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Stratego
ENHANCED HEATING
& COOLING PLANS

Mapping the Renewable Heat Resources in Europe

Work Package 2

Background Report 9



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1 Biomass mapping

The availability of sustainable biomass in the EU is difficult to quantify as it depends on many factors. The operation of biomass and other fuel markets; the available economic incentives; and also the pace of technological change in the renewable energy system all influence the type, amount and geographical origin of biomass, which will contribute to achieve the 20% target for renewable energy supply in 2020. The European Commission states that *“The projected contribution of biomass thus hinges heavily on assumptions.”* (EC, 2015).

Biomass resource assessments differ greatly for the same area or country, because of the many different methods used, because of heterogeneous data, uncertainties in the empirical data base, as well as different perceptions on the technology implied (BEE, 2015).

This means that it is not possible on none of the three levels: ecology, agro-forest economy, and technology to reach agreement on the absolute amounts of biomass, let alone their geographical distribution in a given country or region. Several reports, however, comprise national and sometimes regional accounts for future available biomass for energy purposes (AEBIOM, 2011; AEBIOM, 2014) and also formulate limits of sustainable biomass use (EEA, 2006).

A regionalized account of all biomass resources for the purpose of quantifications of the amounts of available and economically feasible biomass is therefore discouraging to attempt. A simple way of quantifying biomass for energy would be to map the amounts of biomass from forestry operations as well as agricultural residues on the basis of empirical data on current and past management practices. However, a significant proportion of this potential is already being used for energy and non-energy purposes, often outside a quantifiable supply chain. Also, the use of biomass for energy purposes usually brings along a change of management practices, so empirical yield and waste potential data cannot be used. Then, the present management practices and their resulting biomass extraction ratios do not in general represent a state of equilibrium in either an economic or ecologic sense. Finally, the processes and their variables which describe the proportions of biomass that can be harvested on an economic basis in the regional biomass for energy markets are largely unknown on a European scale. Any attempt to map a regional distribution of sustainable and economically available biomass resources is therefore a major challenge.

1.1 Sustainable biomass resources

Sustainability of biomass for energy implies a long-term maintenance of carbon stock and biodiversity. This can only be achieved in forestry when maintaining forest volumes, forest density (in terms of standing volume per area as well as forest area per land area), and forest area and forest ecosystems. Any shift towards lower carbon stock results in a depletion, which should be avoided. For the agricultural sector, this implies the maintenance of soil texture (amount of organic matter, humus) and hence fertility as well as the land available as arable land. It also includes indirect land use change (ILUC) effects, which result from the shift of crops and their substitutes from one part of the world to another, like it is often seen with the replacement of domestic fodder with imported soy beans e.g. due to an increase in domestic energy crops. Any addition to the biomass resource potential should therefore avoid changing land use, the intensity of land use, as well as the present carbon stock per land use unit, assuming that the present land use is sustainable, which can be argued about.

Wood for biomass is increasingly imported from neighboring regions such as the Baltic area, Russia or even traded globally from North America or elsewhere. The present study only includes domestic wood resources from within the EU28 and focuses on the local availability, which excludes long distance transport.

Biomasses used for the production of biofuels are also excluded from the study, which primarily looks at the fuel demands for the heating and power generation sectors.

1.2 Biomass from agriculture

Emphasis is here on residues from agriculture, which are marginal to agricultural production. Dedicated energy crops are not included, partly because they may be too costly for district heat generation, partly because of increasing issues of sustainability. On a large scale, only the waste products of the main agricultural crops, here mainly straw from cereals, are included here.

Assuming that land use remains unchanged and that the present productivity is not increased for the sake of biomass for energy production, the gross potential of straw can be assessed using the present area of arable land and the present productivity of cereal production, as well as the ratio of straw production to cereals production. In Denmark, where the use of straw for energy purposes is probably at its highest development stage, about 40% of the cereals yield is available as straw in a long-term average (Statistics Denmark, 2014).

