

**REPORT //**

# **Updating and integrating LOCATE datasets and maps**

Selection of maps accompanied by a description and explanation following the structure of the online MapFinder

Annexe 2 // September 2022

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**Coordination:**

Zintis Hermansons, Michaela Gensheimer (ESPON EGTC)  
Andreas Müller (e-think energy research)

**Authors**

Giulia Conforto, Andreas Müller, Marcus Hummel, Bernhard Mayr (e-think energy research)  
Lukas Kranzl, Lukas Liebmann, Gustav Resch (TU Wien, Energy Economics Group)

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Contact: [info@espon.eu](mailto:info@espon.eu)

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**Disclaimer**

This document is a final report.

The information contained herein is subject to change and does not  
commit the ESPON EGTC and the countries participating in the  
ESPON 2020 Cooperation Programme.

The final version of the report will be published as soon as approved.



# Contents

<b>Abbreviations .....</b>	<b>7</b>
<b>Set 1: Electricity generation by photovoltaic technology (MWh and MWh/km<sup>2</sup>, 2002, 2012, 2018, and changes) .....</b>	<b>10</b>
<b>Set 2: Electricity generation by wind onshore technology (MWh and MWh/km<sup>2</sup>, 2002, 2012, 2018, changes) .....</b>	<b>14</b>
<b>Set 3: Final energy consumption for space heating, domestic hot water and cooling in buildings of the residential sector (MWh/capita, 2002, 2012, 2018, changes).....</b>	<b>18</b>
<b>Set 4: Final energy consumption for space heating, domestic hot water and cooling in buildings of the private service sectors and public sector (MWh/capita, 2002, 2012, 2018, changes) .....</b>	<b>23</b>
<b>Set 5: Share of renewable energy carriers in final energy consumption for space heating, domestic hot water production and cooling in buildings of the residential sector (in %, 2002, 2012, 2018, changes) .....</b>	<b>28</b>

# List of maps, figures, charts and tables

## List of maps

Map 1. Electricity generation by photovoltaic technology, 2018 [MWh/km2].....	10
Map 2. Electricity generation by wind onshore technology, 2018 [MWh/km2] .....	14
Map 3. Change in energy demand for heating, DHW, and cooling, residential sector per capita (2018 - 2012) [MWh/cap] .....	18
Map 4. Change in energy demand for heating, DHW, private services per capita (2018 - 2012) [MWh/cap] .....	23
Map 5. Share of renewable energy carriers for heating, DHW and cooling, residential buildings 2018 [%] .....	28

## List of tables

Table 1: List of maps developed within the project and related set.....	8
---	---

# Abbreviations

CHP	Combined Heat and Power
DHC	District Heating and Cooling
DHW	Domestic Hot Water
NUTS	Nomenclature of Territorial Units for Statistics (from French: Nomenclature des unités territoriales statistiques)
PV	Photo voltaic
SDGs	Sustainable development goals

