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Sun coupled innovative Heat pumps

D2.2 – Mapping of solar resource and building demand for SunHorizon implementation

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1 INTRODUCTION AND MAIN CONTENTS

Deliverable D2.2 “Mapping of solar resource and building demand for SunHorizon implementation” is dedicated at mapping solar resource potential, solar resource demand and favourable market conditions, including energy prices, local building energy demand and most common Heating and Cooling (H&C) appliances in European countries.

The goal of such task is to increase knowledge on solar sources, on the distribution of the most common solar installations and on the H&C needs in the European Union (EU28), including demonstrator countries.

The mapping activity is performed through an analysis of multiple parameters identified as proxies for the fields of solar resource potential, H&C demand and common technologies and favourable market conditions. The analysis is performed at national level and it is mainly based on EU-wide data sources, in order to preserve the homogeneity of results for each country. In addition, it covers separately – whenever the separation is meaningful – the residential sector and the tertiary sector. In this context, the following definitions apply:

- the **residential sector** includes dwelling stock or other living areas;
- the **tertiary sector** includes economic activities related to trade, hotel and restaurant, traffic and data transmission, finance, health, education, public administration and other services such as waste, sport, social services and real estate.

The analysis is based on quantitative data and it produces qualitative outcomes that are deemed as useful and relevant to the scope of this work. Such outcomes consist in the definition of a low/medium/high score to be assigned to each Country in each field, covering from resource availability to market panorama. The classification into low/medium/high levels, is based on the approach followed in the Deliverable “Roadmaps towards low carbon H&C scenarios” of PLANHEAT project, according to which:

- a **low** grade is associated with numerical values more than 20% lower than the average
- a **medium** grade is associated with numerical values in line with the average, i.e. between +20% and –20%
- a **high** grade is associated with numerical values in line with the average more than 20% higher than the average

Final results consist in the definition of a framework that highlights the main features relevant for the implementation of each Technology Package (TP) studied in SunHorizon in each European country, in terms of availability of solar resource potential, demand, existing technologies for H&C and market conditions.

2 MAPPING OF SOLAR RESOURCE POTENTIAL

The first step to derive suitable maps of solar resource is to select a representative indicator of solar resource potential, which is the most significant parameter for this specific analysis. Considering the technologies developed within SunHorizon, based on the coupling of solar panels with heat pump solutions, it is chosen to express solar resource in terms of global irradiation [kWh/m^2], calculated on annual basis. From this indicator, the potential energy production in terms of electricity and/or heat can be estimated, given the technological features of the solar panel installed (photovoltaic, solar thermal or hybrid).

Figure 2.1 shows global irradiation values in Europe on a theoretical optimally-inclined south-oriented solar module, as derived by the PV-GIS tool developed by the Joint Research Center of the Eurpean Commission. The highest values, reaching more than 2,200 kWh/m^2, are to be found in Cyprus, Italy, Spain, Portugal, Greece and Malta, whilst the lowest values, in the order of 1,000 kWh/m^2 are calculated in some areas of Sweden, Finland, and of the United Kingdom.

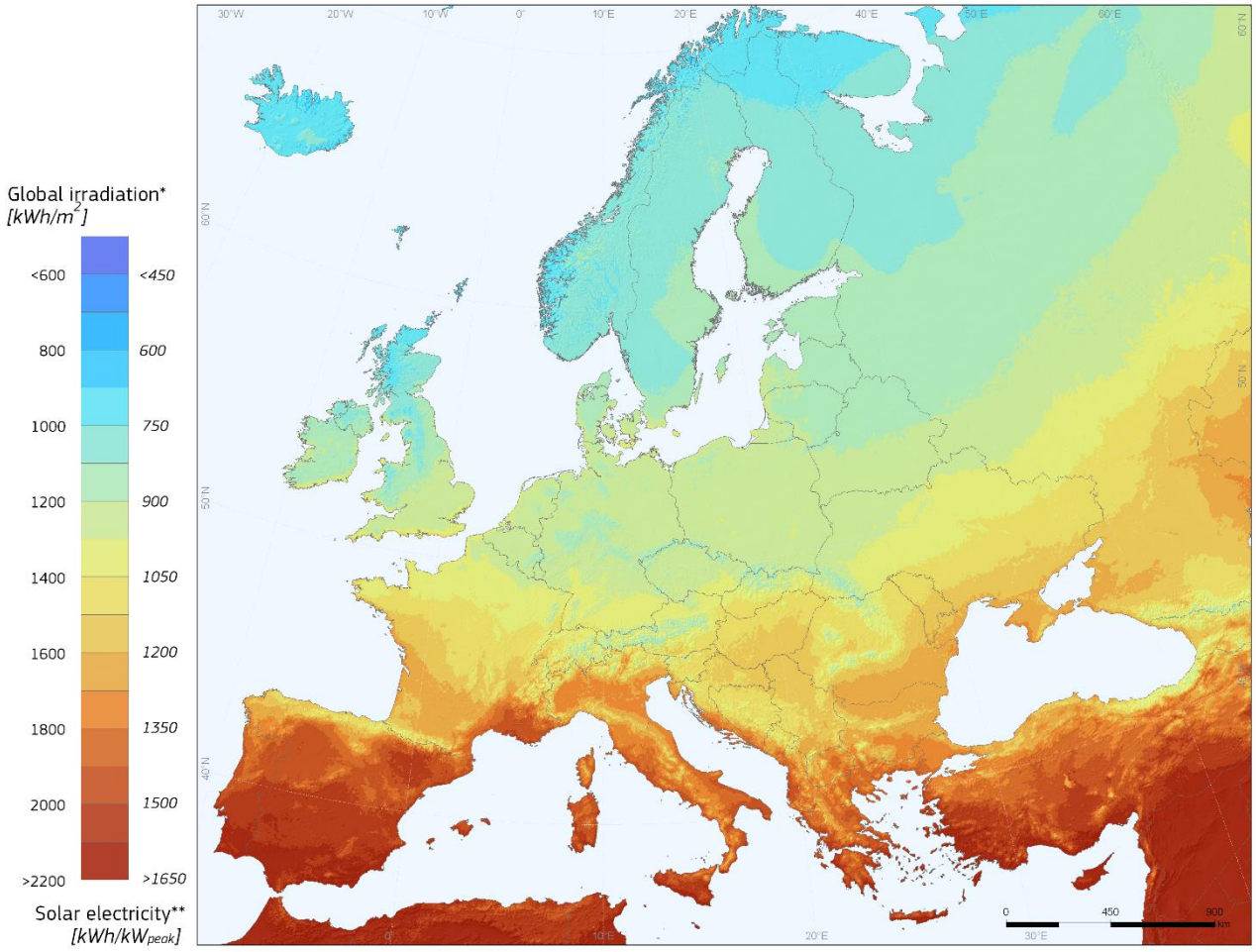

Figure 2.1 – Global Irradiation in Europe (PVGIS © European Communities, 2001 - 2019)

Table 2.1 provides an insight of country-average global irradiation values, calculated for the optimum angle for each country respectively.

Country	Global Irradiation [kWh/m^2]
Austria	1,325
Belgium	1,238
Bulgaria	1,631
Croatia	1,570
Cyprus	2,217
Czech Republic	1,256
Denmark	1,211
Estonia	1,151
Finland	1,054
France	1,513
Germany	1,251
Greece	1,897
Hungary	1,490
Ireland	1,174
Italy	1,750
Latvia	1,175
Lithuania	1,183
Luxembourg	1,243
Malta	2,155
Netherlands	1,242
Poland	1,252
Portugal	1,996
Romania	1,496
Slovakia	1,333
Slovenia	1,444
Spain	1,948
Sweden	1,084
United Kingdom	1,153

Table 2.1 – Country-average global irradiation

Figure 2.2 graphically summarizes global irradiation data collected, sorted by highest to lowest values.

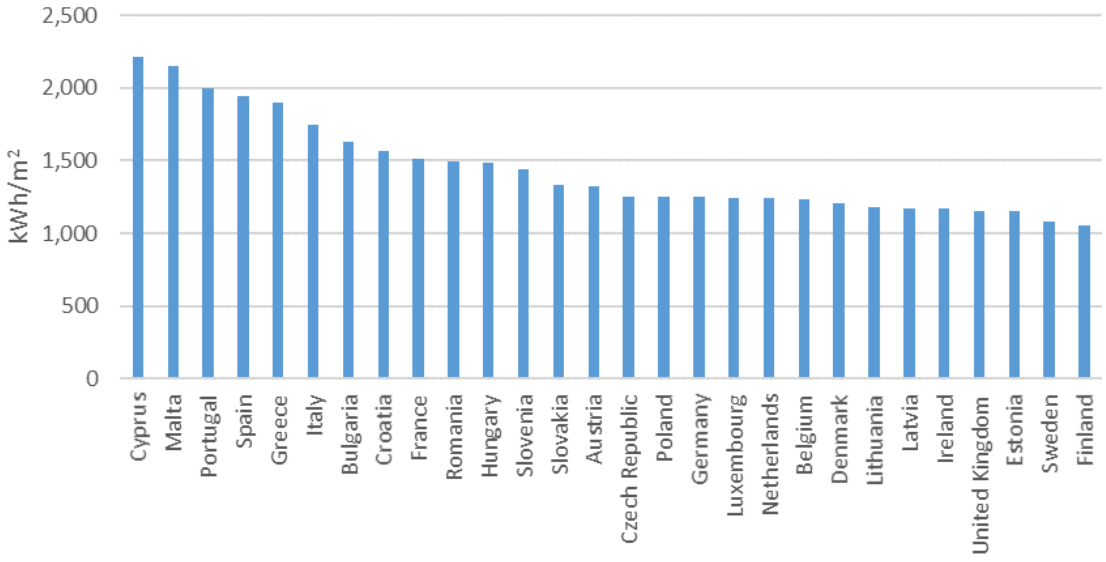

Figure 2.2 – Country-average global irradiation

On the basis of the values of average global irradiation, the following ***classification according to the availability of solar resource potential*** in each country can be outlined:

- countries with low availability of solar resource (less than 1,250 kWh/m^2): Finland, Sweden, Estonia, United Kingdom, Ireland, Latvia, Lithuania, Denmark, Belgium, Netherlands and Luxembourg;
- countries with medium availability of solar resource (between 1,250 kWh/m^2 and 1,500 kWh/m^2):, Germany, Poland, Czech Republic, Austria, Slovakia, Slovenia, Hungary and Romania;
- countries with high availability of solar resource (more than 1,500 kWh/m^2): France, Croatia, Bulgaria, Italy, Greece, Spain, Portugal, Malta and Cyprus.

The aforementioned classification is mapped in **Figure 2.3** below.

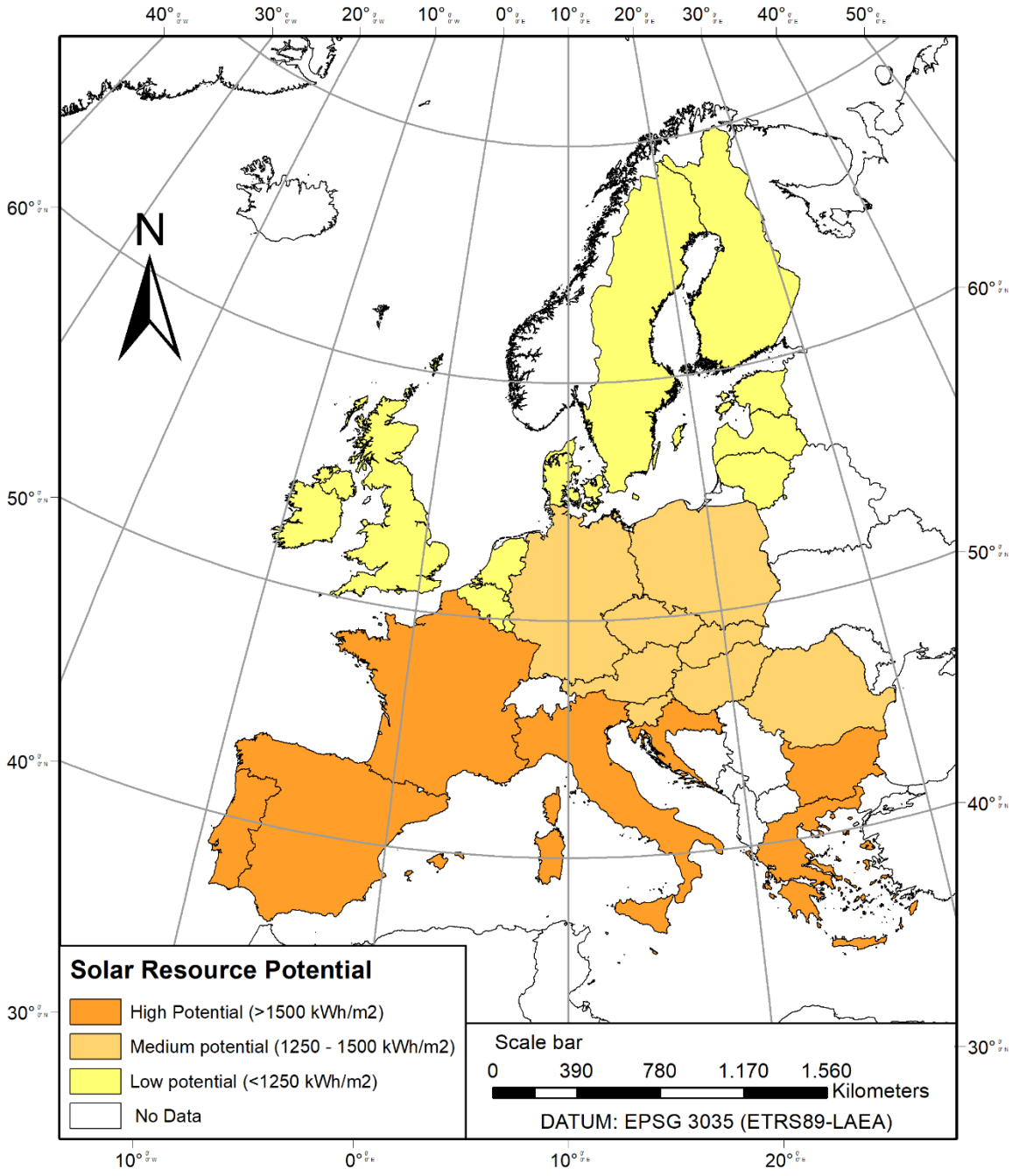

Figure 2.3 – Classification according to solar resource potential (own elaboration)

3 MAPPING OF ENERGY DEMAND AND COMMON H&C APPLIANCES

This section is dedicated to mapping the main features of energy demand for H&C purposes and the most common technologies available and used to cover such demand.

3.1 Energy Demand

This subsection includes a data collection for the estimation of H&C demand in the residential and tertiary sector in European countries.

Energy demand is intended as a "final energy demand", which means the energy input to the heating (or cooling) unit at the final consumer. The demand is mapped at the following two different levels:

- absolute demand level, providing as outputs values of total H&C demand by country and by end-use for the residential sector and the tertiary sector separately;
- specific demand level, providing as outputs values of H&C demand per built-up area by country.