Straw production among the 28 member states was assessed using Eurostat agricultural statistics dating from 2009 to 2013 (where available). An average productivity of cereal production was derived using the 5-year averages of annual production divided by the area on which cereals were planted in that period. Then, agricultural areas were mapped by extracting the “Arable land” land use class from the 2006 Corine land cover database (EEA, 2014). The potential production of cereals, to which the possible straw production is proportional, is hence the locally available arable field area times the productivity achieved in each country. It is here assumed that cereals or similar crops, which would produce similar wastes as straw, are planted on all arable lands, which e.g. does not seem to be the case for the UK. This method further assumes that productivity is the same within a given country and that the national productivity is unchanged. It includes those factors, like the intensity, the degree of mechanization, the economic efficiency etc. of cereal production in a given country, but assumes that cereals can be planted on all arable land.

Since the exact location is neither important nor possible to know, the resulting potential of straw is here summarized within a 30km radius around each location on the map. The distance refers to the distance at which straw usually is transported for small scale applications such as district heating plants. The resulting map, see Figure 1, shows the regional maximal availability of straw from agriculture.

A few restraints have to be considered. First, the present method assumes that all available arable land is used for cereals. Although the Corine land use classification distinguishes quite well between land use and types of agriculture, arable land may also be used for other crops. Neither is it possible to include on this scale the fertility of soils, which effectively reduces the potential to grow cereals.