**Table 1: List of maps developed within the project and related set**

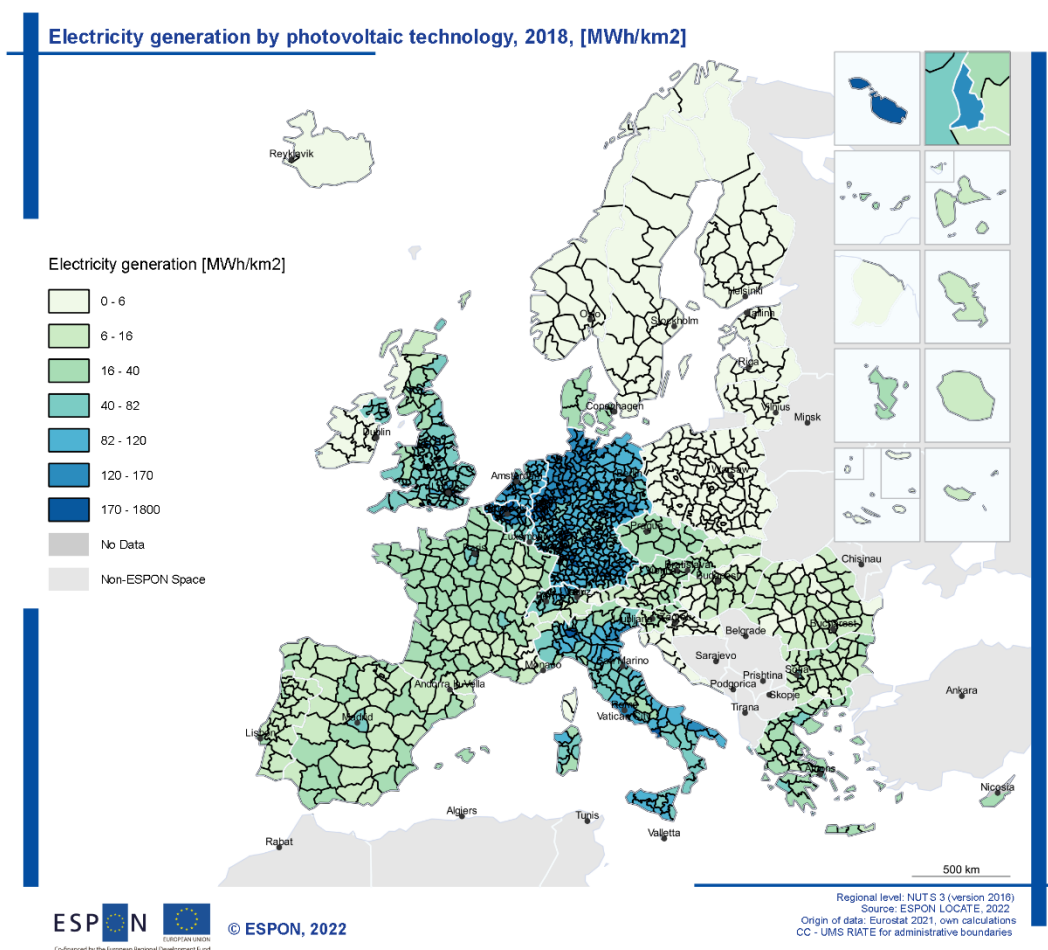
Map Number	File Name	Map Title	Set
1	Map 1_PhtElGnT_2002	Electricity generation by photovoltaic technology, 2002, [GWh]	1
2	Map 2_PhtElGnT_2012	Electricity generation by photovoltaic technology, 2012, [GWh]	1
3	Map 3_PhtElGnT_2018	Electricity generation by photovoltaic technology, 2018, [GWh]	1
4	Map 4_PhtElGnA_2002	Electricity generation by photovoltaic technology, 2002, [MWh/km <sup>2</sup> ]	1
5	Map 5_PhtElGnA_2012	Electricity generation by photovoltaic technology, 2012, [MWh/km <sup>2</sup> ]	1
6	Map 6_PhtElGnA_2018	Electricity generation by photovoltaic technology, 2018, [MWh/km <sup>2</sup> ]	1
7	Map 7_ChangePhtElGnA_2002-2012	Change in electricity generation by photovoltaic technology, 2002-2012, [MWh/km <sup>2</sup> ]	1
8	Map 8_ChangePhtElGnA_2012-2018	Change in electricity generation by photovoltaic technology, 2012-2018, [MWh/km <sup>2</sup> ]	1
9	Map 9_WinElGnT_2002	Electricity generation by wind onshore technology, 2002, [GWh]	2
10	Map 10_WinElGnT_2012	Electricity generation by wind onshore technology, 2012, [GWh]	2
11	Map 11_WinElGnT_2018	Electricity generation by wind onshore technology, 2018, [GWh]	2
12	Map 12_WinElGnA_2002	Electricity generation by wind onshore technology, 2002, [MWh/km <sup>2</sup> ]	2
13	Map 13_WinElGnA_2012	Electricity generation by wind onshore technology, 2012, [MWh/km <sup>2</sup> ]	2
14	Map 14_WinElGnA_2018	Electricity generation by wind onshore technology, 2018, [MWh/km <sup>2</sup> ]	2
15	Map 15_ChangeWinElGnA_2002-2012	Change in electricity generation by wind onshore technology, 2002-2012, [MWh/km <sup>2</sup> ]	2
16	Map 16_ChangeWinElGnA_2012-2018	Change in electricity generation by wind onshore technology, 2012-2018, [MWh/km <sup>2</sup> ]	2
17	Map 17_ResHeatC_2002	Residential buildings, 2002, [MWh/cap], final energy consumption for space heating, hot water and cooling	3
18	Map 18_ResHeatC_2012	Residential buildings, 2012, [MWh/cap], final energy consumption for space heating, hot water and cooling	3
19	Map 19_ResHeatC_2018	Residential buildings, 2018, [MWh/cap], final energy consumption for space heating, hot water and cooling	3
20	Map 20_ChangeResHeatC_2002-2012	Residential buildings, 2002-2012, [MWh/cap], change in final energy consumption for space heating, hot water and cooling	3
21	Map 21_ChangeResHeatC_2012-2018	Residential buildings, 2012-2018, [MWh/cap], change in final energy consumption for space heating, hot water and cooling	3
22	Map 22_PrivHeatC_2002	Private service sector, 2002, [MWh/cap], final energy consumption for space heating, hot water and cooling	4
23	Map 23_PrivHeatC_2012	Private service sector, 2012, [MWh/cap], final energy consumption for space heating, hot water and cooling	4
24	Map 24_PrivHeatC_2018	Private service sector, 2018, [MWh/cap], final energy consumption for space heating, hot water and cooling	4
25	Map 25_ChangePrivHeatC_2002-2012	Private service sector, 2002-2012, [MWh/cap], change in final energy consumption for space heating, hot water and cooling	4
26	Map 26_ChangePrivHeatC_2012-2018	Private service sector, 2012-2018, [MWh/cap], change in final energy consumption for space heating, hot water and cooling	4
27	Map 27_PubHeatC_2002	Public buildings, 2002, [MWh/cap], final energy consumption for space heating, hot water and cooling	4
28	Map 28_PubHeatC_2012	Public buildings, 2012, [MWh/cap], final energy consumption for space heating, hot water and cooling	4
29	Map 29_PubHeatC_2018	Public buildings, 2018, [MWh/cap], final energy consumption for space heating, hot water and cooling	4
30	Map 30_ChangePubHeatC_2002-2012	Public buildings, 2002-2012, [MWh/cap], change in final energy consumption for space heating, hot water and cooling	4



