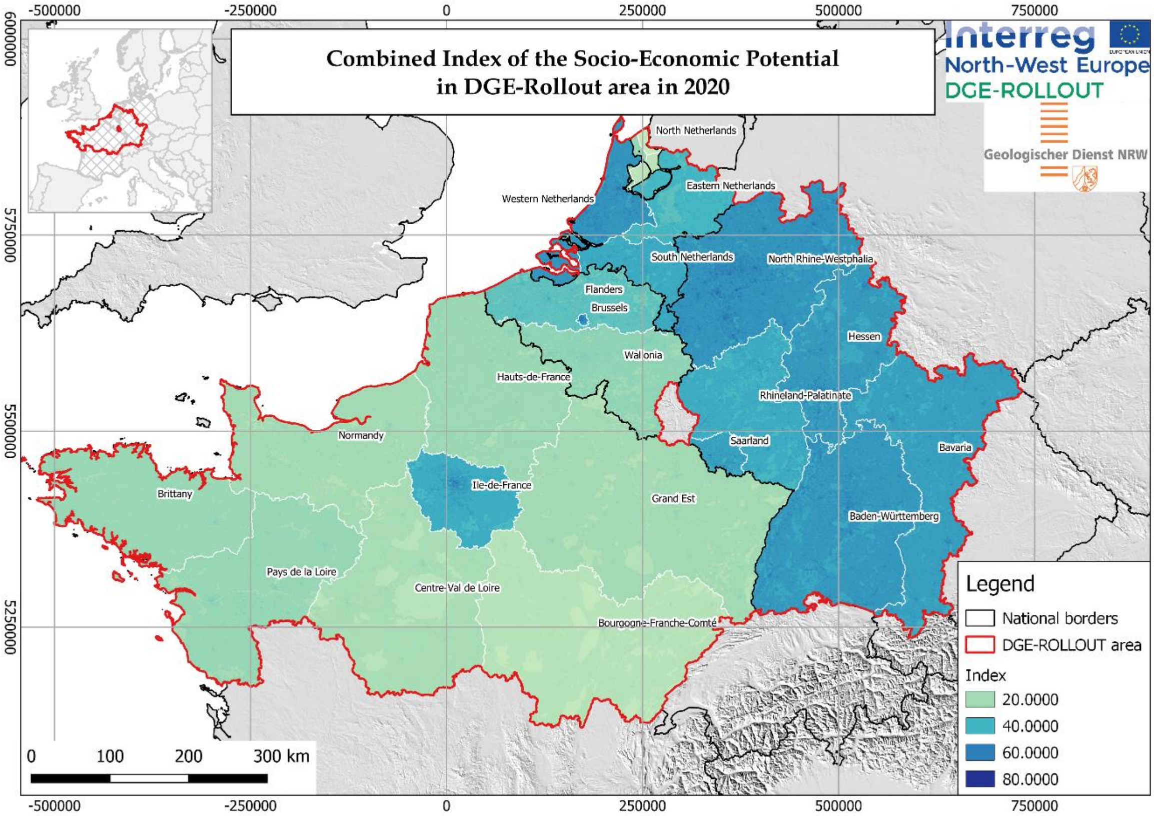

Figure 10 Composite index for the socio-economic potential for deep geothermal energy in the North-West Europe

Discussion

The results are evaluated and compared with the socio-technical pyramid. In the social category, population and heat demand are directly related. The range of gross domestic product in France is wide and presents a contrast between the Ile de France and the surrounding areas. The combined index divides the country into only two areas due to the level of resolution in this factor. The European Union Social Progress Index (EU-SPI) has a small range of difference considering the average value, it could be a further work to use air quality component of the regions, which has a widely range between areas. Finally, in the environment category, protected areas are the critical factor due to the limitation to develop projects. However, this is a local factor to be considered in the region. In the overall visualization they have no impact.

A second map of the index was made to improve the data's visualization. This map shows individual regions results. That is, the data range belonging to each region. The qualitative evaluation allows for a more detailed assessment of the areas with the most significant potential for project development. The available data area differs in France and Germany. For detailed information the reader is invited to the individual report.