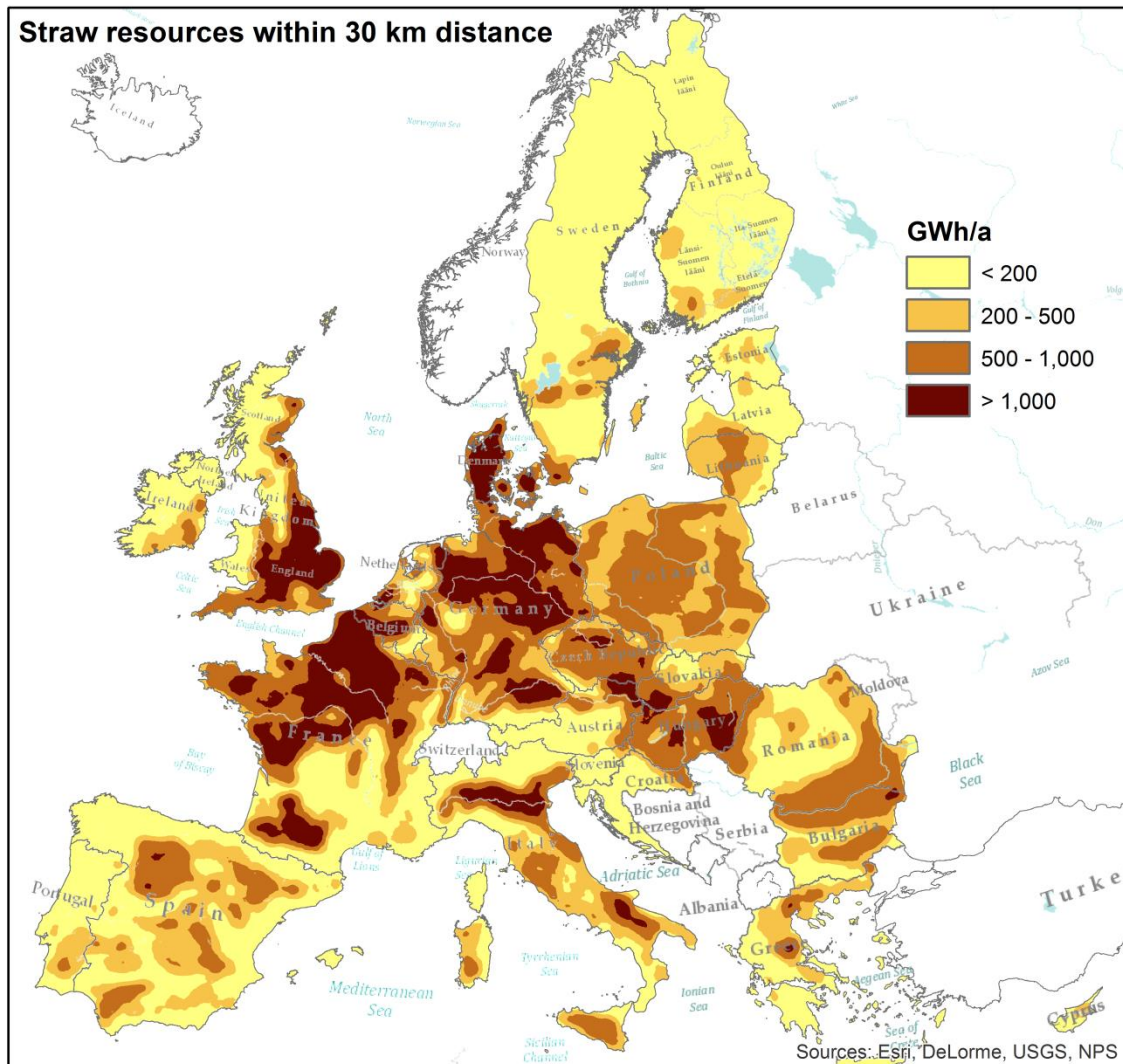


Figure 1: Straw resources from biomass within a distance of 30km of each location. This map shows densities of straw wastes from cereal production from all possible arable lands.

1.3 Biomass from forestry

Similar to the agricultural biomass potential assessment above, the resources of forestry biomass have been based on land use as well as recent productivity. However, forest land use cannot easily be expanded, and forestry management is highly affected by conservation and environmental protection. Therefore the present method of biomass resource assessment from the European forest sector excludes national conservation areas (domestic designated areas), (EEA, 2015a) as well as areas subject to the Natura2000 directive (EEA, 2015b). Also, although the distribution of forests of different densities and species highly depend on the local and regional geography, a uniform productivity is being applied within each country.

Forest distribution by density is done using the forest density map available at 1km resolution from the European Forest Institute (EFI, 2014). It shows the percentage of forest coverage and density combined for each square kilometre, resulting in a count of dense hectares per km². That means if there are patches of forest within a km², or heterogeneous forest density within that area unit, the value of the grid is still a count of hectares. Only the total density was used, disregarding the

difference between deciduous and coniferous species, for which no distinction is made in the Eurostat table of forest productivity.

From the forest density maps those areas are excluded, which are Natura2000 areas or domestic conservation areas (except IUCN code “V”, which comprises many areas of protected landscape character, where forestry operations are not affected by conservation legislation). This is done mainly to reduce the high pressure on remaining natural forests as well as national parks or smaller habitat areas, from which no commercial forest extraction is expected (in fact the Danish Nationalpark Thy is a major source of wood chips from sustainable forest management and the gradual modification of the national park area to near-nature state forest, which may take decades to implement).

The Eurostat tables for forest increment and felling, which contain productivity data since 1990, were used to derive long term averages (20 years) of the increment due to net forest volume and area growth as well as the extraction of timber. This should level out storm events as well as major changes in management practices, which are significant in particular for some member states in the East of Europe under the structural change towards a more commercial timber production.

This study assumes that across Europe, 20% of the annual felling and a further 10% of the net increment can be used for energy purposes. This includes the sustainable use of felling residues, which can be up to 50%, which otherwise would be left in the forest, as well as the extraction of predominantly young, non-commercial timber in thinning operations as part of forest management. A wood resource extraction ratio ($\text{m}^3/(\text{ha} \cdot \text{a})$) was calculated using the actual forest management statistics in combination with these assumptions. The extraction ratio was multiplied with the forest density map that excludes conservation areas, as well as a heat value of wood residues to derive an energy density map. Finally, a 30km radius was applied for accounting locally available biomass resources, see Figure 2. Although forest residues can be economically transported over larger distances, the emphasis is here on locally available resources. And since no allocation of resources on specific locations is made, a further increase of distances is not necessary. The resulting map shows the regional availability of forest resources under the chosen constraints.