The former level is important to provide a framework of the largest energy consumers in Europe, whereas the latter one, even though it is characterized by a greater uncertainty related to the estimation of the residential area, should identify the countries where energy consumption is more intensive, either due to local climate conditions or to the conditions of the existing building stock. At a first sight, the former level may seem not of interest because it mostly depends on the size of the nation (a large country with low specific energy demand has always a much higher absolute energy demand compared to a small country with high specific energy demand), but coupled with the latter level provides an indication of where the H&C demand is significant and the market size is sufficiently large to make worthy the promotion of efficient H&C systems.

For the mapping of energy demand, **end-use** indicates the scope for which the demanded H&C energy is necessary. For the residential sector, it includes space heating, water heating and space cooling, whereas for the tertiary sector it includes the same end-uses of the residential one, as well as process heating and process cooling for example in the case of food retailers, or repairing activities. **Built-up area** for both the residential and tertiary sector corresponds to the useful floor area, which can be considered heated during cold months and, where relevant, cooled during warm months.

Energy demand for H&C purposes in the residential and tertiary sectors is estimated on the basis of profiles of heating and cooling demand available statistics for European Member States (MSs) in 2015 within the Heat Roadmap Europe project[1], which aims at identifying and developing low-carbon heating and cooling strategies for 14 EU MSs. The project also includes a consistent and robust estimation of H&C demand at national level for European MSs, divided by sub-sector and end-use.

Indeed, most of the other available ready-to-use sources, statistics and energy balances, such as those available in Eurostat[2], provide aggregate data either by sector or end-use, making the task of deriving homogeneous and coherent results quite demanding, as a number of assumptions is likely to be introduced.

Table 3.1 shows H&C total annual demand for the residential sector by country. The heating demand is disaggregated according to end-use, i.e.: space heating and hot water production. Cooling demand covers the demand for space cooling, only. It is worth mentioning that additional heating demand for the residential sector

[1] https://heatroadmap.eu/
[2] https://ec.europa.eu/eurostat

is associated with cooking activities, but it is not relevant for this mapping considering the features of technologies proposed by SunHorizon.

Country	Space Heating [TWh/y]	Water Heating [TWh/y]	Space Cooling [TWh/y]
Austria	47.3	8.3	0.0
Belgium	69.1	9.9	0.0
Bulgaria	14.7	3.5	0.1
Croatia	20.2	2.8	0.1
Cyprus	1.1	1.0	1.9
Czech Republic	49.3	9.9	0.0
Denmark	33.6	7.7	0.0
Estonia	7.5	0.8	0.0
Finland	46.7	3.8	0.0
France	325.0	31.4	1.2
Germany	449.4	106.5	0.1
Greece	28.8	7.3	4.3
Hungary	45.7	5.2	0.1
Ireland	22.3	4.3	0.0
Italy	288.8	45.3	10.9
Latvia	9.8	1.6	0.0
Lithuania	10.1	1.9	0.0
Luxembourg	5.0	0.5	0.0
Malta	0.2	0.1	0.5
Netherlands	84.8	12.6	0.0
Poland	164.0	20.6	0.0
Portugal	6.6	7.1	0.8
Romania	49.6	8.2	0.3
Slovakia	17.9	3.2	0.0
Slovenia	9.6	1.9	0.0
Spain	63.4	52.1	5.4
Sweden	46.6	9.4	0.0
United Kingdom	273.5	70.3	0.1
TOTAL	**2,190.6**	**437.2**	**25.8**

Table 3.1 – Final energy demand for H&C in the residential sector (Heat Roadmap Europe)

Table 3.2 shows H&C annual demand for the tertiary sector by country. Demand values are disaggregated according to end-use, i.e.: space H&C demand, process H&C demand and hot water heating demand.

Country	Space Heating [TWh/y]	Process Heating [TWh/y]	Water Heating [TWh/y]	Space Cooling [TWh/y]	Process Cooling [TWh/y]
Austria	20.3	1.1	1.6	0.3	1.5
Belgium	29.5	1.5	2.4	0.4	2.6
Bulgaria	4.6	0.6	0.3	0.6	0.1
Croatia	3.2	0.3	0.3	0.3	0.4
Cyprus	0.4	0.1	0.2	0.7	0.1
Czech Republic	18.5	1.1	1.3	0.2	0.8
Denmark	11.6	1.0	0.8	0.1	1.8
Estonia	2.7	0.2	0.1	0	0.1
Finland	19.4	0.9	1.1	0.1	1.3
France	111.7	7.8	14.3	3.4	13.0
Germany	243.7	11.5	17.7	1.6	17.2

Country	Space Heating [TWh/y]	Process Heating [TWh/y]	Water Heating [TWh/y]	Space Cooling [TWh/y]	Process Cooling [TWh/y]
Greece	3.5	1.0	0.8	4.0	1.0
Hungary	18.8	0.7	1.4	0.3	0.4
Ireland	9.0	0.5	0.7	0	0.8
Italy	81.5	5.9	12.1	14.7	10.9
Latvia	4.3	0.2	0.2	0	0.1
Lithuania	3.8	0.3	0.2	0	0.3
Luxembourg	2.7	0.1	0.2	0	0.5
Malta	0.4	0.1	0.2	0.2	0.1
Netherlands	37.9	2.8	3.5	0.4	4.8
Poland	46.9	2.8	2.7	0.5	2.2
Portugal	4.6	1.1	1.8	1.4	0.8
Romania	12.9	1.1	1.0	0.7	0.6
Slovakia	9.2	0.5	0.6	0	0.3
Slovenia	2.4	0.3	0.2	0.2	0.3
Spain	35.5	4.9	5.4	13.3	4.8
Sweden	26.9	1.7	1.5	0.2	3.1
United Kingdom	92.2	9.6	10.9	1.1	3.0
TOTAL	**858.1**	**59.7**	**83.5**	**44.7**	**72.7**

Table 3.2 – Final energy demand for H&C in the tertiary sector (Heat Roadmap Europe)

Finally, **Table 3.3** shows the heating demand, the cooling demand, including both the residential and tertiary sector for all the considered end-uses, and the overall H&C demand for each country. It appears that the overall energy demand is mostly determined by the heating demand for most of the European countries.

Country	Heating Demand [TWh/y]	Cooling Demand [TWh/y]	Total Demand [TWh/y]
Austria	78.6	1.8	80.4
Belgium	112.4	3.0	115.4
Bulgaria	23.7	0.8	24.5
Croatia	26.8	0.8	27.6
Cyprus	2.8	2.7	5.5
Czech Republic	80.1	1.0	81.1
Denmark	54.7	1.9	56.6
Estonia	11.3	0.1	11.4
Finland	71.9	1.4	73.3
France	490.2	17.6	507.8
Germany	828.8	18.9	847.7
Greece	41.4	9.3	50.7
Hungary	71.8	0.8	72.6
Ireland	36.8	0.8	37.6
Italy	433.6	36.5	470.1
Latvia	16.1	0.1	16.2
Lithuania	16.1	0.3	16.4
Luxembourg	8.5	0.5	9.0
Malta	1.0	0.8	1.8
Netherlands	141.6	5.2	146.8
Poland	237	2.7	239.7
Portugal	21.2	3.0	24.2
Romania	72.8	1.6	74.4

Country	Heating Demand [TWh/y]	Cooling Demand [TWh/y]	Total Demand [TWh/y]
Slovakia	31.4	0.3	31.7
Slovenia	14.4	0.5	14.9
Spain	161.3	23.5	184.8
Sweden	86.1	3.3	89.4
United Kingdom	456.5	4.2	460.7
TOTAL	**3,628.9**	**143.2**	**3,772.1**

Table 3.3 – Final total energy demand for H&C

Figure 3.1, Figure 3.2 and Figure 3.3 graphically summarize the collected data, aggregated for both residential and tertiary sector by type of demand i.e. heating, cooling and total demand respectively, and sorted by highest to lowest demand values.

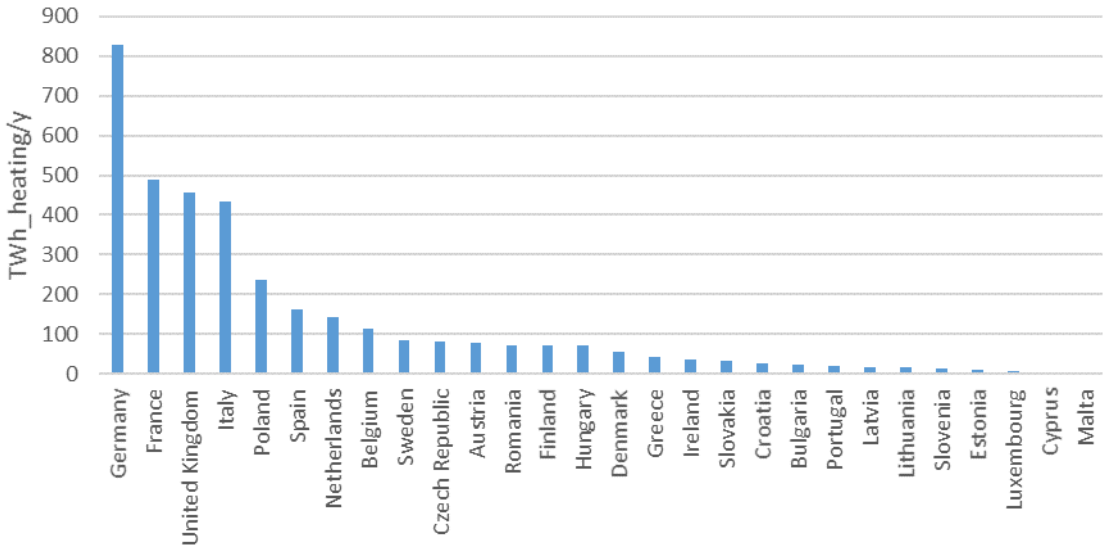

Figure 3.1 – Final total energy demand for heating

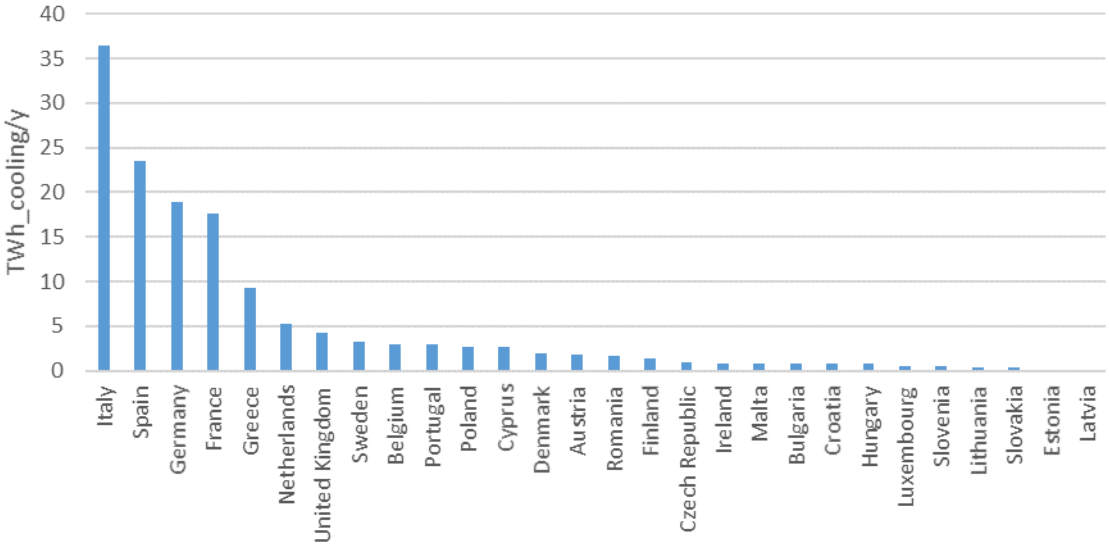

Figure 3.2 – Final total energy demand for cooling

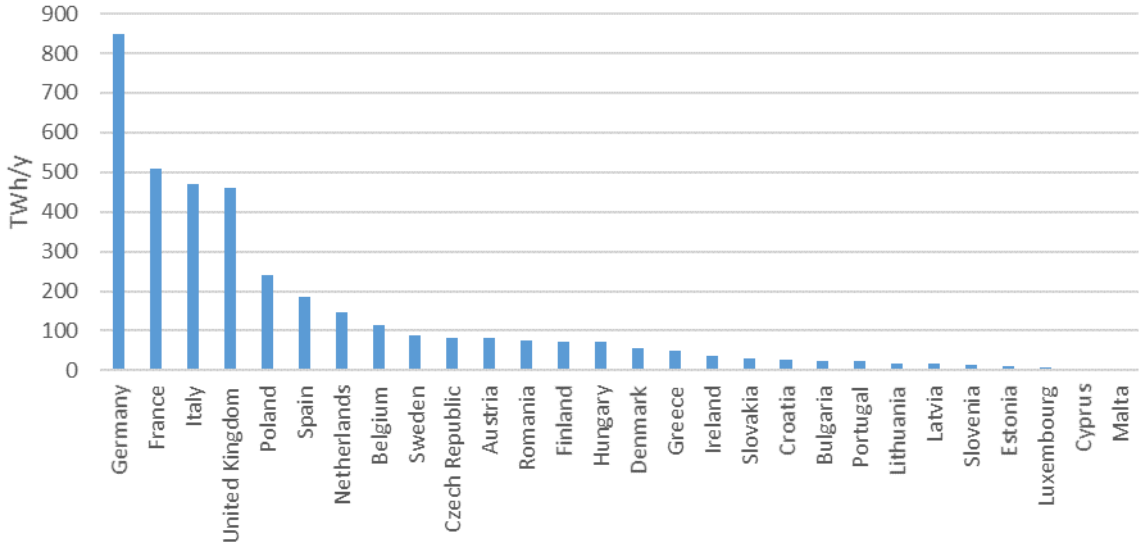

Figure 3.3 – Final total energy demand for H&C

On the basis of the results obtained, the following ***classification according to heating demand*** can be outlined:

- countries with low values of heating demand (less than 25 TWh/y): Bulgaria, Portugal, Latvia, Lithuania, Slovenia, Estonia, Luxembourg, Cyprus and Malta;
- countries with medium values of heating demand (between 25 TWh/y and 80 TWh/y): Czech Republic, Austria, Romania, Finland, Hungary, Denmark, Greece, Ireland, Slovakia and Croatia;
- countries with high values of heating demand (more than 80 TWh/y): Germany, France, United Kingdom, Italy, Poland, Spain, Netherlands, Belgium and Sweden.

The aforementioned classification is mapped in **Figure 3.4** below.