31	Map 31_ChangePubSHatC_2012-2018	Public buildings, 2012-2018, [MWh/cap], change in final energy consumption for space heating, hot water and cooling	4
32	Map 32_ResRenEn_2002	Residential buildings, 2002, [%], share of renewable energy carriers, heating, hot water and cooling, incl. electricity and district heating	5
33	Map 33_ResRenEn_2012	Residential buildings, 2012, [%], share of renewable energy carriers, heating, hot water and cooling, incl. electricity and district heating	5
34	Map 34_ResRenEn_2018	Residential buildings, 2018, [%], share of renewable energy carriers, heating, hot water and cooling, incl. electricity and district heating	5
35	Map 35_ChangeResRenEn_2002-2012	Residential buildings, 2002-2012, [pp], change in share of renewable energy carriers, heating, hot water and cooling, incl. electricity and district heating	5
36	Map 36_ChangeResRenEn_2012-2018	Residential buildings, 2012-2018, [pp], change in share of renewable energy carriers, heating, hot water and cooling, incl. electricity and district heating	5
37	Map 37_ServiceRenEn_2002	Service sector, 2002, [%], share of renewable energy carriers, heating, hot water and cooling, incl. electricity and district heating	5
38	Map 38_ServiceRenEn_2012	Service sector, 2012, [%], share of renewable energy carriers, heating, hot water and cooling, incl. electricity and district heating	5
39	Map 39_ServiceRenEn_2018	Service sector, 2018, [%], share of renewable energy carriers, heating, hot water and cooling, incl. electricity and district heating	5
40	Map 40_ChangeServiceRenEn_2002-2012	Service sector, 2002-2012, [pp], change in share of renewable energy carriers, heating, hot water and cooling, incl. electricity and district heating	5
41	Map 41_ChangeServiceRenEn_2012-2018	Service sector, 2012-2018, [pp], change in share of renewable energy carriers, heating, hot water and cooling, incl. electricity and district heating	5

# 1 Set 1: Electricity generation by photovoltaic technology (MWh and MWh/km2, 2002, 2012, 2018, and changes)

Only one map is shown here as an example, but the description below applies to all the maps of this set, please refer to Table 1 for the full list of maps included in set 1.



**Map 1. Electricity generation by photovoltaic technology, 2018 [MWh/km2]**

Theme: Environment and Energy

Project: Updating and integrating LOCATE datasets and maps

Programme: ESPON 2020 Cooperation Programme implemented by the ESPON EGTC

Publication: Final delivery

- In 2018, the countries with the greatest electricity generation by photovoltaic (PV) technology were Germany, Italy, and the United Kingdom. They also showed the highest generation by PV per km<sup>2</sup>, along with Belgium, the Netherlands and Switzerland.

- **Germany and the United Kingdom also showed the largest increase in electricity generation from PV technology between 2012 and 2018.**
- **Plummeting levelized cost of electricity from PV made this technology competitive with other well-established electricity sources in a growing list of regions, and sometimes the cheapest option, thanks also to vast newly installed capacities globally and in Europe.**
- **Supporting policies, regulations, and market conditions greatly impact the deployment of PV technology, as this has not grown according to solar potentials. Grid access is another key element, often requiring a strengthening of local distribution grids.**
- **Regions with high solar potentials and low levelized costs of PV electricity generation often show comparatively low disposable income. In these regions, public policies are essential to promote solar energy and include it in territorial planning, especially in urban areas where other renewable sources are not available (e.g., wind), while building-integrated PV can be used in almost every building type and across all sectors.**

### Observations for policy

Europe entered a phase of its clean energy transition, where accelerating the deployment of low-carbon energy sources becomes more and more urgent. Additionally, high energy prices due to the ongoing conflict in Ukraine create further opportunities for renewable energy. Expanding electricity generation by photovoltaics could reduce energy imports, increase energy security and independence, decrease electricity generation costs, reduce carbon intensity, and create employment and income.