The present method neglects the fact that in some areas the biomass is already used in existing bioenergy schemes or otherwise a commercial commodity that is not available for energy purposes. Further, the productivity rates are calculated as national averages, while the real forest sector is rather heterogenic, with high-intensity areas as well as low-productivity forest. Cross-border flows of timber are not considered across the external EU borders. Finally, not all of the wood in the periphery of Europe is equally accessible for transport to energy plants, e.g. in Northern Scandinavia.

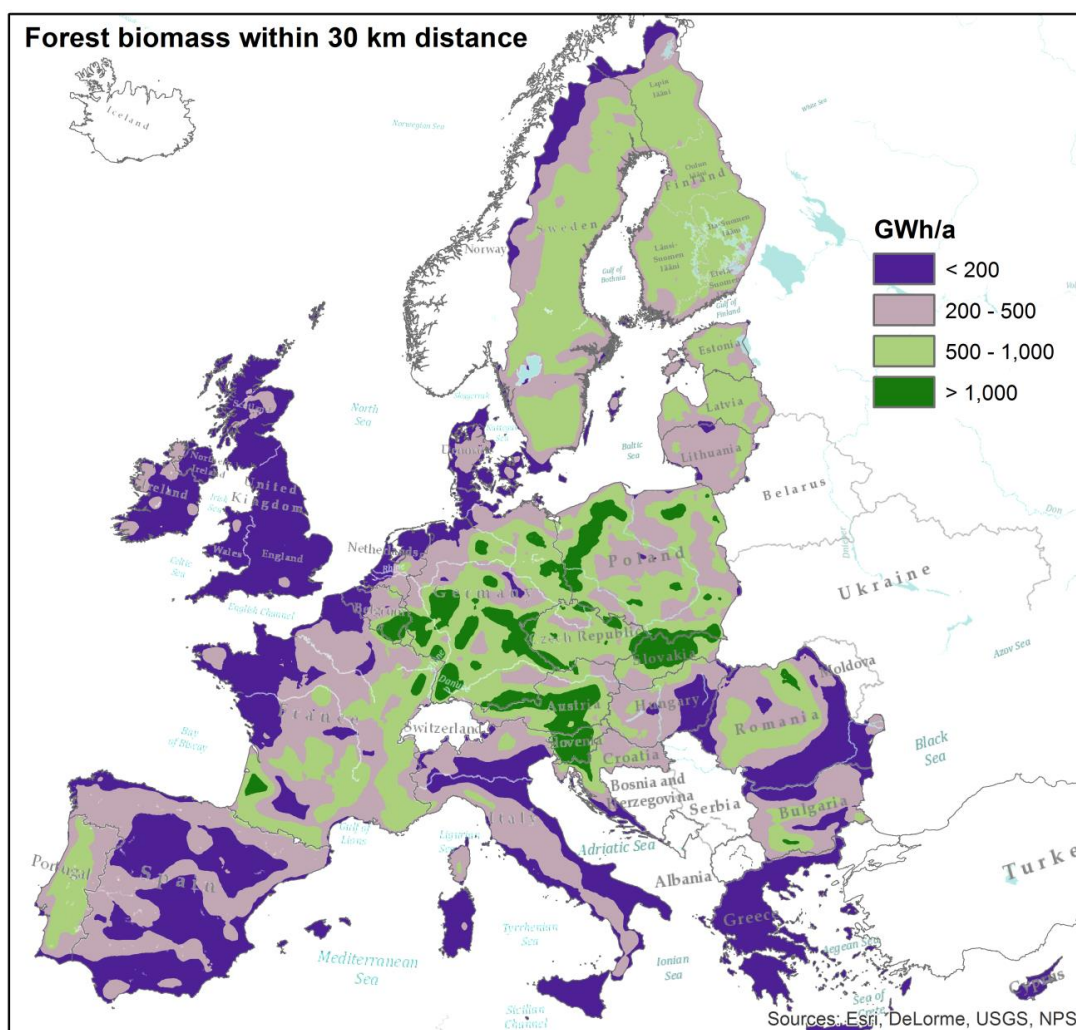


Figure 2: Potential biomass resources from forestry including thinning as fraction of annual increment and logging residues as share of annual felling. The map shows densities by accounting for forest biomass available within a radius of 30km around each location.