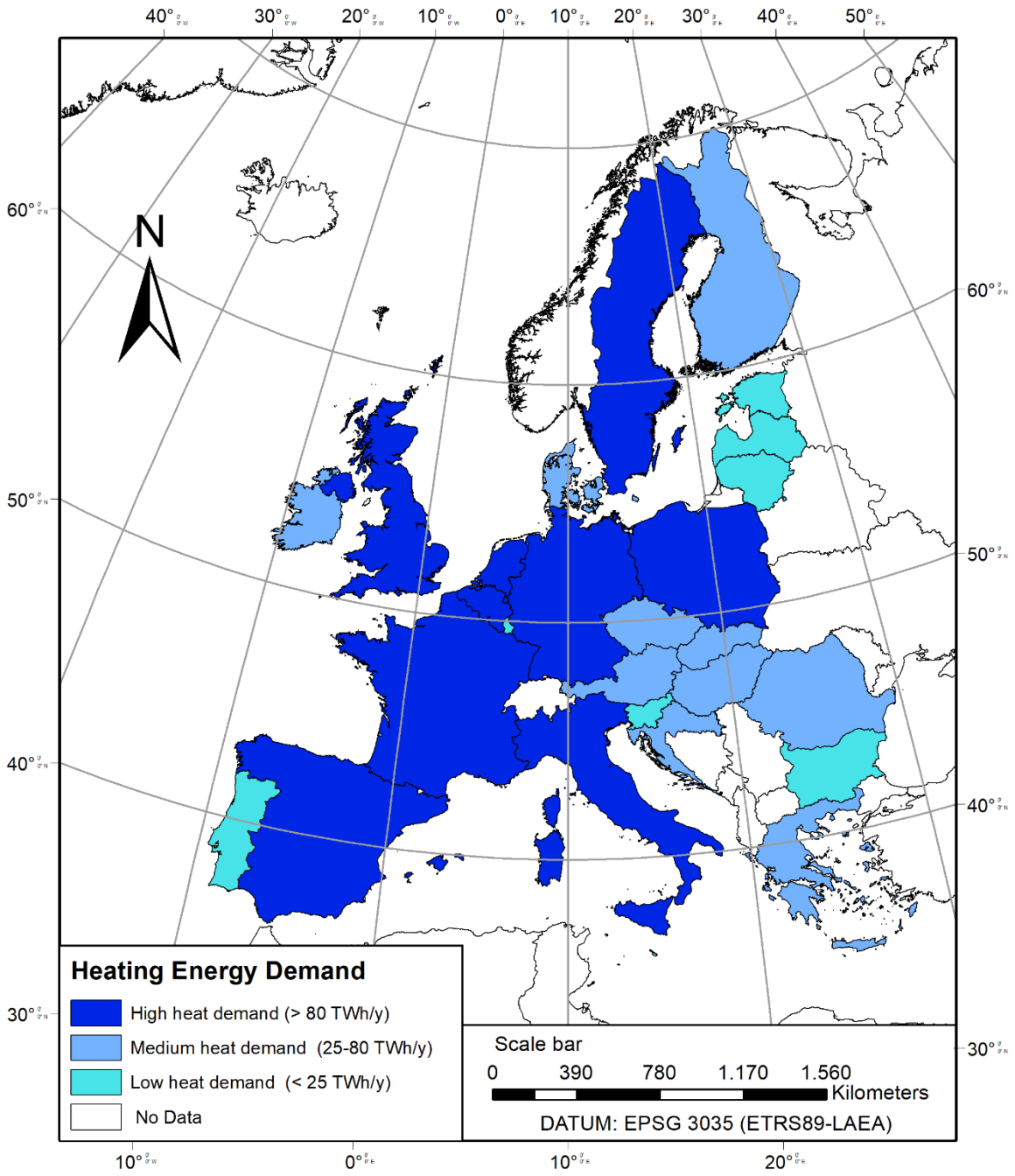

Figure 3.4 – Classification according to total final demand for heating (own elaboration)

On the basis of the results obtained, the following ***classification according to cooling demand*** can be outlined:

- countries with low values of cooling demand (less than 1 TWh/y): Ireland, Malta, Bulgaria, Croatia, Hungary, Luxembourg, Slovenia, Lithuania, Slovakia, Estonia and Latvia;
- countries with medium values of cooling demand (between 1 TWh/y and 3 TWh/y): Belgium, Portugal, Poland, Cyprus, Denmark, Austria, Romania, Finland and Czech Republic;
- countries with high values of cooling demand (more than 3 TWh/y): Italy, Spain, Germany, France, Greece, Netherlands, United Kingdom and Sweden.

The aforementioned classification is mapped in **Figure 3.5** below.

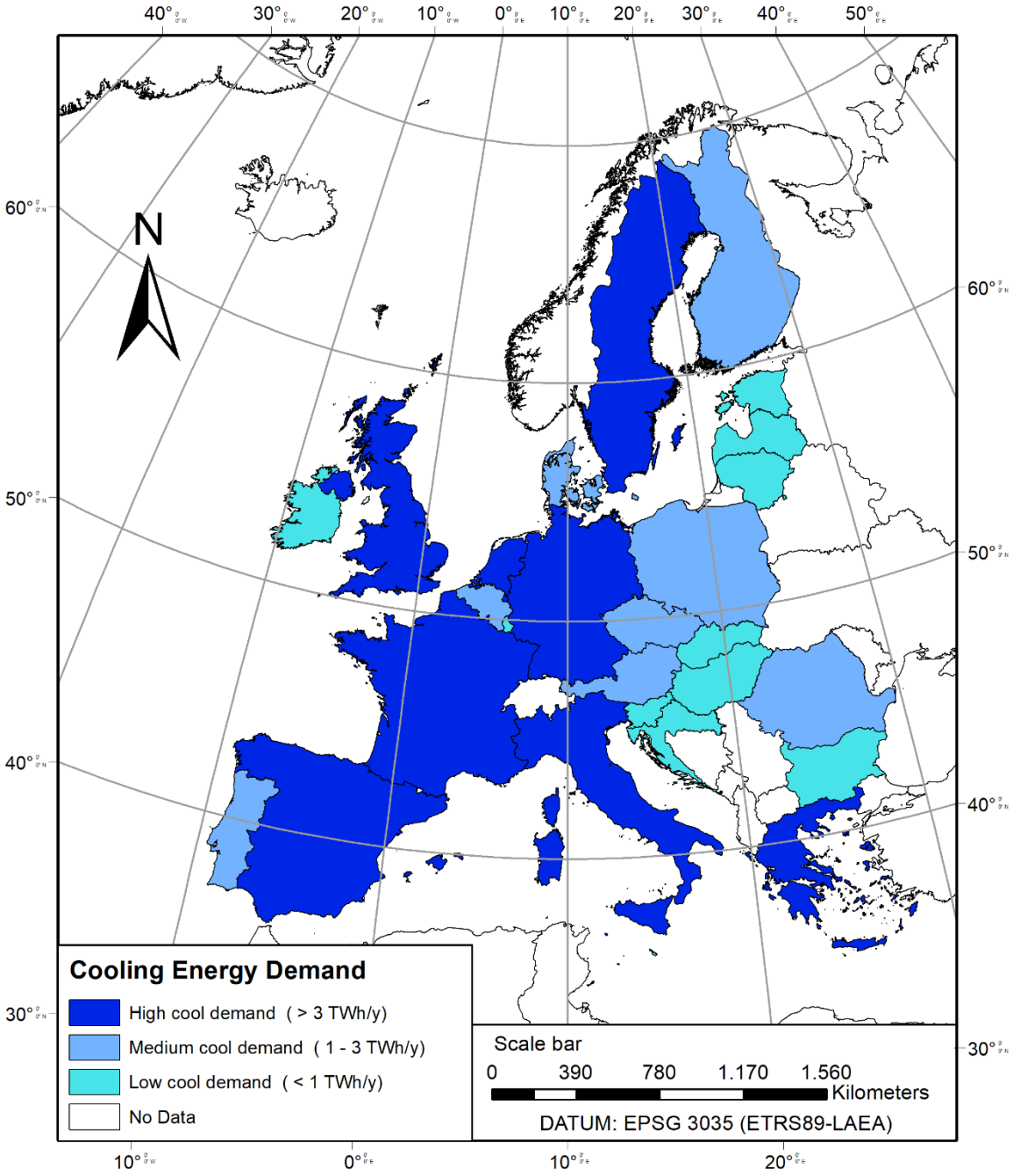

Figure 3.5 – Classification according to total final demand for cooling (own elaboration)

The ***classification according to total demand*** corresponds to the one outlined for heating demand. The same mapping scenario is provided for total H&C energy demand and it is represented in **Figure 3.6**.

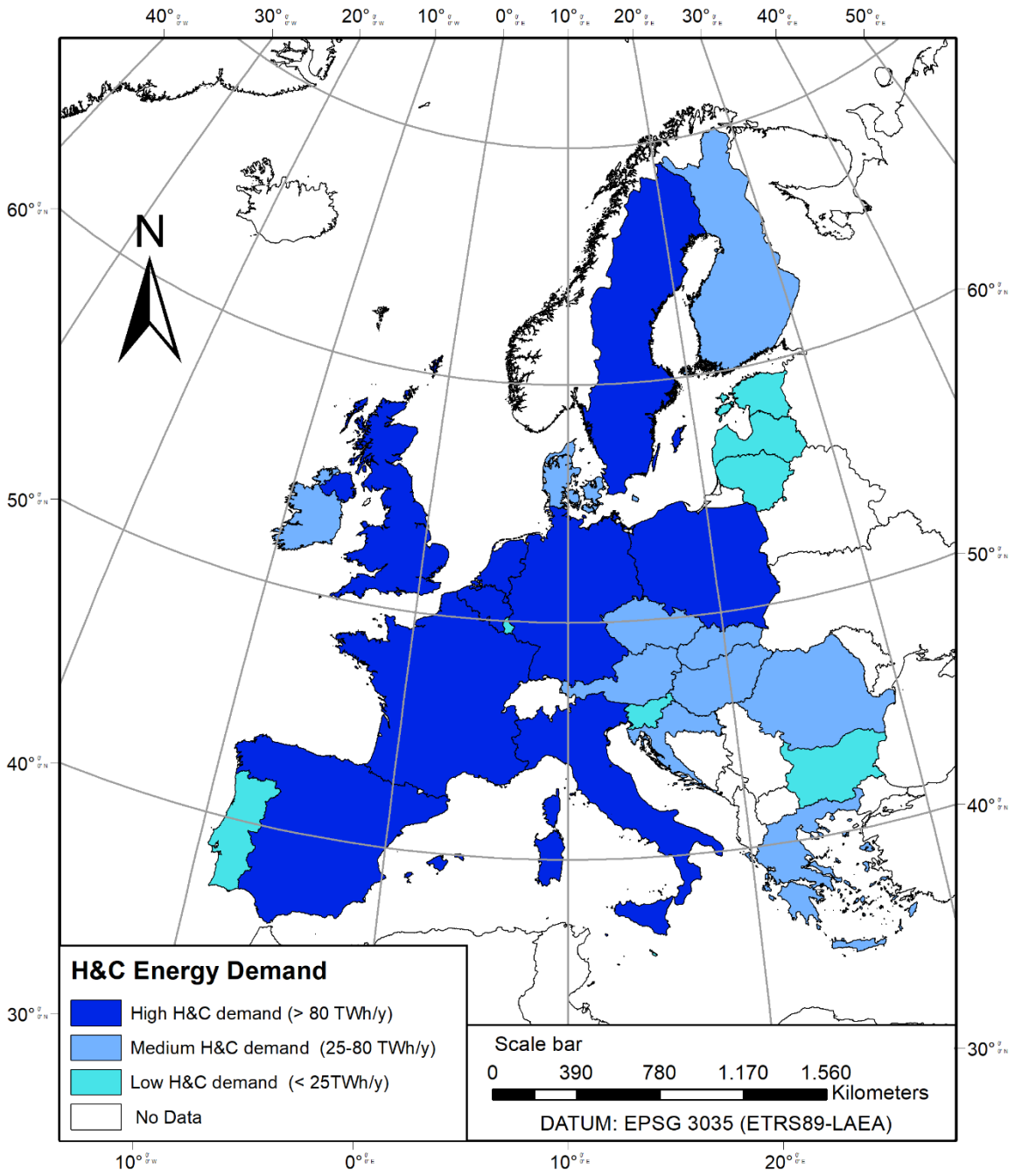

Figure 3.6 - Classification according to total final demand for H&C (own elaboration)

As a second step of the analysis, a specific indicator, normalized on built-up area is calculated. The purpose of introducing such indicator is to investigate the trend of the H&C demand in the European countries normalized to building net area, for the residential sector and for the tertiary sector respectively. Data about total floor area are gathered from the EU building database website[3] and are representative of 2014 for the case of the residential sector and of 2013 for the case of tertiary sector.

[3] https://ec.europa.eu/energy/en/eu-buildings-database

Table 3.4 illustrates the heating demand and the cooling demand for the residential sector per built-up unit area dedicated to the residential sector.

Country	Heating [kWh/m²/y]	Cooling [kWh/m²/y]
Austria	116.0	-
Belgium	184.3	-
Bulgaria	54.8	0.3
Croatia	141.7	0.6
Cyprus	31.5	28.5
Czech Republic	157.7	-
Denmark	116.3	-
Estonia	200.6	-
Finland	175.4	-
France	114.4	0.4
Germany	146.8	-
Greece	61.8	7.4
Hungary	113.0	0.2
Ireland	126.2	-
Italy	111.9	3.6
Latvia	166.1	-
Lithuania	135.8	-
Luxembourg	191.2	-
Malta	11.2	18.7
Netherlands	109.9	-
Poland	179.5	-
Portugal	20.7	1.2
Romania	161.1	0.8
Slovakia	123.0	-
Slovenia	161.2	-
Spain	47.5	2.2
Sweden	118.4	-
United Kingdom	126.1	-
AVERAGE	**121.6**	**2.3**

Table 3.4 – Final demand for H&C in the residential sector per built-up unit area

In correspondence with the previous table, **Table 3.5** includes the heating demand and the cooling demand for the tertiary sector per built-up unit of area dedicated to the tertiary sector.

Country	Heating [kWh/m²/y]	Cooling [kWh/m²/y]
Austria	83.8	6.6
Belgium	180.2	16.2
Bulgaria	62.0	7.9
Croatia	106.3	19.6
Cyprus	84.2	96.3
Czech Republic	119.1	5.7
Denmark	116.2	16.5
Estonia	240.0	8.0
Finland	176.0	11.5
France	141.2	17.3
Germany	163.4	11.3
Greece	72.1	68.0

Country	Heating [kWh/m²/y]	Cooling [kWh/m²/y]
Hungary	143.3	4.8
Ireland	123.9	9.7
Italy	349.4	89.9
Latvia	198.0	4.2
Lithuania	82.8	1.9
Luxembourg	210.4	35.1
Malta	222.9	95.5
Netherlands	80.5	9.5
Poland	105.0	5.4
Portugal	71.8	21.1
Romania	240.0	20.8
Slovakia	100.8	2.9
Slovenia	202.8	35.0
Spain	131.1	51.8
Sweden	144.4	15.8
United Kingdom	139.5	5.1
AVERAGE	**146.1**	**24.8**

Table 3.5 – Final energy demand for H&C in the tertiary sector per built-up unit area

Table 3.6 summarizes, per each country, the heating demand and cooling demand, aggregated for the residential sector and for the tertiary sector, as well as the total H&C demand.