Solar photovoltaics is likely to play a fundamental role in achieving a sustainable energy transition in Europe. Largely neglected for a long time, this technology has seen rapid expansion in the last decade, and more potential remains untapped. Decreasing production costs and vast newly installed capacities made PV technology competitive with other well-established sources in Europe and more regions globally. Plummeting levelized cost of electricity from PV, made this technology even the cheapest option sometimes.

However, to exploit its mostly untapped potential, more adaptation measures and policies in the power sector are needed to integrate distributed generation and cope with its variable nature. This includes shortened and simplified procedures for small- and large-scale PV installations permits, adequate financial incentives, either investment-focused or generation-based and enhanced grid access through the strengthening of local distribution grids to accommodate larger shares of PV generation.

Electricity generation by photovoltaics does not follow proportionally the potential for solar energy production. Supporting policies, regulations, and market conditions impact the level of diffusion of photovoltaic installations and generation. In this sense, considering that the highest solar potentials are found in southern Europe, where disposable income and electricity grid infrastructure is often more limited compared to other Member States, public policy interventions are essential to sustain deployment, especially where a larger generation would make PV electricity the cheapest option.

## Policy context

Energy is a key sector of the European agenda. The current target for renewable energy of 32% by 2030 was set in the Renewable Energy Directive 2018/2001/EU. Then in 2019, the European Green Deal presented a set of policy measures needed to meet the higher climate ambitions, including the Sustainable Europe Investment Plan and the Just Transition Mechanism. A Clean Planet for All set out the strategic long-term vision for a prosperous, modern, competitive, and climate-neutral economy by 2050. In 2021 the Commission presented a proposal for amending the Renewable Energy Directive and raising the renewable energy target to 40% by 2030. Also, the Cohesion Policy, the Territorial Agenda 2030, and the 2030 Agenda for Sustainable Development (SDGs 7 and 12) aim all at a greener and climate-resilient Europe, supporting the low-carbon transition, reducing emissions, and investing in renewable energy and energy efficiency.

## Map interpretation

Looking at the map, urban regions in western and central Europe show the highest electricity generation per km<sup>2</sup> by photovoltaic technology, against rural regions in South-Eastern Europe, which register the lowest values. Many regions still neglect this technology despite their high solar potential.

Between 2012 and 2018, the largest increase in electricity generated by photovoltaics took place in the United Kingdom, Germany, France, and the Netherlands. The only country showing a decrease in photovoltaic electricity generation was Slovenia, where the electricity generated by photovoltaic technology in 2018 was 41 GWh lower than in 2012. The smallest increase between 2012 and 2018 took place in Albania, Latvia, and Serbia. The label “No Data” indicates regions where data was not available or could not be estimated.

## Concepts and methods

Data on photovoltaic electricity generation was provided by Eurostat (2022b). The data refers to the yearly total electricity generation by photovoltaic technology in MWh for the year 2018. In addition, population distribution (Eurostat, 2022a) and building footprint (Müller, 2018a) were used as auxiliary indicators. The data on electricity generation by photovoltaic technology of ESPON Locate (2018) for the years 2002 and 2012 was updated to fit the NUTS 2016 nomenclature.

## Keywords

*Environment, Photovoltaic Electricity Generation, Renewable Energy, Sustainable Development*