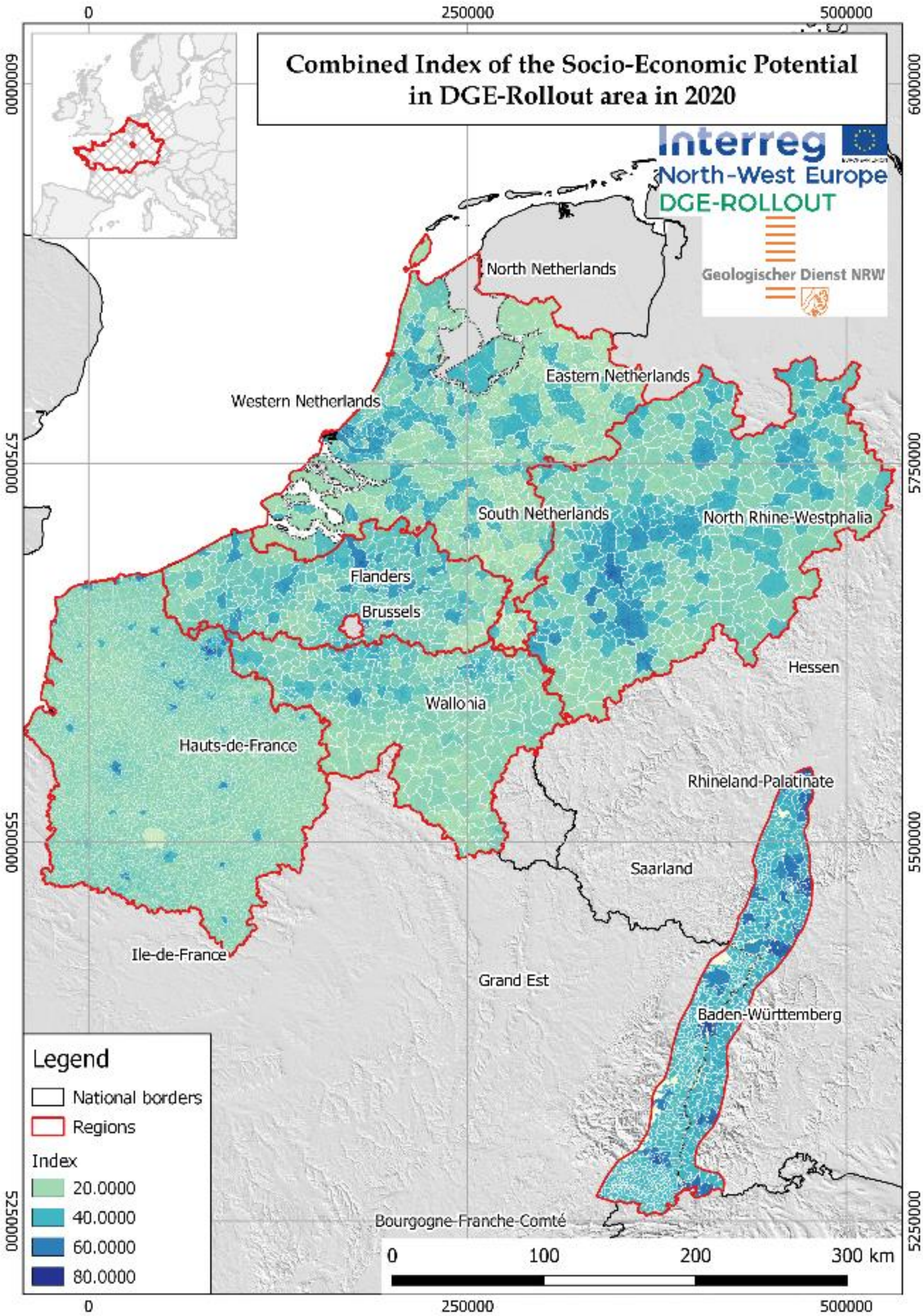

Figure 11 Composite index for the socio-economic potential for deep geothermal energy in the North-West Europe, the limits are defined per region.

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 are separated into two groups in agreement with the benefits of the society. First, the areas with infrastructure and heat demand. Second, areas with the environmental factor. This mainly refers to the reduction of CO2 emissions. The decisive factor for this reduction is the change in the source of energy generation.

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Appendix A

Factor	Database
Population distribution	Landesdatenbank Nordrhein-Westfalen: Tabelle abrufen (nrw.de)
Heat demand	Fraunhofer IEG, 2021. *Map of the spatial distribution of the heat demand at the surface. Deliverable T1.2.1,* s.l.: DGE-Rollout project.
Income	Statistics | Eurostat (europa.eu)
Employment / Forecast	Renewable Energy Employment by Country (irena.org)
Social level map	EU Social Progress Index - 2020 | Data | European Structural and Investment Funds (europa.eu)
District heating	Energieatlas NRW
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://ec.europa.eu/environment/nature/natura2000/data/index_en.htm

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