Country	Heating [kWh/m²/y]	Cooling [kWh/m²/y]	Total [kWh/m²/y]
Austria	199.8	6.6	206.3
Belgium	364.4	16.2	380.6
Bulgaria	116.8	8.2	125.0
Croatia	247.9	20.2	268.1
Cyprus	115.8	124.8	240.6
Czech Republic	276.8	5.7	282.5
Denmark	232.5	16.5	249.0
Estonia	440.6	8.0	448.6
Finland	351.4	11.5	362.9
France	255.6	17.7	273.2
Germany	310.2	11.3	321.5
Greece	133.9	75.4	209.3
Hungary	256.3	5.0	261.3
Ireland	250.2	9.7	259.9
Italy	461.3	93.6	554.9
Latvia	364.0	4.2	368.3
Lithuania	218.6	1.9	220.5
Luxembourg	401.6	35.1	436.6
Malta	234.2	114.3	348.4
Netherlands	190.4	9.5	199.8
Poland	284.5	5.4	290.0
Portugal	92.5	22.3	114.8
Romania	401.1	21.6	422.7
Slovakia	223.8	2.9	226.8
Slovenia	364.0	35.0	399.0
Spain	178.6	54.0	232.6

Country	Heating [kWh/m²/y]	Cooling [kWh/m²/y]	Total [kWh/m²/y]
Sweden	262.8	15.8	278.6
United Kingdom	265.6	5.1	270.7
AVERAGE	**267.7**	**27.0**	**294.7**

Table 3.6 – Final total energy demand for H&C per built-up unit area

Figure 3.7, **Figure 3.8** and **Figure 3.9** graphically summarize the collected data, aggregated for both residential and tertiary sector by type of demand i.e. heating, cooling and total demand respectively, and sorted by highest to lowest demand values.

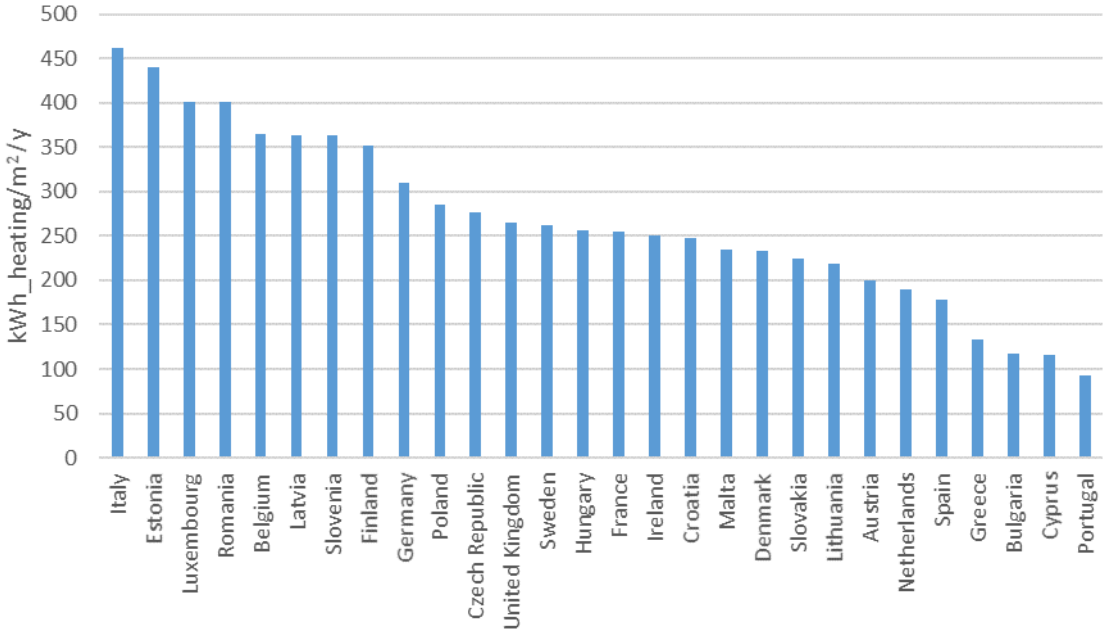

Figure 3.7 – Final total energy demand for heating per built-up unit area

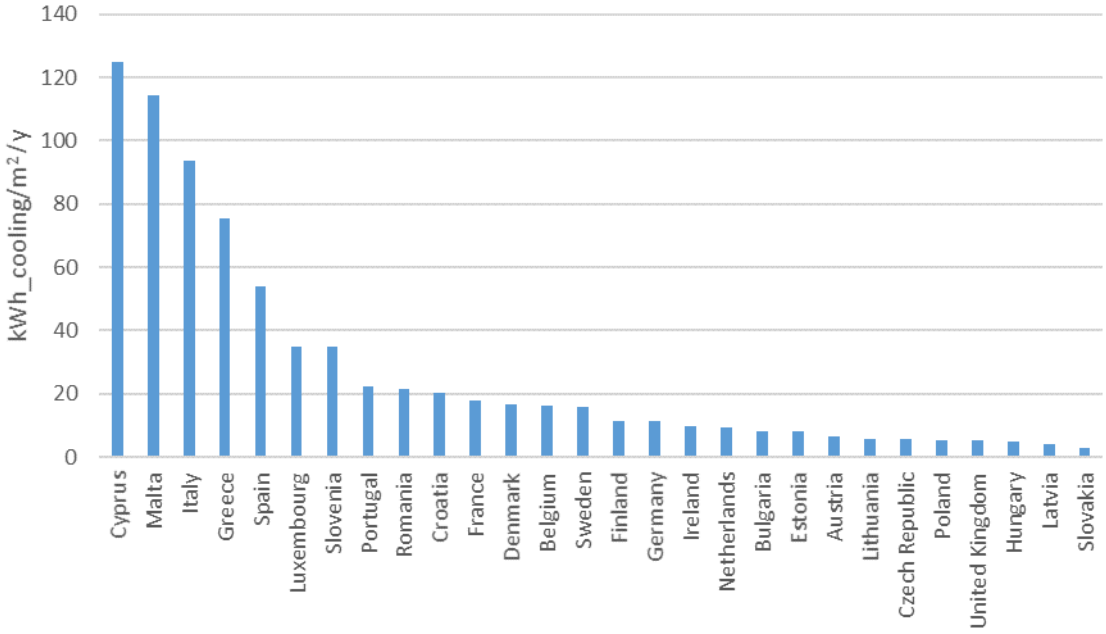

Figure 3.8 – Final total energy demand for cooling per built-up unit area

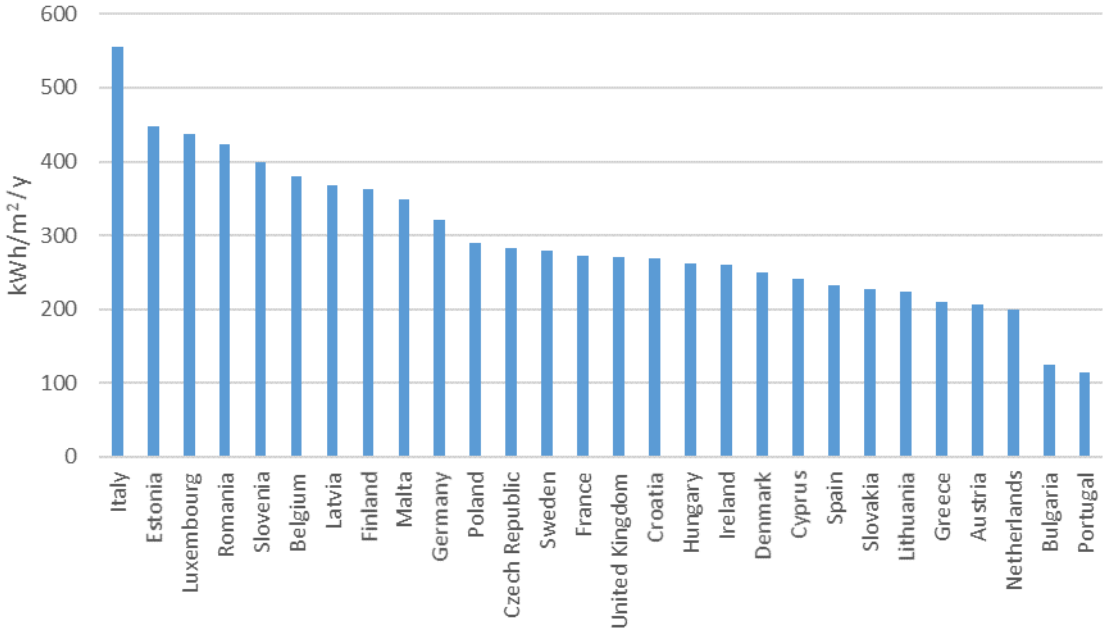

Figure 3.9 – Final total energy demand for H&C per built-up unit area

On the basis of the results obtained in Table 3.6, the following ***classification according to heating demand per unit area*** can be outlined:

- countries with low values of heating demand (less than 230 kWh/m²/y): Portugal, Cyprus, Bulgaria, Greece, Spain, Netherlands, Austria, Lithuania and Slovakia;
- countries with medium values of heating demand (between 230 kWh/m²/y and 300 kWh /m²/y): Denmark, Malta, Croatia, Ireland, France, Hungary, Sweden, United Kingdom, Czech Republic and Poland;
- countries with high values of heating demand (more than 300 kWh/m²/y): Germany, Finland, Slovenia, Latvia, Belgium, Romania, Luxembourg, Estonia and Italy.

The aforementioned classification is mapped in **Figure 3.10** below.

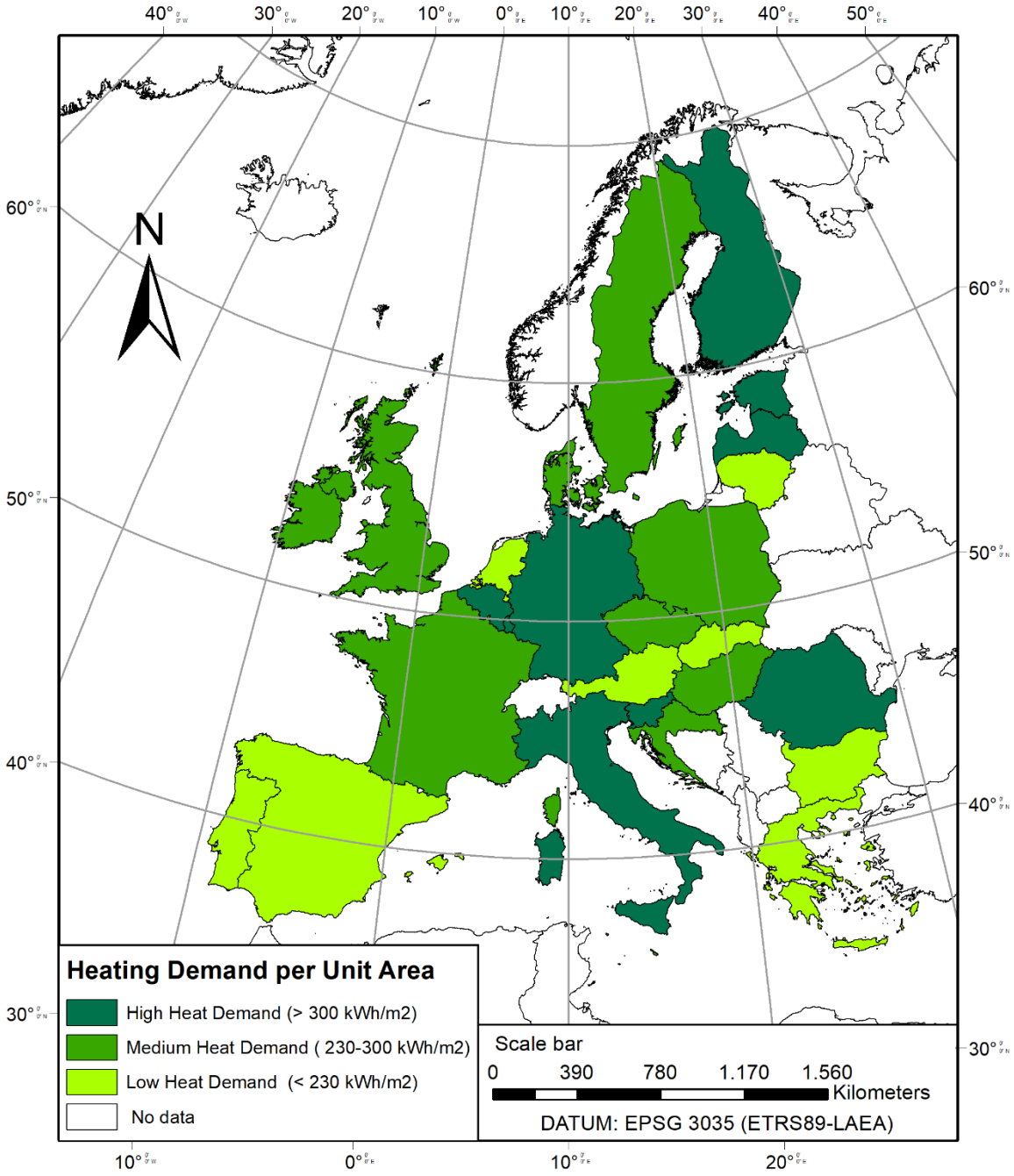

Figure 3.10 – Classification according to heating demand per unit area (own elaboration)

On the basis of the results obtained in Table 3.6, the following ***classification according to cooling demand per unit area*** can be outlined:

- countries with low values of cooling demand (less than 8 kWh/m²/y): Slovakia, Latvia, Hungary, United Kingdom, Poland, Czech Republic, Lithuania, Austria and Estonia;
- countries with medium values of cooling demand (between 8 kWh/m²/y and 21 kWh /m²/y): Bulgaria, Netherlands, Ireland, Germany, Finland, Sweden, Belgium, Denmark, France and Croatia;
- countries with high values of cooling demand (more than 21 kWh/m²/y): Romania, Portugal, Slovenia, Luxembourg, Spain, Greece, Italy, Malta and Cyprus.

The aforementioned classification is mapped in **Figure 3.11** below.