## Literature

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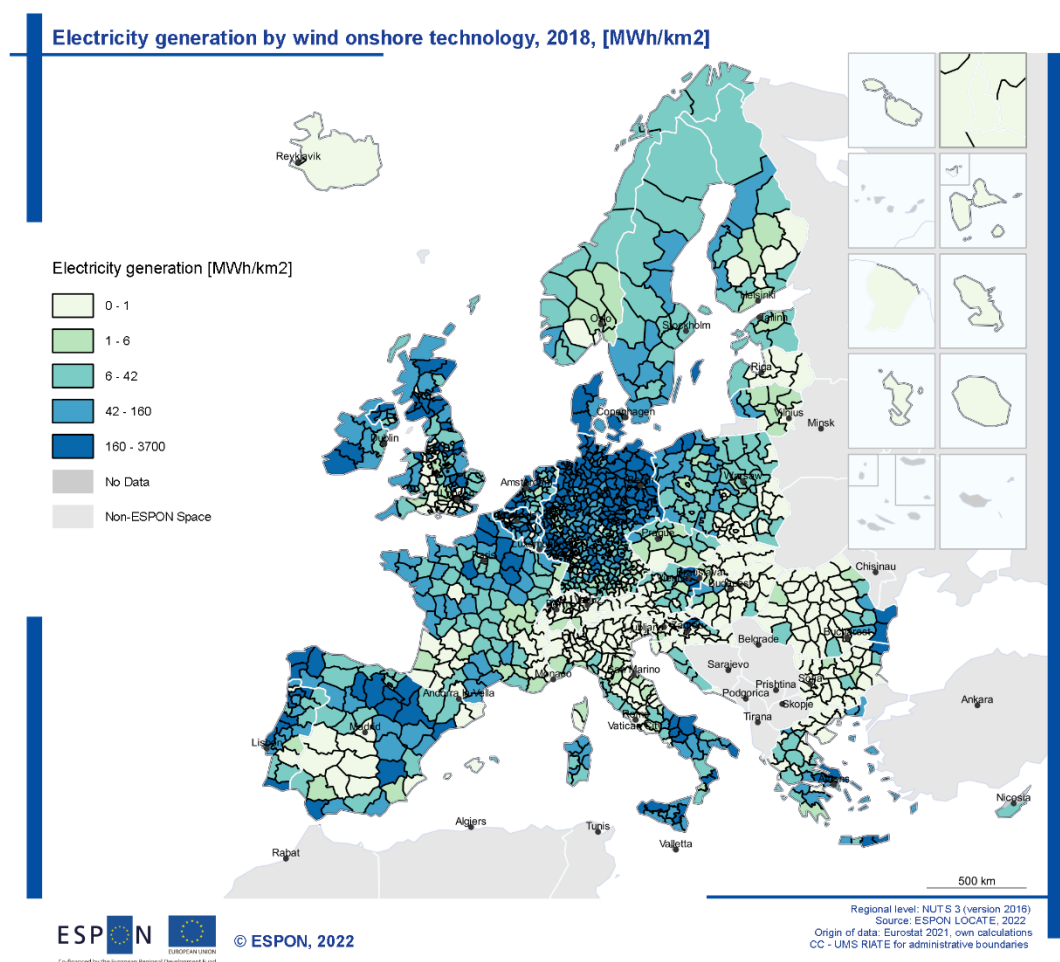
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## Set 2: Electricity generation by wind onshore technology (MWh and MWh/km<sup>2</sup>, 2002, 2012, 2018, changes)

Only one map is shown here as an example, but the description below applies to all the maps of this set, please refer to Table 1 for the full list of maps included in set 2.



### Map 2. Electricity generation by wind onshore technology, 2018 [MWh/km<sup>2</sup>]

Theme: Environment and Energy

Project: Updating and integrating LOCATE datasets and maps

Programme: ESPON 2020 Cooperation Programme implemented by the ESPON EGTC

Publication: Final delivery

- In 2018, the countries with the greatest electricity generation by wind onshore were Germany, the United Kingdom, and Spain. They also showed the highest power generation by wind onshore per km<sup>2</sup>, along with Portugal, Austria, the Netherlands and Belgium.

- **Germany and the United Kingdom also showed the largest increase in electricity generation from wind onshore between 2012 and 2018.**
- **Decreasing levelized cost of electricity from wind onshore made this technology competitive with other well-established electricity sources in a growing list of regions in Europe and globally.**
- **Supporting policies, regulations and market conditions impact the level of diffusion of wind onshore installation, as this does not grow proportionally to local wind potentials.**
- **Overall power systems and market development are needed to avoid curtailment and allow further uptake of on-shore wind electricity. As wind onshore installations are not allowed close to urban settlements and the best sites for this technology are usually far away from urban areas, where most of the electricity demand is concentrated, construction and upgrade of transmission lines must be accounted for in the uptake of this technology.**

## Observations for policy

To achieve the European clean energy transition accelerating the deployment of renewable energy becomes more and more important. At the same time, high energy prices due to the ongoing conflict in Ukraine, create additional opportunities for renewable energy. Increasing electricity generation by wind onshore could reduce energy imports, increase energy security and independence, provide electricity at low generation costs, reduce carbon intensity, as well as create employment and new income.

Wind onshore could play a crucial role in the European energy transition. This technology, neglected until the last three decades, has seen a rapid expansion from less than 20MW in 2000 to the current almost 200GW. To exploit further its untapped potential, adaptation measures and policies in the power sector are needed. Key barriers to wind onshore integration and uptake are: lack of consistent policy signals, which creates uncertainty for wind turbine production facilities; unstandardized and time-consuming regulatory and permitting processes; utilities' concerns about power system integration of distributed and variable electricity supply; public concerns related to visual, noise, land use, and other environmental impacts; availability of skilled labour.

Electricity generation by wind onshore technology does not grow proportionally to local wind potentials, which reveals how supporting policies, regulations and market conditions impact the level of diffusion of this technology. Overall power systems and market development are needed to avoid curtailment and allow further uptake of on-shore wind electricity. In fact, the best on-shore wind electricity generation sites are usually far away from urban areas, where most of the electricity demand is concentrated, thus transmission lines construction and costs shall be accounted for in the diffusion of this technology.