The total amounts of straw and wood for energy purposes in the five Stratego countries are given in Table 1. The figures reflect the current productivity of the forest sector and the assumed productivity in the agricultural sector. The rationale is that while changes in forest productivity take decades to implement, the change of crops on available arable land could be accomplished within much shorter times. Of course the emphasis on straw and other waste materials as marginal products implies that there is a market for the crops produced. The same applies for forest products and is linked to forest and agricultural policies, which, as stated before, are not necessarily operating at optimum at present times.

Table 1: Biomass amounts in TWh/a in the target countries.

Member state	Forest biomass	Straw
CZ	22.26	6.08
HR	10.57	0.82
IT	23.64	16.16
RO	30.68	10.74
UK	7.72	18.25

2 Mapping geothermal heat resources relative to district heating potentials

Geothermal heat of sufficient temperature and volume may be found under large parts of Europe. In order to assess the potential for geothermal energy, underground temperature (enthalpy) is only one of several selection criteria. The bedrock permeability and the presence of water influence the heat flow as well. That means that a study of the geothermal heat supply is based on interpreted information on the geological conditions. Still, a great deal of uncertainty remains. The GeoDH project (GeoDH, 2015) has mapped reservoirs and other conditions that indicate favourable conditions for geothermal heat. For the present assessment of geothermal energy sources the GeoDH project kindly made available the geographical data layers that are the basis of geothermal mapping.