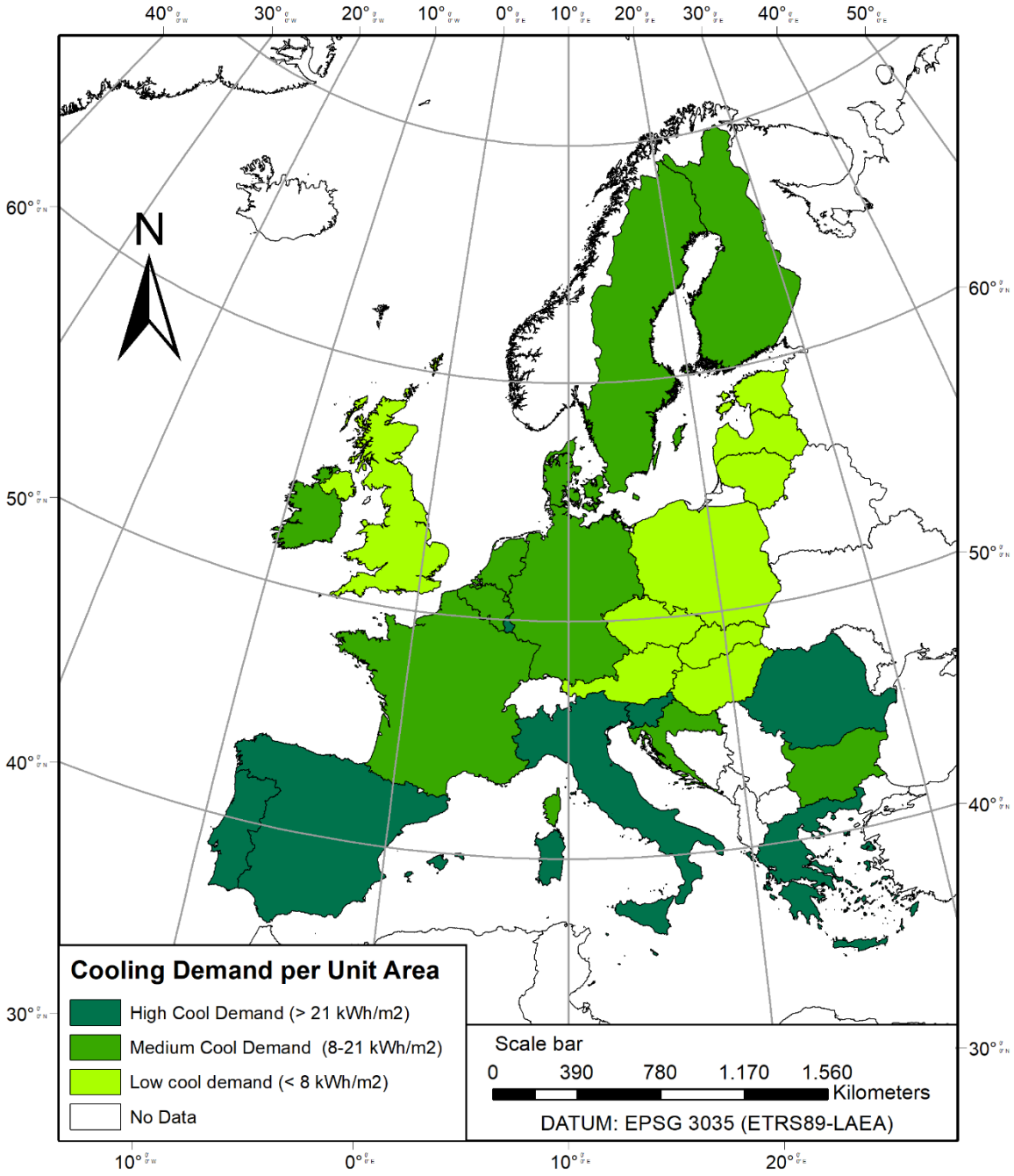

Figure 3.11 – Classification according to cooling demand per unit area (own elaboration)

On the basis of the results obtained in Table 3.6, the following **classification according to total H&C demand per unit area** can be outlined:

- countries with low values of H&C demand (less than 245 kWh/m²/y): Portugal, Bulgaria, Netherland, Austria, Greece, Lithuania, Slovakia, Spain and Cyprus;
- countries with medium values of H&C demand (between 245 kWh /m²/y and 330 kWh/m²/y): Denmark, Ireland, Hungary, Croatia, United Kingdom, France, Sweden, Czech Republic, Poland and Germany;
- countries with high values of H&C demand (more than 330 kWh/m²/y): Malta, Finland, Latvia, Belgium, Slovenia, Romania, Luxembourg, Estonia and Italy.

The aforementioned classification is mapped in **Figure 3.12** below.

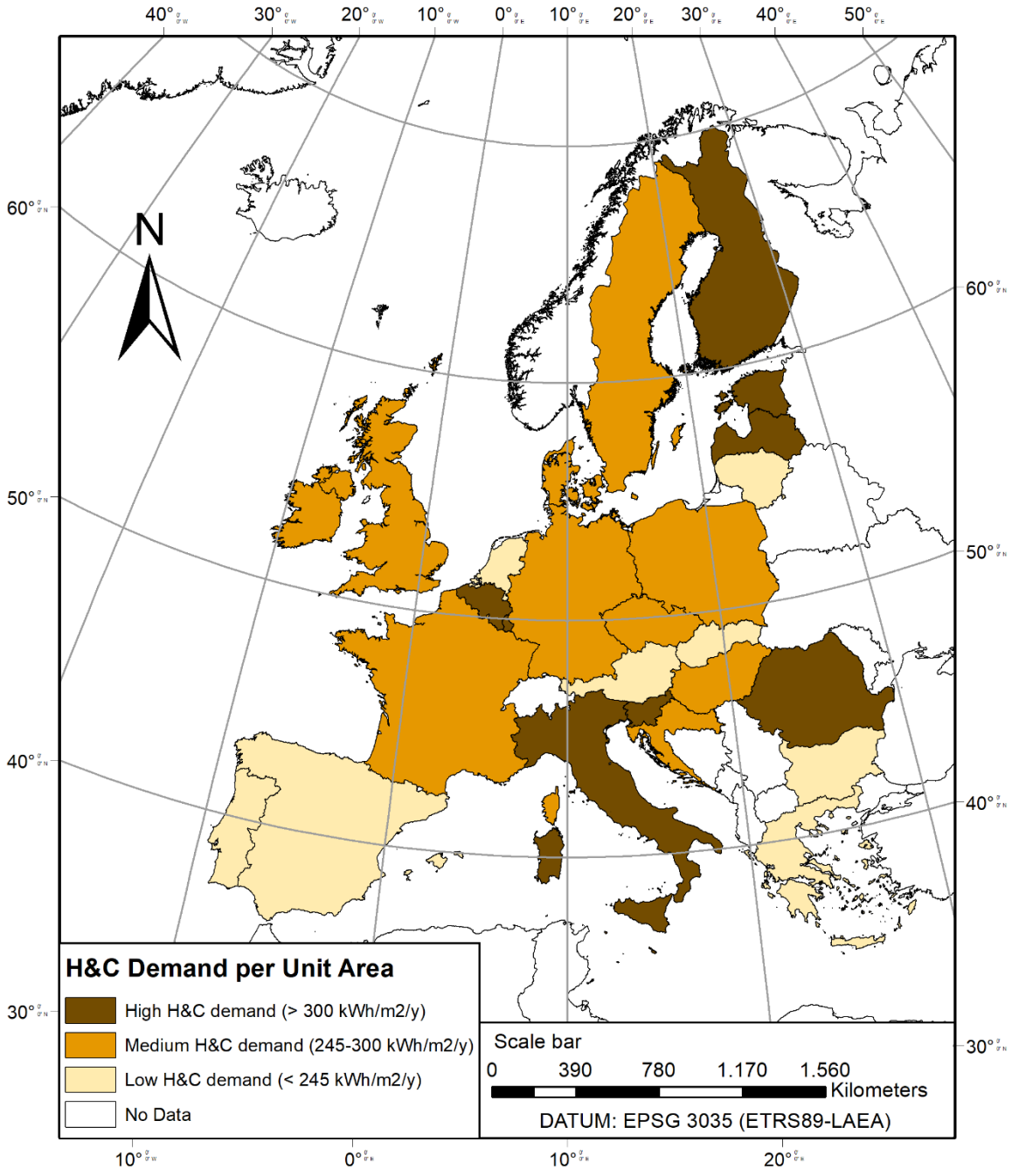

Figure 3.12 – Classification according to H&C demand per unit area (own elaboration)

3.2 Common H&C appliances

This subsection includes an overview of the most common H&C appliances encountered across European countries in the residential and tertiary sectors. Appliances are analysed separately for heating and cooling purposes.

Data on common H&C appliances are gathered and aggregated from the analyses performed within the above-mentioned Heat Roadmap Europe project[4]. In such context, common H&C appliances are defined through a combination of specific technologies (e.g. heat pump) and energy carriers (e.g. natural gas), which can be associated with a specific appliance only indirectly.

For the purpose of this work, appliances considered for heating purposes are boilers, district H&C distribution systems, resistance heating systems, solar thermal systems and heat pumps. Boilers can be associated to energy vectors such as biomass, coal, oil and natural gas, whereas electricity can feed resistance heating systems and heat pumps.

Table 3.7 illustrates the share of demand satisfied through the use of each technology and related energy carriers, with respect to the total heating demand of the residential sector.

Country	Boilers				District Heating	Resistance Heating	Heat Pumps	Solar Thermal
	Biomass	Coal	Oil	Gas				
Austria	31%	-	19%	22%	14%	10%	1%	3%
Belgium	7%	1%	36%	47%	-	8%	-	-
Bulgaria	46%	9%	1%	3%	20%	18%	2%	1%
Croatia	56%	-	6%	26%	7%	6%	-	-
Cyprus	0%	-	48%	-	-	5%	-	47%
Czech Republic	24%	10%	-	32%	23%	10%	1%	-
Denmark	23%	-	7%	17%	44%	7%	1%	-
Estonia	42%	1%	-	6%	35%	14%	1%	-
Finland	24%	-	9%	-	34%	30%	2%	-
France	21%	1%	18%	37%	4%	17%	2%	-
Germany	11%	1%	28%	44%	10%	4%	1%	1%
Greece	18%	-	51%	11%	1%	9%	2%	7%
Hungary	16%	3%	2%	60%	11%	8%	-	-
Ireland	1%	20%	42%	25%	-	11%	-	-
Italy	21%	-	7%	56%	3%	10%	3%	1%
Latvia	50%	1%	4%	9%	32%	4%	-	-
Lithuania	44%	5%	3%	8%	38%	1%	-	-
Luxembourg	5%	-	36%	55%	-	4%	-	-
Malta	-	-	-	-	-	100%	-	-
Netherlands	6%	-	-	85%	4%	4%	1%	-
Poland	14%	40%	1%	16%	24%	5%	-	-
Portugal	32%	-	22%	35%	-	7%	-	4%
Romania	61%	1%	1%	20%	16%	1%	-	-
Slovakia	2%	1%	-	65%	27%	4%	-	-
Slovenia	52%	-	17%	13%	8%	10%	-	1%
Spain	24%	1%	26%	37%	0%	9%	-	2%
Sweden	18%	-	1%	1%	49%	23%	8%	-
United Kingdom	5%	2%	9%	76%	-	9%	-	-
AVERAGE	**23%**	**3%**	**14%**	**29%**	**14%**	**12%**	**2%**	**3%**

Table 3.7 – Use of appliances for heating purposes in the residential sector

Table 3.8 illustrates the share of demand satisfied through the use of each technology and related energy carriers, with respect to the total heating demand of the tertiary sector.

[4] https://heatroadmap.eu/

Country	Boilers				District Heating	Resistance Heating	Heat Pumps	Solar Thermal
	Biomass	Coal	Oil	Gas				
Austria	7%	-	13%	28%	43%	6%	1%	2%
Belgium	1%	-	27%	57%	4%	8%	1%	2%
Bulgaria	11%	-	4%	20%	24%	13%	2%	29%
Croatia	3%	-	16%	42%	11%	8%	-	18%
Cyprus	29%	-	43%	-	-	14%	-	-
Czech Republic	4%	1%	-	58%	25%	10%	-	-
Denmark	4%	-	4%	14%	66%	10%	-	1%
Estonia	3%	-	10%	27%	47%	7%	-	3%
Finland	5%	-	13%	2%	59%	18%	-	2%
France	4%	-	20%	57%	7%	11%	-	1%
Germany	10%	-	31%	45%	6%	6%	1%	1%
Greece	9%	-	23%	30%	-	23%	2%	13%
Hungary	11%	-	2%	74%	8%	4%	1%	-
Ireland	4%	2%	28%	49%	2%	8%	1%	5%
Italy	3%	-	7%	76%	4%	6%	1%	4%
Latvia	21%	2%	11%	26%	34%	4%	-	2%
Lithuania	12%	12%	2%	16%	49%	7%	-	2%
Luxembourg	-	-	20%	43%	33%	3%	-	-
Malta	-	-	71%	-	-	14%	-	-
Netherlands	4%	-	2%	81%	4%	7%	2%	-
Poland	5%	15%	10%	38%	23%	6%	1%	2%
Portugal	13%	-	23%	35%	4%	21%	-	3%
Romania	1%	-	6%	64%	17%	7%	1%	3%
Slovakia	1%	13%	2%	70%	7%	7%	1%	-
Slovenia	7%	-	28%	17%	17%	17%	-	14%
Spain	4%	-	30%	40%	1%	17%	-	6%
Sweden	1%	-	14%	4%	53%	26%	1%	-
United Kingdom	1%	-	8%	71%	5%	13%	1%	1%
AVERAGE	**6%**	**2%**	**17%**	**39%**	**20%**	**11%**	**1%**	**4%**

Table 3.8 – Use of appliances for heating purposes in the tertiary sector

To conclude, **Table 3.9** shows the share of demand satisfied through the use of each technology and related energy carriers, with respect to the total heating demand of both the residential and tertiary sector (minor imperfections in balances of percentages are related to rounding of decimal figures), and the same data are also represented in **Figure 3.13** below.