## Policy context

Energy is a key sector of the European agenda. The current target for renewable energy of 32% by 2030 was set in the Renewable Energy Directive 2018/2001/EU. The European Green Deal presented 2019 a set of policy measures needed to meet the higher climate ambitions, including the Sustainable Europe Investment Plan and the Just Transition Mechanism. A Clean Planet for All set out the strategic long-term vision for a prosperous, modern, competitive and climate-neutral economy by 2050. In 2021



the Commission presented a proposal for amending the Renewable Energy Directive and raising the renewable energy target to 40% by 2030. Also, the Cohesion Policy, the Territorial Agenda 2030 and the 2030 Agenda for Sustainable Development (SDGs 7 and 12) aim all at a greener and climate-resilient Europe, supporting the low-carbon transition, investing in renewable energy and energy efficiency, and reducing emissions.

## Map interpretation

Looking at the map, Germany, the United Kingdom, Spain, and France had the greatest generation by wind onshore technology in 2018. The highest electricity generation per km<sup>2</sup> by wind onshore was registered in the same countries along with regions in Portugal, Austria, the Netherlands and Belgium. Due to regulations on the minimum distance of wind turbines from settlement areas, the lowest values are found in urban regions. This technology is still neglected in several regions despite high potentials. Between 2012 and 2018, the largest increase in electricity generated from wind onshore took place in Germany, the United Kingdom, and France. The only country showing a decrease in wind electricity generation was Hungary, where the electricity generated by wind onshore in 2018 was 163 GWh lower than in 2012. No change took place in Slovakia. The smallest increases between 2012 and 2018 took place in Slovenia, Latvia and Iceland. The label “No Data” indicates regions where data was not available or could not be estimated, such as some islands (e.g. the Canary Islands, the Azores, and Madeira).

## Concepts and methods

Data on installed wind onshore capacities was provided by Wind Farm Database 2021 (The Wind Power, 2021). Data on wind onshore electricity generation was provided by (Eurostat, 2022b). The data refers to the yearly total electricity generation by wind onshore technology in MWh and average full load hours for the year 2018 per country. In addition, the land-use classifications (CLC 2012) on the hectare level were used as auxiliary indicators. Here we considered only grid cells which belong to one of the following CLC-Code types (211 (non-irrigated arable land), 231 (pastures), 241 (annual crops associated with permanent crops), 242 (complex cultivation patterns), 243 (land principally occupied by agriculture, with significant areas of natural vegetation), 244 (agroforestry areas), 324 (transitional woodland-shrub) and 333 (sparsely vegetated areas). The data on electricity generation by wind onshore technology of ESPON Locate (2018) for the years 2002 and 2012 was updated to fit the NUTS 2016 nomenclature.

## Keywords

*Environment, Wind Onshore Generation, Renewable Energy, Sustainable Development*

## Literature

Bundesamt für Energie 2022, Teilstatistiken, Schweizer Statistik der Erneuerbaren Energien June 28, 2022, 1:38 p.m. <https://www.bfe.admin.ch/bfe/de/home/versorgung/statistik-und-geodaten/energiestatistiken/teilstatistiken.html>



Corine Land Cover (CLC) 2012, Version 18.5.1.] <https://land.copernicus.eu/pan-european/corine-land-cover/clc-2012/view>