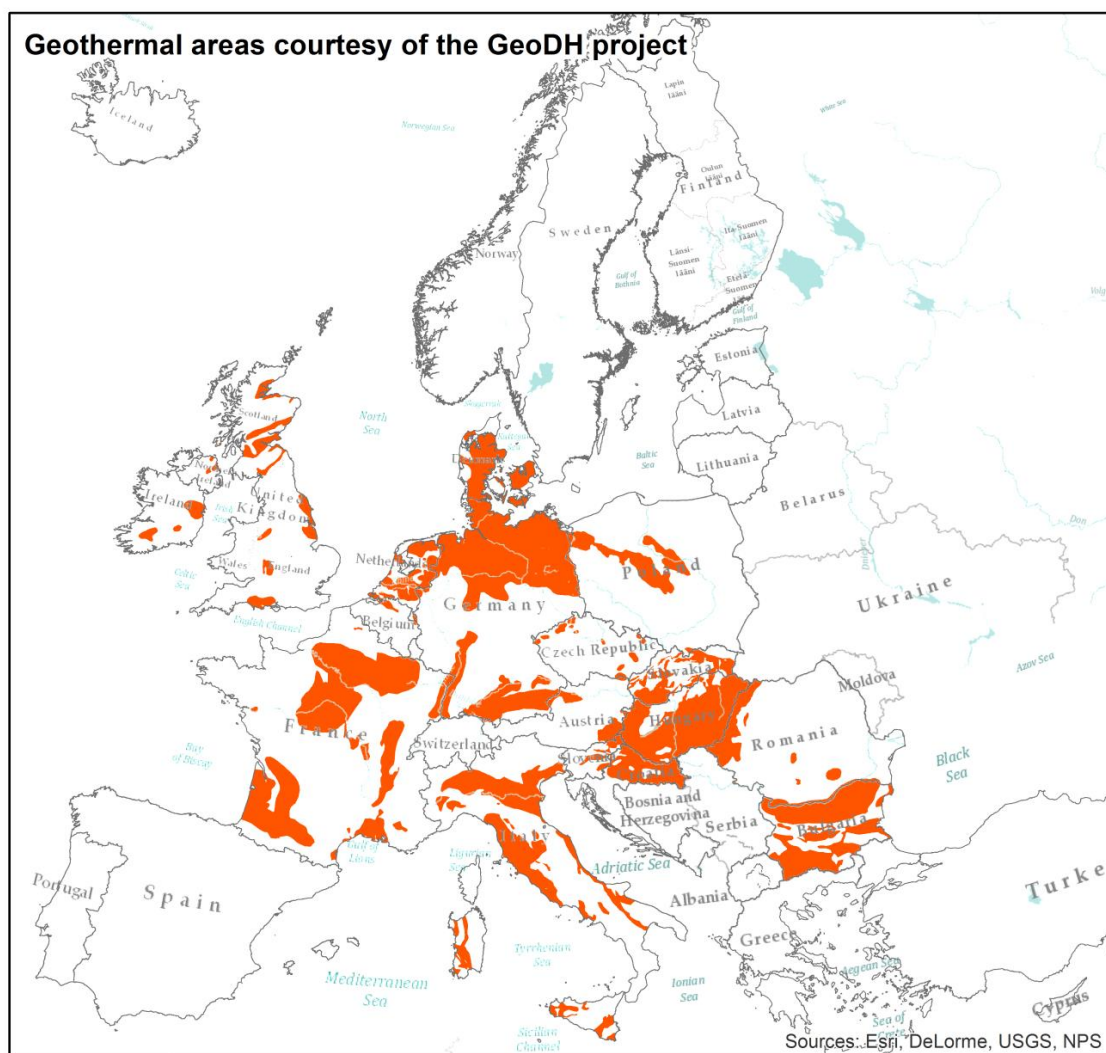


Figure 3: Map of suitable geothermal areas, which are characterised by hot sedimentary aquifers or other potential reservoirs.

From the several layers available in the GeoDH GIS, “hot sedimentary aquifers” and “other potential reservoirs” were chosen, as they are deemed suitable for geothermal district heating and cooling.

Further, the temperature levels at certain depths are relevant to look at, where one would look for temperatures exceeding 60°C and located no deeper than 3km (GeoDH, 2015).

It was found that the map below (Figure 3) is not concise, as e.g. the city of Lund in Sweden has installed a geothermal district heating system, while it is not located within one of the favourable areas. For further development of the model a more advanced method like the one used for the Geoelec project (Geoelec, 2014) could be made available for the present atlas.

To assign the geothermal heat potentials to district heating potentials, the heat demand in prospective district heating areas of different size was summarized by location within geothermal areas, see Table 2. Also, for each prospective district heating system an attribute of geothermal potential has been assigned if it lies within a geothermal area.

Table 2: Heat demand located in potential geothermal areas by the size of district heating system (in PJ annual heat demand)

	< 0.3 PJ	0.3-1 PJ	1-3 PJ	3-10 PJ	>10 PJ	Total
CZ	6.59	5.80	13.25	3.70	-	29.342
HR	11.48	5.32	2.24	-	12.08	31.119
IT	110.93	53.48	70.09	42.50	319.51	596.506
RO	15.19	2.78	6.03	3.63	27.83	55.449
UK	18.98	13.00	22.96	15.48	33.38	103.812

3 Mapping sources of ambient heat in surface and sewage water bodies

Ambient heat as a source of heat to be used by means of large-scale heat pumps has been mapped using land-use mapping (Corine) of surface water bodies exceeding 1 hectare in size as well as rivers (EEA) and their network hierarchy. The rationale is that surface water, still or running may be used as low-temperature heat reservoirs. The size and vicinity of lakes, the access to coastal waters, as well as the run-off volume of rivers are assumed to be relational to the contribution to heat that is possible to deliver by heat pumps. A series of factors makes an absolute assessment of heat quantities extremely difficult, which is why the accessibility of surface water is here expressed on a scale of 1 (poor) to 5 (excellent). While the total potential of heat recoverable from the environment is related to the net solar radiation, the following factors limit this: environmental considerations, technical feasibility, water rights, alternative uses, as well as temperature levels.