Country	Boilers				District Heating	Resistance Heating	Heat Pumps	Solar Thermal
	Biomass	Coal	Oil	Gas				
Austria	24%	-	17%	24%	23%	9%	1%	3%
Belgium	6%	1%	34%	50%	1%	8%	-	1%
Bulgaria	38%	7%	2%	7%	21%	17%	2%	7%
Croatia	49%	-	7%	28%	7%	6%	-	3%
Cyprus	8%	-	47%	-	-	8%	-	37%
Czech Republic	19%	8%	-	39%	23%	10%	-	-
Denmark	19%	-	7%	17%	49%	7%	1%	-
Estonia	32%	1%	3%	12%	38%	12%	1%	1%
Finland	18%	-	10%	1%	42%	27%	2%	1%
France	16%	-	19%	43%	4%	15%	1%	-
Germany	11%	1%	29%	44%	9%	5%	1%	1%
Greece	17%	-	47%	14%	1%	11%	2%	8%

Country	Boilers				District Heating	Resistance Heating	Heat Pumps	Solar Thermal
	Biomass	Coal	Oil	Gas				
Hungary	14%	2%	2%	64%	10%	7%	-	-
Ireland	2%	15%	38%	32%	1%	10%	1%	2%
Italy	17%	-	7%	61%	3%	9%	2%	1%
Latvia	42%	1%	6%	14%	33%	4%	-	1%
Lithuania	35%	7%	3%	11%	41%	2%	-	1%
Luxembourg	4%	-	31%	51%	12%	4%	-	-
Malta	-	-	50%	-	-	40%	-	-
Netherlands	5%	-	1%	84%	4%	5%	1%	-
Poland	12%	34%	3%	21%	24%	6%	-	1%
Portugal	25%	-	22%	35%	1%	12%	-	3%
Romania	49%	1%	2%	29%	16%	2%	-	1%
Slovakia	2%	5%	1%	67%	20%	5%	-	-
Slovenia	43%	-	19%	14%	10%	11%	-	3%
Spain	19%	1%	27%	38%	-	11%	-	3%
Sweden	12%	-	5%	2%	51%	24%	5%	-
United Kingdom	4%	1%	9%	75%	1%	10%	-	-
AVERAGE	**19%**	**3%**	**16%**	**31%**	**16%**	**11%**	**1%**	**3%**

Table 3.9 – Use of appliances for heating purposes

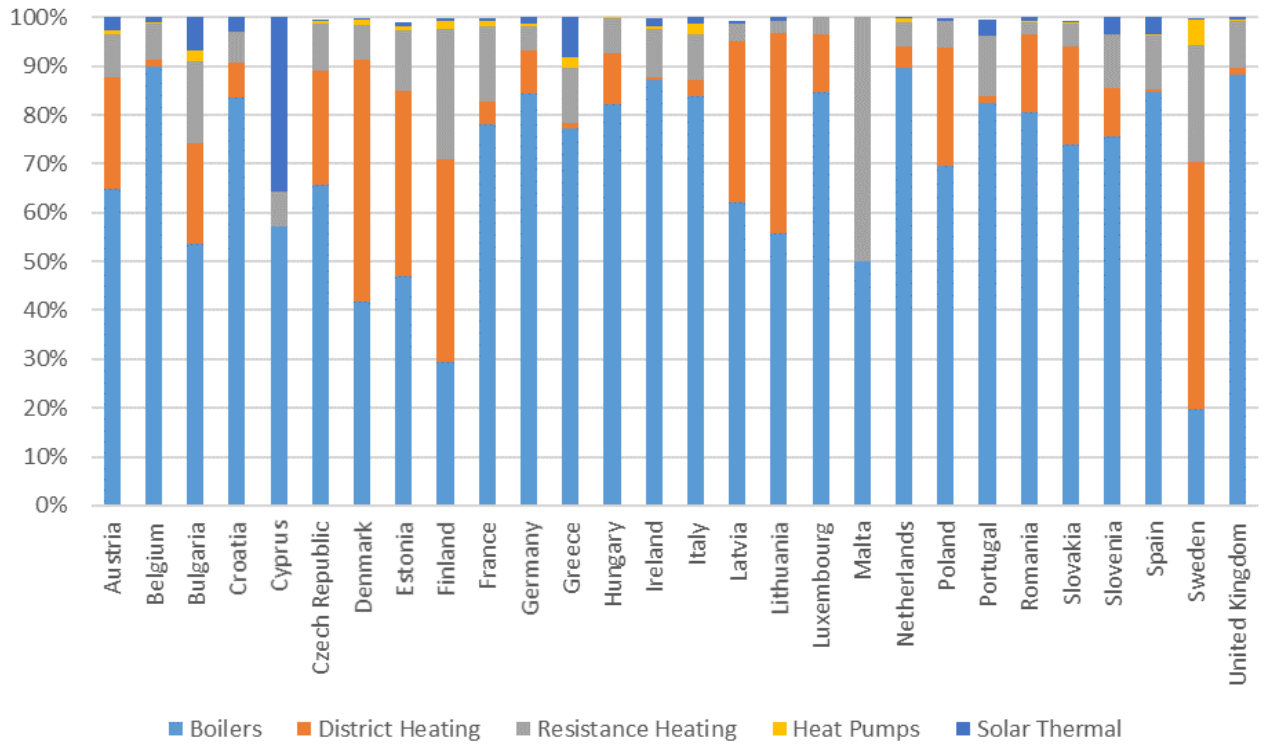

Figure 3.13 – Use of appliances for heating purposes

Overall, boilers are the most common technology encountered, even though different sources (both renewables and non-renewables) are used as fuels. In some countries, such as Denmark, Estonia, Finland, Lithuania and Sweden, district heating is largely employed to satisfy the heating demand. Furthermore, resistance heating technology is quite spread in all countries, even though only with minor shares. To conclude, heat pumps and solar thermal systems are found only in some countries and their capacity is limited compared to the overall demand of the country.

As for the cooling demand of the residential and of the tertiary sector, in all the countries where such demand exists, it can be considered entirely satisfied by electric appliances based on compression cooling, with sufficient degree of accuracy for the purpose of this document.

4 MAPPING OF MARKET CONDITIONS

This section is dedicated to mapping the main market parameters able to act as drivers or barriers to the replicability of SunHorizon solutions.

4.1 Energy Costs

The first parameter considered is the average energy purchase cost in the different Member States. Countries where energy is more expensive will more likely convert to alternative energy systems and sources, aiming at reducing overall costs for energy supply. Costs are analysed for the main energy vectors only, i.e. electricity, natural gas, district heating and fuel oil. Such sources cover more than 50% of the H&C demand in all the countries, exceeding 70% of the total demand in 20 countries. The largest part of the energy input not covered by these fuels is constituted by biomass, whose cost has been excluded since there is significant price variation among various biomass sources and not enough data are retrievable to provide a classification aligned with the scope of this work. To conclude, costs of energy produced from coal burning or from solar thermal systems are not included in the analysis because these sources represent only a minor proportion of the H&C energy supply.

Table 4.1 reports energy costs, representative for household and tertiary end-users in each European country. Specifically, electricity and natural gas costs are derived from the Eurostat database and are average values for the period between 2016 and the first semester of 2018 (included). Such values include all the applicable taxes and levies. District heating cost does not include taxes and is representative for 2013, whereas fuel oil price is updated at April 2019 and it includes also taxes and duties. Whenever data at country level are not available, EU average has been used.

Country	Electricity [€/kWh]	Natural gas [€/kWh]	District heating [€/kWh]	Fuel Oil [€/t]
Austria	0.1988	0.0681	0.0680	491.7
Belgium	0.2751	0.0538	-	416.5
Bulgaria	0.0962	0.0353	0.0335	531.2
Croatia	0.1277	0.0378	0.0457	581.7
Cyprus	0.1746	-	-	700.4
Czech Republic	0.1468	0.0567	0.0673	374.7
Denmark	0.3071	0.0865	0.1040	957.5
Estonia	0.1264	0.0381	0.0608	531.2
Finland	0.1576	-	0.0587	531.2
France	0.1721	0.0665	0.0673	598.8
Germany	0.3006	0.0626	0.0760	531.2
Greece	0.1733	0.0577	-	523.1
Hungary	0.1124	0.0356	0.0432	511.4
Ireland	0.2337	0.0649	-	582.8
Italy	0.2176	0.0772	0.0684	511.0
Latvia	0.1590	0.0397	0.0540	531.2
Lithuania	0.1144	0.0392	0.0702	531.2
Luxembourg	0.1660	0.0420	0.0698	531.2
Malta	0.1288	-	-	531.2
Netherlands	0.1607	0.0796	0.0698	745.0
Poland	0.1398	0.0423	0.0734	414.8
Portugal	0.2282	0.0812	-	655.5
Romania	0.1263	0.0317	0.0623	472.9
Slovakia	0.1481	0.0440	-	563.3

Country	Electricity [€/kWh]	Natural gas [€/kWh]	District heating [€/kWh]	Fuel Oil [€/t]
Slovenia	0.1616	0.0559	0.0594	658.1
Spain	0.2265	0.0746	-	447.9
Sweden	0.1940	0.1148	0.0731	885.5
United Kingdom	0.1858	0.0493	0.0457	531.2

Table 4.1 – Energy costs for the main sources (Eurostat Database, European District Heating Price Series, Weekly Oil Bulletin)

On the basis of data collected about most common H&C system in each country and their energy vectors, and of the costs of energy sources presented in this section, it is possible to outline a classification – considering the criteria previously introduced in Section 1 to assign qualitative scores - on the basis of energy cost for H&C purposes in the residential and tertiary sector, as shown in **Table 4.2** below.

Explicitly, the criteria can be stated as follows:

- as for electricity cost: low cost < 0.147 €/kWh, medium cost 0.147 €/kWh – 0.186 €/kWh, high cost > 0.186 €/kWh;
- as for natural gas cost: low cost < 0.042 €/kWh, medium cost 0.042 €/kWh – 0.065 €/kWh, high cost > 0.065 €/kWh;
- as for district heating cost: low cost < 0.059 €/kWh, medium cost 0.068 €/kWh – 0.065 €/kWh, high cost > 0.104 €/kWh;
- as for fuel oil cost: low cost < 532.1 €/t, medium cost 532.1 €/t – 563.3 €/t, high cost > 563.3 €/t.

Indeed, the classification covers only the relevant sources for the specific country analysed (i.e. sources contributing to at least 10% to the overall energy supply for H&C).

Country	Electricity	Natural gas	District heating	Fuel Oil
Austria	high	high	medium	Low
Belgium	high	medium	-	Low
Bulgaria	low	-	low	-
Croatia	-	low	-	-
Cyprus	medium	-	-	High
Czech Republic	low	medium	medium	-
Denmark	high	high	high	-
Estonia	low	low	medium	-
Finland	medium	-	low	medium
France	medium	high	-	high
Germany	-	medium	-	medium
Greece	medium	medium	-	low
Hungary	-	low	low	-
Ireland	high	medium	-	high
Italy	high	high	-	-
Latvia	-	low	low	-
Lithuania	-	low	high	-
Luxembourg	-	low	high	medium
Malta	low	-	-	medium
Netherlands	-	high	-	-
Poland	-	medium	high	-
Portugal	high	high	-	high
Romania	-	low	medium	-
Slovakia	-	medium	medium	-
Slovenia	medium	medium	-	high
Spain	high	high	-	low

Country	Electricity	Natural gas	District heating	Fuel Oil
Sweden	high	-	high	-
United Kingdom	medium	medium	-	-

Table 4.2 – Classification of costs for the main energy sources

An overall classification according to energy costs for H&C purposes is obtained as a quali-quantitative average, weighted on the consumption of each studied energy sources in the correspondent country.

On the basis of the results obtained, the following ***classification according to average energy cost*** can be outlined:

- countries with low energy cost: Croatia, Latvia, Bulgaria, Hungary, Romania, Malta, Luxembourg, Greece and Finland;
- countries with medium energy cost: Estonia, Germany, Belgium, United Kingdom, Czech Republic, Slovakia, Slovenia, Poland, Austria and Lithuania;
- countries with high energy cost: Cyprus, Spain, Netherlands, Ireland, France, Italy, Sweden, Denmark and Portugal.

The aforementioned classification is mapped in **Figure 4.1** below.

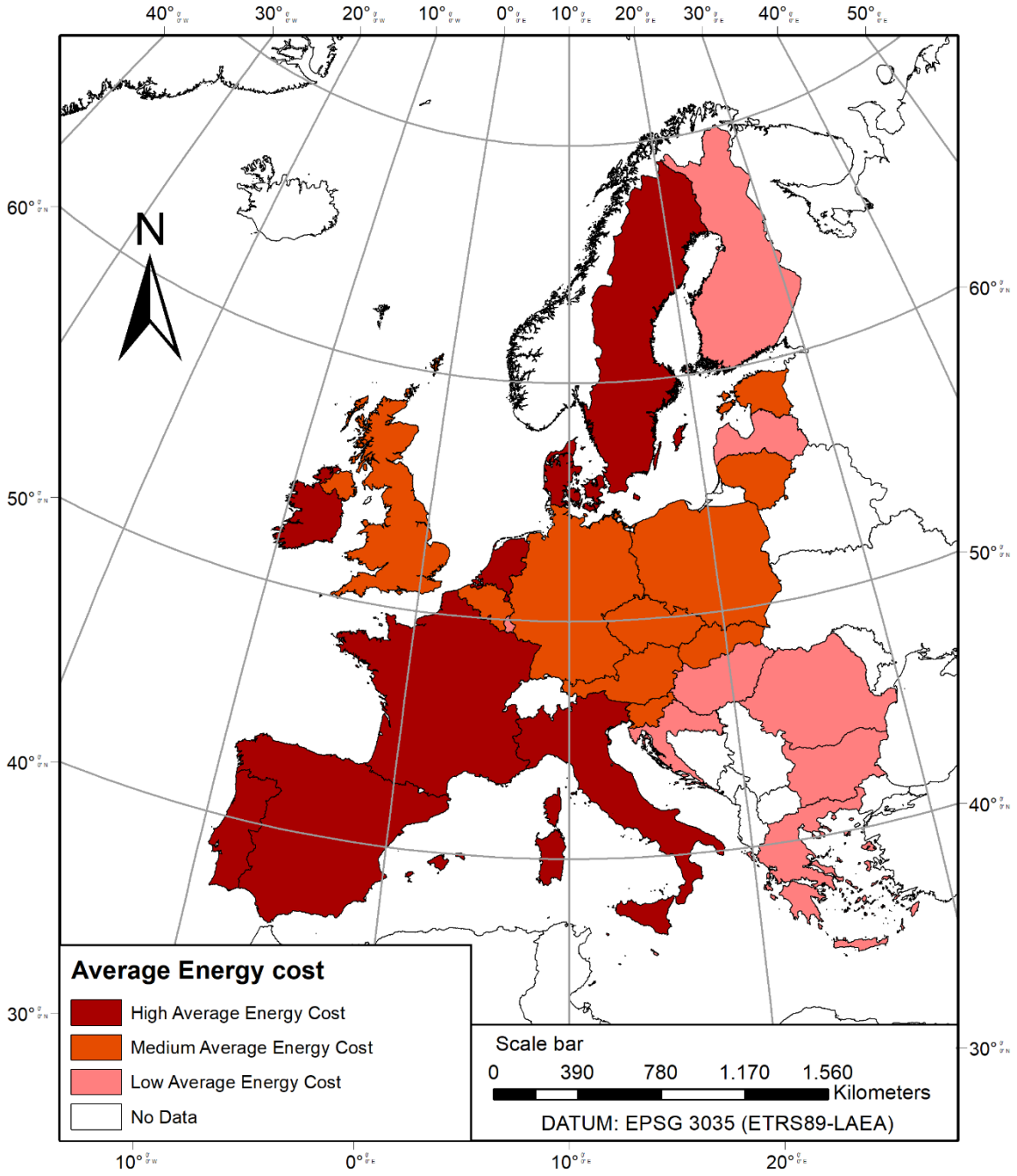

Figure 4.1 - Classification according to average energy cost (own elaboration)

4.2 Support Schemes

With the aim of providing full characterization of market conditions, available support mechanisms for the development of installations based on the use of solar energy for H&C applications are provided. In parallel, considering that some of the SunHorizon solutions also include the installation of technologies to produce electricity from solar resource, either to feed common appliances or specific equipment of the solution itself, also support schemes dedicated to electricity generation through solar panels are investigated.

The entire analysis is based on the most updated information retrievable from RES LEGAL Europe[5] and it is integrated mainly on the basis of MS's reports about their progress towards renewable energy goals established by the European Commission and of other updated sources.

It is highlighted that the analysis provides only a preliminary overview on the existence of support schemes in different Countries, but is not sufficiently detailed to capture the coverage of such supports, for example in terms of sizes of eligible plants or duration of the support in time. Besides, it is not excluded that specific temporary funding opportunities or advantageous fees locally exist in some of the Countries where such measures are identified as absent. Furthermore, considering that the specific amount and form of support often depends on the specific plant or installation, the analysis is performed at qualitative level.