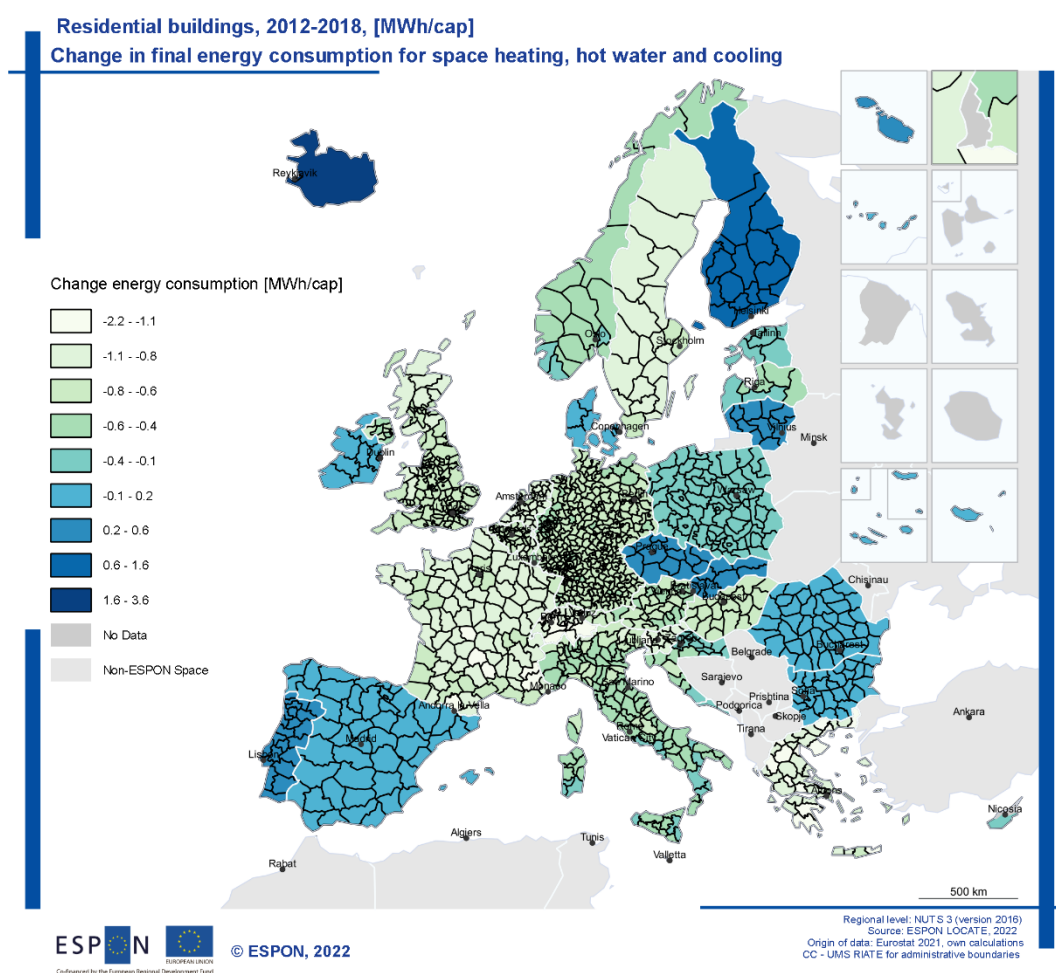
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## Set 3: Final energy consumption for space heating, domestic hot water and cooling in buildings of the residential sector (MWh/capita, 2002, 2012, 2018, changes)

Only one map is shown here as an example, but the description below applies to all the maps of this set, please refer to Table 1 for the full list of maps included in set 3.



**Map 3. Change in energy demand for heating, DHW, and cooling, residential sector per capita (2018 - 2012) [MWh/cap]**

Theme: Environment and Energy

Project: Updating and integrating LOCATE datasets and maps

Programme: ESPON 2020 Cooperation Programme implemented by the ESPON EGTC

Publication: Final delivery

- Final energy consumption per capita in heating and cooling varies significantly across Europe due to different climates, buildings' status and floor area per capita.

- **Opposing changes in this indicator in both periods of observation (2002-2012, 2012-2018) can be partly explained by demographic developments and were mostly driven by policies affecting the demand for floor area per capita and the buildings' energy performance.**
- **Persistent trends in energy consumption per capita are observed in both periods (2002-2012, 2012-2018): where consumption decreased, it kept decreasing and where it grew, it kept growing. Only partly explained by demographic changes, this shows the need for strong policy measures to steadily increase efficiency and sufficiency more uniformly.**
- **While consumption decreased more in the residential sector than in the service sector, the overall development does not seem enough to meet the targets of the Green Deal and the Fit-for-55 package of the European Commission.**
- **Heating and Cooling are essential parts of the European decarbonization policy. Mapping their demand is essential for energy management and planning, zoning, and identifying areas with potential for district networks.**

## Observations for policy

Heating and cooling are crucial for the European transition to a clean and carbon-neutral economy by 2050. Heating and cooling in buildings and industry account for about half of the EU's energy consumption, representing the biggest energy end-use sector, ahead of transport and electricity. Approximately 3/4<sup>th</sup> of heating and cooling is generated using fossil fuels with only the remaining part produced with renewable energy. Therefore, significantly reducing energy consumption, fossil fuel dependency and emissions in this sector is essential to achieving the EU's climate and energy goals.

Space heating and hot water production represent the greatest part of households' final energy consumption. Cooling demand is much smaller, but on a growing trend, also because of rising temperatures. The highest demand per plot area is in densely populated urban areas: for heating in colder regions (northern Europe) and for cooling in warmer regions (southern Europe). However, if the focus is on energy consumption per capita, sparsely populated areas tend to have higher specific consumption data. Leaving the local climate conditions aside, this is mostly due to larger heat floor areas per capita and buildings with higher energy losses due to less favourable volume-to-surface ratios.

Mapping the demand for heating and cooling is an essential step to plan, manage and decarbonize the heat and cold supply. However, consistent comprehensive data is difficult to find. These maps can help start a zoning assessment and identify areas with potential for district heating and cooling. Besides, the current high energy prices of natural gas and oil products, also due to the war in Ukraine, create further opportunities for increasing the share of local renewable and waste heat, while reducing energy import dependency, emissions, and energy bills.