Proximity to surface water has been mapped in a focal statistics function, which summarizes the number of 1ha cells per km² within a radius of 5km. Hereby a density surface, which describes the area of lakes and coastal waters within the given radius, is produced. By reclassification to a scale of 1 to 5 a linear relation between the water area within reach of a heat pump and each prospective location of a district heating system has been established, where a value 5 indicates the highest availability of surface water.

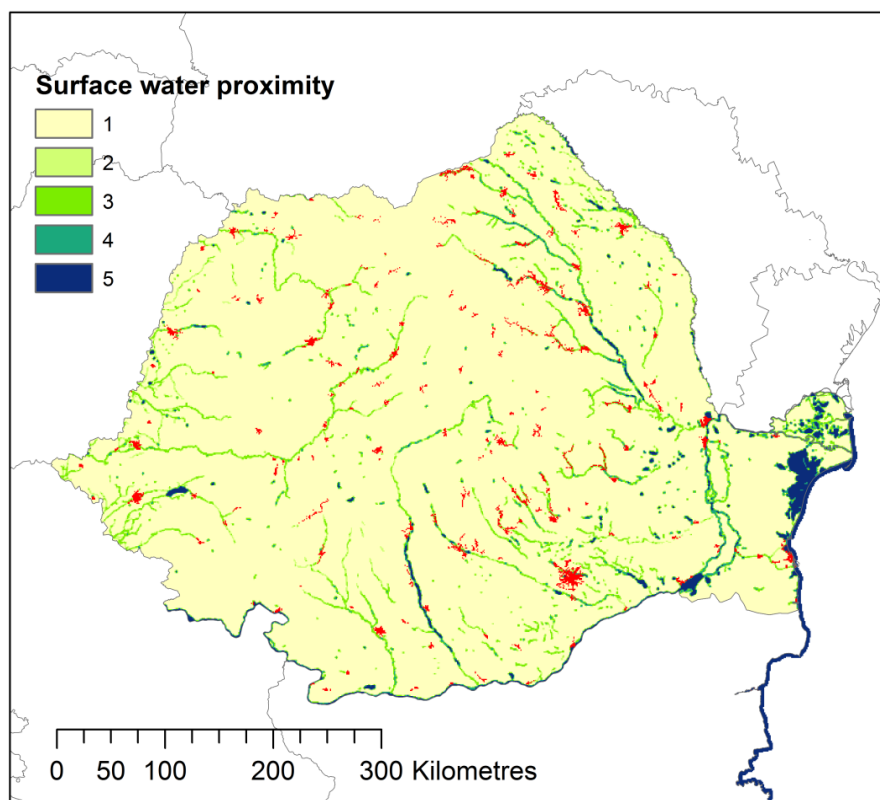


Figure 4: Map of surface water proximity for Romania.

For rivers, the European river network database (EEA) was used, which describes the river network hierarchy by means of the Strahler method, where the rank of rivers is increased from values of 1 onwards every time two rivers of the same order intersect. This results in an approximation of the

run-off volumes of all rivers in Europe, which is thought to be proportional to the amount of low-temperature heat that can be extracted from rivers by means of heat pumps.

In order to assign the potential of river- and lake-based heat pumps, the highest potential score available at each prospective district heating system was related to these by means of a spatial statistics operation. Figure 4 shows the surface water proximity assessment in five classes relative to urban areas in Romania.

Heat extracted from sewage water by means of large heat pumps is assumed to be proportional to the population of towns and cities. A report by the heat pump manufacturer Ochsner (2012) assumes that 5% of heat demand can be covered in towns and cities with more than 10.000 people. Table 3 shows the potential of sewage water heat, which has been calculated using the population count (Geostat, see chapter 2.7) and calculated heat demand for each prospective district heating system with more than 10,000 inhabitants within the DH system boundaries.

Table 3: Heat extractable from urban sewage systems by means of heat pumps.

Country	Heat demand covered by sewage water (PJ)
CZ	1.37
HR	0.28
IT	7.61
RO	1.39
UK	13.87

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