Numerous policy instruments available to support the deployment of renewable energy exist in each MS, with the aim of meeting the renewable energy targets set for 2020.

Common mechanisms in national renewable energy support policies, applicable to the case of thermal energy generated through solar systems, include:

- price-based support schemes, guaranteeing good levels of competitiveness on the market for the generation of thermal energy from RES;
- loans, subsides, facilitating investments required for installation / operation of plants based on RES;
- tax benefits, consisting in a decrease of taxation for owners / operators / beneficiaries of plants based on RES.

Common mechanisms in national renewable energy support policies, applicable to the case of electricity generation through solar systems, include:

- feed-in tariffs, guaranteeing financial stability to operators of renewable energy plants by establishing a fixed retail price for electricity produced by renewable energy sources and sold to the national grid;
- feed-in premiums, offering to operators of renewable energy plants selling electricity to the national grid an additional payment on top of the electricity market price;
- net metering, promoting self-consumption of electricity produced from RES;
- loans, subsides, facilitating investments required for installation / operation of plants based on RES;
- tax benefits, consisting in a decrease of taxation for owners / operators / beneficiaries of plants based on RES.

Table 4.3 indicates, for each country, the support mechanism currently in place with respect to H&C applications based on solar energy.

Country	Price-based support	Loans / Subsidies	Tax Benefits	Overall support for solar H&C applications
Austria	no	yes	no	low
Belgium	no	yes	yes	high
Bulgaria	no	yes	no	low
Croatia	no	no	no	absent
Cyprus	no	no	no	absent
Czech Republic	no	yes	no	low

[5] http://www.res-legal.eu/home/

Country	Price-based support	Loans / Subsidies	Tax Benefits	Overall support for solar H&C applications
Denmark	no	no	yes	low
Estonia	no	yes	no	low
Finland	no	yes	no	low
France	no	yes	yes	high
Germany	no	yes	no	low
Greece	no	yes	yes	high
Hungary	no	no	no	absent
Ireland	no	yes	yes	high
Italy	yes	no	yes	high
Latvia	no	no	no	absent
Lithuania	yes	no	no	low
Luxembourg	no	yes	no	low
Malta	no	yes	no	low
Netherlands	no	yes	yes	high
Poland	no	yes	no	low
Portugal	no	yes	no	low
Romania	no	yes	no	low
Slovakia	no	yes	no	low
Slovenia	no	yes	no	low
Spain	no	no	no	absent
Sweden	no	no	yes	low
United Kingdom	yes	yes	no	high

Table 4.3 – Support schemes for solar H&C applications (RES LEGAL Europe)

Table 4.4 indicates, for each country, the support mechanism currently in place with respect to electricity generation from solar energy.

Country	Feed-in Tariff / Premium	Net metering	Loans / Subsidies	Tax Benefits	Overall support for electricity generation
Austria	yes	no	yes	no	medium
Belgium	no	yes	yes	no	medium
Bulgaria	no	no	no	no	absent
Croatia	no	no	yes	no	low
Cyprus	no	yes	yes	no	medium
Czech Republic	yes	no	yes	no	medium
Denmark	yes	yes	yes	no	high
Estonia	yes	no	no	no	low
Finland	no	no	yes	no	low
France	yes	no	no	yes	medium
Germany	yes	no	yes	no	medium
Greece	yes	yes	yes	yes	high
Hungary	yes	yes	yes	no	high
Ireland	no	no	yes	no	low
Italy	no	yes	yes	yes	high
Latvia	no	yes	no	no	low
Lithuania	yes	yes	yes	yes	high
Luxembourg	yes	no	yes	no	medium
Malta	yes	no	no	no	low
Netherlands	yes	yes	yes	yes	high
Poland	no	no	yes	yes	medium
Portugal	yes	no	no	no	low
Romania	no	no	yes	no	low
Slovakia	yes	no	yes	yes	high
Slovenia	no	no	yes	no	low
Spain	no	no	no	no	absent
Sweden	no	no	yes	yes	medium
United Kingdom	yes	no	no	yes	medium

Table 4.4 - Support schemes for electricity generation from solar energy (RES LEGAL Europe)

An overall classification according to the availability of support schemes for solar energy applications, dedicated either to electricity generation or H&C, is obtained by considering the qualitative assessments shown in previous Table 4.3 and Table 4.4. For the assessment, the availability of support schemes for solar thermal installations is considered as predominant on the availability of support schemes for solar electricity generation.

Thus, the following ***classification according to availability of support schemes*** can be outlined:

- countries with low availability of support schemes: Austria, Bulgaria, Croatia, Cyprus, Czech Republic, Estonia, Finland, Germany, Latvia, Luxembourg, Malta, Poland, Portugal, Romania, Slovenia, Spain and Sweden;
- countries with medium availability of support schemes: Denmark, Hungary, Ireland, Lithuania and Slovakia;
- countries with high availability of support schemes: Belgium, France, Greece, Italy, Netherlands and United Kingdom.

The aforementioned classification is mapped in **Figure 4.2** below.

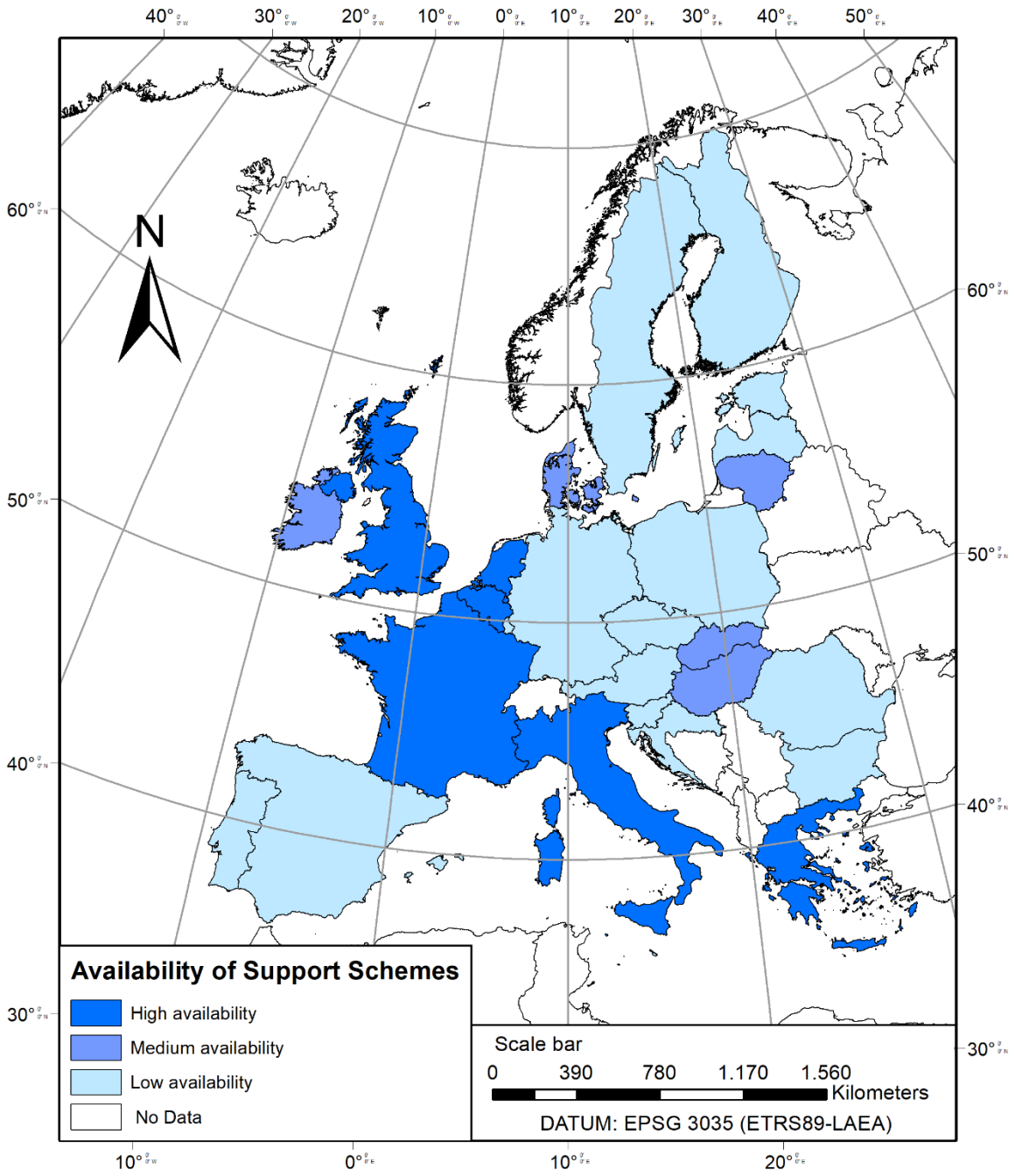

Figure 4.2 - Classification according to availability of support schemes (own elaboration)

5 OUTCOMES

In this section, the main features of each country relevant for the potential application of SunHorizon solutions are summarized and collected.

First outcomes are intended to provide a general overview of countries potentially suitable for the installation of solar technologies.

Subsequently, a more detailed analysis is performed for each SunHorizon technology package and each demo site, taking into account its specific purpose and application in relationship with the classifications outlined for the studied replicability criteria.

5.1 General overview

As a result of the mapping task, **Table 5.1** reports an overview including the main classifications obtained in the previous sections, including the classification with respect to solar resource potential, overall H&C demand and market conditions for each country, in order to identify at general level those countries that are more suitable for the installation of solar applications in general.

For the final classification according to market conditions, energy costs are considered as predominant over the availability of support schemes for solar energy applications. Furthermore, for the assessment of the overall suitability of a country for the installation of technologies based on solar energy, where qualitative average among scores of solar resource potential, H&C energy demand per unit area and market conditions is not immediate, it is considered that the overall level of suitability is correspondent to the two equal levels encountered for the aforementioned categories.

Country	Solar resource potential	H&C energy demand per unit area	Market conditions	Overall suitability for solar energy installations
Austria	medium	low	medium	medium
Belgium	low	high	medium	medium
Bulgaria	high	low	low	low
Croatia	high	medium	low	medium
Cyprus	high	low	medium	medium
Czech Republic	medium	medium	medium	medium
Denmark	low	medium	high	medium
Estonia	low	high	medium	medium
Finland	low	high	low	medium
France	high	medium	high	high
Germany	medium	medium	medium	medium
Greece	high	low	medium	medium
Hungary	medium	medium	low	medium
Ireland	low	medium	high	medium
Italy	high	high	high	high
Latvia	low	high	low	low
Lithuania	low	low	medium	low
Luxembourg	medium	high	low	medium
Malta	high	high	low	high
Netherlands	medium	low	high	medium
Poland	medium	medium	medium	medium
Portugal	high	low	medium	medium
Romania	medium	high	low	medium
Slovakia	medium	low	medium	medium

Country	Solar resource potential	H&C energy demand per unit area	Market conditions	Overall suitability for solar energy installations
Slovenia	medium	high	medium	medium
Spain	high	low	medium	medium
Sweden	low	medium	medium	medium
United Kingdom	low	medium	medium	medium

Table 5.1 – Overview of main classifications

Countries with high level of solar resource potential, high values of H&C demand, and high energy costs are those where the installation of SunHorizon technologies is more promising.

Besides, additional suitable countries for the installation of SunHorizon technologies are those characterized by high values of H&C demand and positive market conditions. Indeed, the classification in terms of solar energy resource for the countries considered plays a secondary role for the replicability evaluation, as in Europe, solar installed power can be relatively high also in those countries with low solar resource potential (e.g.: United Kingdom, characterized by low levels (average global irradiation < 1,250 kWh/m^2) of solar resource potential, is the third European country for total installed PV capacity).

To conclude, also the share of H&C demand satisfied by fossil based resources can be interpreted as a proxy to assess the suitability of a country towards the installation of solar-based technologies. In those cases, where a high share of energy consumed for H&C is generated from fossil-based resources, it is more likely that solar plants are installed, while, in those cases in which H&C demand is already satisfied by non-solar renewable energy resources, the likelihood that solar technologies are installed is probably lower. Reasonably, in the latter case, the final decision about the best energy supply type is driven by the comparison of energy costs between different renewable energy sources available.

Countries with shares of fossil based resources (coal, oil, gas) over 50% for heating purposes in both residential and tertiary sectors are Belgium, France, Germany, Greece, Hungary, Ireland, Italy, Luxembourg, Netherland, Poland, Portugal, Slovakia, Spain and United Kingdom. Nevertheless, this indication should be considered as an approximation considering that also electricity is characterized by a certain share of fossil based energy, depending on the energy mix of the country and considering that electricity is often used for heating purposes and it is the sole energy vector in the case of cooling.

5.2 Specific outcomes for Technology Packages replicability

In this section, the conclusions of the mapping analysis are tailored to each technology package, in order to understand in which countries the most favourable overall conditions for the installation and replication of the TPs can be encountered.

Before the investigation of such results, a brief description of each TP presented in **Table 5.6** below, highlighting the main features relevant for the identification of favourable conditions for replication.

Technology Package		Purpose
#1	TVP SOLAR thermal panels + BOOSTHEAT heat pump	Space heating, domestic hot water production (also during non-solar periods)
#2	DUALSUN hybrid panels + BOOSTHEAT heat pump	Space heating, support for domestic hot water and electricity production
#3	TVP SOLAR thermal panels + FAHRENEIT chiller	Space heating, space cooling, domestic hot water production (winter season)
#4	DUALSUN hybrid panels + BDR THERMEA GROUP reversible heat pump	Space heating, domestic hot water and electricity production
#5	TVP SOLAR thermal panels + BOOSTHEAT heat pump + FAHRENEIT chiller	Space heating, space cooling, domestic hot water production (winter season)

Table 5.2 - Overview of the Technology Packages

For each TP, replicability is evaluated through subsequent steps, consisting at first in the evaluation of replicability in terms of existing demand, then of market conditions and finally in terms of resource potential and energy costs.

The first step is the assessment of the compatibility between the output provided by the TP (i.e.: heating, cooling, heating and cooling) and the existing demand in each country.

As a second step, the potential installation of a TP in a country is evaluated based on exiting support schemes, which can be dedicated to electricity generation, solar thermal installations or both. As a result, depending on the output provided by the TP, different forms of support can exist in different countries.

Finally, the previous assessments are integrated with the level of solar resource potential in each country and the favourability of market conditions, in order to obtain the final replicability assessment of each TP in each MS.

It is expected that the overall replicability potential is high where a demand for the output of the TP exists, where financial support facilitates the installation of the TP and where solar resource potential and market conditions are favourable.

Table 5.7 illustrates the assessment of the replicability potential for each technology package on the basis of specific energy demand (i.e.: heating / cooling / H&C) in each country. Indeed, a TP is considered as replicable in terms of demand conditions in case it is able to satisfy a type demand that actually exists and that it is significant in amount in the country where replication is assessed.

For the evaluation, TPs are associated with previously collected data about energy demand as follows:

- TP#1, TP#2 are evaluated based on the values of heating demand per unit area registered in each country;
- TP#3 is evaluated based on the value of cooling demand per unit area registered in each country;
- TP#4, TP#5 are evaluated based on the values of H&C demand per unit area registered in each country.

TP / Country	#1, #2	#3	#4, #5
Austria	low	low	low
Belgium	high	medium	high
Bulgaria	low	medium	low
Croatia	medium	medium	medium
Cyprus	low	high	low
Czech Republic	medium	low	medium
Denmark	medium	medium	medium
Estonia	high	low	high
Finland	high	medium	high
France	medium	medium	medium
Germany	high	medium	medium
Greece	low	high	low
Hungary	medium	low	medium
Ireland	medium	medium	medium
Italy	high	high	high
Latvia	high	low	high
Lithuania	low	low	low
Luxembourg	high	high	high
Malta	medium	high	high

Country \ TP	#1, #2	#3	#4, #5
Netherlands	low	medium	low
Poland	medium	low	medium
Portugal	low	high	low
Romania	low	high	high
Slovakia	low	low	low
Slovenia	high	high	high
Spain	low	high	low
Sweden	medium	medium	medium
United Kingdom	medium	low	medium

Table 5.3 – Replicability of TPs according to energy demand

Table 5.8 illustrates the assessment of the replicability potential for each technology package on the basis of specific market conditions (i.e.: average energy cost and availability of support for thermal applications / support for electricity generation / both kinds of support) in each country. Indeed, a TP is considered as replicable in terms of market conditions in case support schemes that can facilitate the installation of each specific TP exist in the country where replication is assessed.

For the evaluation, TPs are associated with previously collected data as follows:

- TP#1, TP#3, TP#5 are evaluated based on the availability of support schemes for H&C applications;
- TP#2, TP#4 based on the availability of support schemes for H&C applications and for electricity generation.

Country \ TP	#1, #3, #5	#2, #4
Austria	low	low
Belgium	high	high
Bulgaria	low	low
Croatia	low	low
Cyprus	low	low
Czech Republic	low	low
Denmark	low	medium
Estonia	low	low
Finland	low	low
France	high	high
Germany	low	low
Greece	high	high
Hungary	low	medium
Ireland	high	medium
Italy	low	medium
Latvia	low	low
Lithuania	low	medium
Luxembourg	low	low
Malta	low	low
Netherlands	high	high
Poland	low	low
Portugal	low	low
Romania	low	low
Slovakia	low	medium
Slovenia	low	low

TP / Country	#1, #3, #5	#2, #4
Spain	low	low
Sweden	low	low
United Kingdom	high	high

Table 5.4 – Replicability of TPs according to the availability of support schemes

Finally, **Table 5.9** matches the information collected in previous Table 5.7 and Table 5.8 to the classifications associated with availability of resource potential and energy costs, in order to outline the overall replicability potential for each SunHorizon TP in each MS.

For the assessment of the qualitative level of replicability, the following criteria are introduced for the combination of the four parameters considered (i.e.: energy demand, availability of support schemes, availability of resource potential and energy costs):

- whenever the majority parameters present the same level, that level is considered as the overall level of replicability (e.g.: medium resource availability, medium energy cost, medium energy demand and low availability of support scheme yield to an overall medium potential for replicability);
- a high level combined with a low level corresponds to a medium level, to be combined with the remaining parameters (e.g.: high resource availability, high energy cost, low energy demand, low availability of support schemes yields to an overall medium potential for replicability);
- intermediate levels are introduced to represent those cases where there is variability in the levels of the parameters (e.g.: low availability of resource, medium energy cost, high energy demand, high availability of support schemes yield to a medium/high potential for replicability).

The matching criteria are based on the implicit assumption that the parameters are equally relevant for the replicability assessment.

TP / Country	#1	#2	#3	#4	#5
Austria	medium/low	medium/low	medium/low	medium/low	medium/low
Belgium	medium/high	medium/high	medium	medium/high	medium/high
Bulgaria	low	low	medium/low	low	low
Croatia	medium/low	medium/low	medium/low	medium/low	medium/low
Cyprus	medium	medium	*high*	medium	medium
Czech Republic	medium	medium	medium/low	medium	medium
Denmark	medium/low	medium	medium/low	medium	medium/low
Estonia	medium/low	medium/low	low	medium/low	medium/low
Finland	low	low	low	low	low
France	*high*	*high*	*high*	*high*	*high*
Germany	medium	medium	medium	medium	medium
Greece	low	medium	*high*	medium	medium
Hungary	medium/low	medium	low	medium	medium/low
Ireland	medium/high	medium	medium/high	medium	medium/high
Italy	*high*	*high*	*high*	*high*	*high*
Latvia	low	low	low	low	low
Lithuania	low	medium/low	low	medium/low	low
Luxembourg	medium/low	medium/low	medium/low	medium/low	medium/low
Malta	medium/low	medium/low	medium	medium	medium
Netherlands	medium/high	medium/high	medium/high	medium/high	medium/high
Poland	medium	medium	medium/low	medium	medium

TP / Country	#1	#2	#3	#4	#5
Portugal	medium	medium	*high*	medium	medium
Romania	low	low	medium/low	medium/low	medium/low
Slovakia	medium/low	medium	medium/low	medium	medium/low
Slovenia	medium	medium	medium	medium	medium
Spain	medium	medium	*high*	medium	medium
Sweden	medium/low	medium/low	medium/low	medium/low	medium/low
United Kingdom	medium	medium	medium/low	medium	medium

Table 5.5 – Replicability of TPs

Table 5.5 shows that the replicability potential is mainly related to the specific features of each country rather than on the technology package considered, except for a few exceptions for TP#3, which is the only one dedicated to cooling purposes only.

France and Italy stand as the only countries where the replicability potential of all the TPs is high. On the other hand, Cyprus, Greece, Portugal, and Spain present a high replicability potential for TP#3.

5.3 Specific outcomes for Demo Sites replicability

As a further results of the mapping activity, the analysis carried out in the previous section is repeated in this section with reference to each demo site. Demo sites indeed represent specific applications the technology packages and they can provide real examples of implementation of TPs in different climate conditions and in case of different final end-user (i.e.: residential sector, tertiary sector).

Before the investigation of such results, a brief description of each demo site and associated technology solution is presented in **Table 5.6** below, highlighting the main features relevant for the identification of favourable conditions for replication. Specifically, for each demo, the type of sector concerned, the needs satisfied by the installed innovative technologies and the specific technology packages foreseen by the design are described.

Demo Site		Sector	Needs	TP	Technology Solution
#1	Berlin (Germany)	Residential	Space heating, domestic hot water production, thermal energy storage	TP#1	BOOSTHEAT heat pump, DUALSUN hybrid panels, RATIOTHERM storage tank
#2	Nurnberg (Germany)	Residential	Space heating, domestic hot water production, electricity production, thermal energy storage	TP#2	BOOSTHEAT heat pump, DUALSUN hybrid panels
#3	Saint Cugat del Vallés (Spain)	Tertiary	Space cooling, thermal energy storage	TP#3	TVP SOLAR thermal panels, FAHRENEIT chiller
#4	Madrid (Spain)	Residential	Space heating and cooling, domestic hot water production, electricity production, thermal energy storage	TP#4	BDR THERMEA GROUP reversible heat pump, DUALSUN hybrid panels, BOOSTHEAT heat pump
#5	San Lorenzo de Hortons (Spain)	Residential	Domestic hot water production, electricity production, thermal energy storage	TP#4	BDR THERMEA GROUP reversible heat pump, DUALSUN hybrid panels

Demo Site		Sector	Needs	TP	Technology Solution
#6	Verviers – sport center (Belgium)	Tertiary	Domestic hot water production, thermal energy storage	TP#1	TVP SOLAR thermal panels, BOOSTHEAT heat pump
#7	Verviers – swimming pool (Belgium)	Tertiary	Domestic hot water production, electricity production, thermal energy storage	TP#2	BOOSTHEAT heat pump, DUALSUN hybrid panels
#8	Riga (Latvia)	Residential	Space heating, domestic hot water production, electricity production, thermal energy storage	TP#2	BOOSTHEAT heat pump, DUALSUN hybrid panels

Table 5.6: - Overview of the Demo Sites

Table 5.7 illustrates the assessment of the replicability potential for each technology package on the basis of specific energy demand (i.e.: heating / cooling / H&C) in each country. For the evaluation, TPs are associated with previously collected data as follows:

- DS#1, DS #2, DS #5, DS #8 are evaluated based on the values of heating demand per unit area in the residential sector;
- DS #3 is evaluated based on the value of cooling demand per unit are in the tertiary sector;
- DS #4 is evaluated based on the value of H&C demand per unit are in the residential sector;
- DS #6, DS #7 are evaluated based on the values of heating demand per unit area in the tertiary sector.

DS / Country	#1, #2, #5, #8	#3	#4	#6, #7
Austria	medium	low	medium	low
Belgium	high	medium	high	high
Bulgaria	low	low	low	low
Croatia	medium	medium	medium	medium
Cyprus	low	high	low	low
Czech Republic	high	low	high	medium
Denmark	medium	medium	medium	medium
Estonia	high	medium	high	high
Finland	high	medium	high	high
France	medium	medium	low	medium
Germany	medium	medium	medium	medium
Greece	low	high	low	low
Hungary	low	low	low	medium
Ireland	medium	medium	medium	medium
Italy	low	high	medium	high
Latvia	high	low	high	high
Lithuania	medium	low	medium	low
Luxembourg	high	high	high	high
Malta	low	high	low	high
Netherlands	low	medium	low	low
Poland	high	low	high	low
Portugal	low	high	low	low
Romania	high	high	high	high
Slovakia	medium	low	medium	low
Slovenia	high	high	high	high
Spain	low	high	low	medium

DS / Country	#1, #2, #5, #8	#3	#4	#6, #7
Sweden	medium	medium	medium	medium
United Kingdom	medium	low	medium	medium

Table 5.7 – Replicability of DSs according to energy demand

Table 5.8 illustrates the assessment of the replicability potential for each technology package on the basis of specific market conditions (i.e.: average energy cost and availability of support for thermal applications / support for electricity generation / both kinds of support) in each country. For the evaluation, TPs are associated with previously collected data as follows:

- #1, #3, #6 matched with availability of support schemes for H&C applications;
- #2, #4, #5, #7, #8 matched with availability of support schemes for H&C applications and for electricity generation.

DS / Country	#1, #3, #6	#2, #4, #5, #7, #8
Austria	low	low
Belgium	high	high
Bulgaria	low	low
Croatia	low	low
Cyprus	low	low
Czech Republic	low	low
Denmark	low	medium
Estonia	low	low
Finland	low	low
France	high	high
Germany	low	low
Greece	high	high
Hungary	low	medium
Ireland	high	medium
Italy	low	medium
Latvia	low	low
Lithuania	low	medium
Luxembourg	low	low
Malta	low	low
Netherlands	high	high
Poland	low	low
Portugal	low	low
Romania	low	low
Slovakia	low	medium
Slovenia	low	low
Spain	low	low
Sweden	low	low
United Kingdom	high	high

Table 5.8 – Replicability of DSs according to the availability of support schemes

Finally, **Table 5.9** matches the information collected in previous Table 5.7 and Table 5.8 to the classifications associated with availability of resource potential and energy costs, in order to outline the overall replicability potential for each SunHorizon DS in each MS.

For the assessment of the qualitative level of replicability, the matching criteria previously introduced are followed.

DS / Country	#1	#2, #5, #8	#3	#4	#6	#7
Austria	medium	medium	medium/low	medium	medium/low	medium/low
Belgium	medium/high	medium/high	medium	medium/high	medium/high	medium/high
Bulgaria	low	low	low	low	low	low
Croatia	medium	medium/low	medium/low	medium/low	medium/low	medium/low
Cyprus	medium	medium	*high*	medium	medium	medium
Czech Republic	medium	medium	medium/low	medium	medium	medium
Denmark	medium/low	medium	medium/low	medium	medium/low	medium
Estonia	medium/low	medium/low	medium/low	medium/low	medium/low	medium/low
Finland	low	low	low	low	low	low
France	*high*	*high*	*high*	*high*	*high*	*high*
Germany	medium	medium	medium	medium	medium	medium
Greece	medium	medium	*high*	medium/low	medium/low	medium
Hungary	low	medium/low	low	medium/low	medium/low	medium
Ireland	medium/high	medium	medium/high	medium	medium/high	medium
Italy	medium	medium/high	*high*	medium/high	*high*	*high*
Latvia	low	low	low	low	low	low
Lithuania	medium/low	medium	low	medium	low	medium/low
Luxembourg	medium/low	medium/low	medium/low	medium/low	medium/low	medium/low
Malta	low	low	medium	low	medium	medium
Netherlands	medium/high	medium/high	medium/high	medium/high	medium/high	medium/high
Poland	medium	medium	medium/low	medium	medium/low	medium/low
Portugal	medium	medium	*high*	medium	medium	medium
Romania	medium/low	medium/low	medium/low	medium/low	medium/low	medium/low
Slovakia	medium	medium	medium/low	medium	medium/low	medium
Slovenia	medium	medium	medium	medium	medium	medium
Spain	medium	medium	*high*	medium	medium/high	medium/high
Sweden	medium/low	medium/low	medium/low	medium/low	medium/low	medium/low
United Kingdom	medium	medium	medium/low	medium	medium	medium

Table 5.9 – Replicability of DSs

As for the case of TPs, Table 5.9 shows that the replicability potential is mainly related to the specific features of each country with respect to solar energy installations rather than on the specific technological solution implemented among those realized in SunHorizon demo sites.

France is the only country with high level of replicability potential for all the demo cases, followed by Italy that presents high levels of replicability for DS#3, DS#6 and DS#7. As expected, these results are aligned with those already extrapolated from the analysis of replicability potential for the TPs.

6 Conclusions

Deliverable D2.2 “Mapping of solar resource and building demand for SunHorizon implementation” is dedicated at mapping solar resource potential, solar resource demand and favourable market conditions, including energy prices, local building energy demand and most common Heating and Cooling (H&C) appliances in European countries.

The mapping exercise has led to general results (Section 5.1), providing an overview about Countries where installation of solar technologies seems more promising considering the availability of solar resource potential, the energy demand for H&C applications, the most commonly used appliances for H&C purposes, the average energy cost and the presence of support schemes.

In additional, various disaggregated results of the mapping exercise have been exploited for the assessment of replicability of SunHorizon technology packages and demo cases across Europe (Section 5.2 and Section 5.3). The assessment has been performed taking into account the specific end-use of the technology package, the sector where it is applied in the correspondent demo site and the presence of support schemes specific for the technologies foreseen, along with considerations about resource potential and energy cost.

As a general finding, it appears that the replicability potential is mainly driven by the country’s features with respect to solar resource availability, energy demand, cost of fossil-based energy sources and availability of supporting schemes for solar energy installations rather than on the specific technology package considered in the assessment. In addition, as core result of the mapping activity, the most promising countries for the replicability of SunHorizon innovations are identified. France and Italy stand as the only countries where the replicability potential of all the TPs is high. On the other hand, Cyprus, Greece, Portugal, and Spain present a high replicability potential for TP#3, dedicated to space cooling.

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