## Policy context

Heating and cooling are a key sector of the European decarbonization agenda, affected by all energy and climate targets according to the Green Deal and the Fit-for-55 package of the European Commission: GHG emissions reduction, increasing the share of renewable energy, and increasing energy ef-

efficiency. The obligation to submit and regularly update a national Comprehensive Assessment of efficient heating and cooling potentials was introduced with the Energy Efficiency Directive (2012/27/EU). In 2016 the Commission proposed a first heating and cooling strategy, then advanced by a series of roundtables. In 2019 the European Green Deal included a Sustainable Europe Investment Plan and the Just Transition Mechanism. In the context of long-term decarbonization of the heating and cooling sector, in 2020 the Commission adopted the EU strategy on energy system integration and the renovation wave strategy. Also, A Clean Planet for All set out in 2021 the strategic long-term vision for a prosperous, modern, competitive and climate-neutral economy by 2050. This includes the targets for energy efficiency improvements set out in the Energy Efficiency Directive, which would also need to be taken up in the building sector. The proposed Energy Performance of Buildings Directive foresees measures like minimum energy performance standards and other instruments like renovation passports or digital building logbooks. Still, they shall be implemented stringently to avoid lock-in effects. Finally, the Cohesion Policy, the Territorial Agenda 2030 and the 2030 Agenda for Sustainable Development (SDGs 7 and 12) aim all at a greener and climate-resilient Europe, supporting the low-carbon transition, investing in renewable energy and energy efficiency, and reducing emissions.

## Map interpretation

Looking at the maps, the northern regions show the highest final energy consumption per capita for space heating, domestic hot water and space cooling in the residential sector, while the southern and eastern regions show the lowest values.

Between 2012 and 2018, an increase in final energy consumption per capita for heating, cooling, and domestic hot water took place at the northern, eastern, and western margins of the Union: Iceland, Finland, Portugal, the Czech Republic, Slovakia, and Lithuania. In the same period, the largest decrease took place in France, Slovenia, Sweden, Greece, the United Kingdom and the Netherlands. The tendency of final energy consumption in MWh/cap seen in the first observation period (2002-2012) was mostly confirmed in the second period (2012-2018): regions with growing consumption continued their consumption growth (Czech Republic, Finland, Iceland) and the other way round (the United Kingdom, France, the Netherlands). However, further analysis is needed to disaggregate the impact of demographic development (very diversified across regions), efficiency improvements, and service indicators such as floor area per capita.

The maps show a lower energy consumption per capita in the metropolitan areas due to a higher share of multi-family houses compared to rural areas. This calls for spatial policies regarding the settlement densities and type of new building construction. The label “No Data” indicates regions where data was not available or could not be estimated, such as some oversea French territories for instance.

## Concepts and methods

Data on the final energy consumption for heating and cooling on the NUTS 0 (country) level were provided by Eurostat (Eurostat, 2022c). Using the Energy balance sheets provided by Eurostat (April

2022 (Eurostat 2022d) edition, except for the United Kingdom, where the June 2021 (Eurostat, 2021) version was used), a consistent data series for the energy consumption per energy carrier group was created for the period 2000 to 2019 (natural gas, oil, coal, district heating, electricity and renewable energy carriers). Missing data was extrapolated from time series of energy carrier consumption of at least five years. The energy carrier share of total energy demand was kept constant for missing years, where time series of four years or less was available. Where no data were available, the average share of all countries (weighted by the square root of the national consumption) was applied per energy carrier to the total sectoral demand of that energy carrier. For Switzerland, we draw on data provided by Prognos (2021). Liechtenstein does not have sector-specific energy consumption data. Taking into account the very different climate as well as different building construction practices and heritage in the overseas territories of France, we did not estimate the energy consumption for space heating and domestic hot water preparation.

The national energy consumption was broken down to the NUTS 3 level for the year 2012 by using the open data set of the Hotmaps project, which provides heat density maps on the hectare level for residential and non-residential buildings (Müller and Fallahnejad, 2018). The Hotmaps dataset is built with a top-down approach: starting from data at the country level (NUTS 0) and estimating data down to the hectare level using a series of regional indicators (Müller et al., 2019). The data refers to the total final energy consumption for space heating, hot water production and space cooling in residential buildings in megawatt hour per capita (MWh per capita) for the years 2002, 2012 and 2018. To estimate deviating developments in different NUTS 3 regions within a country for the energy consumption analysed here, the population growth (Eurostat, 2022a) was used as an indicator. For the conversion of the dataset with different NUTS 3 definitions (NUTS 2013, NUTS 2021 to NUTS 2016), data was resampled on the hectare level using the population layer of the Hotmaps project.

## Keywords

*Heating and Cooling Demand, Residential Buildings, Final Energy Consumption, Sustainable Development*

## Literature

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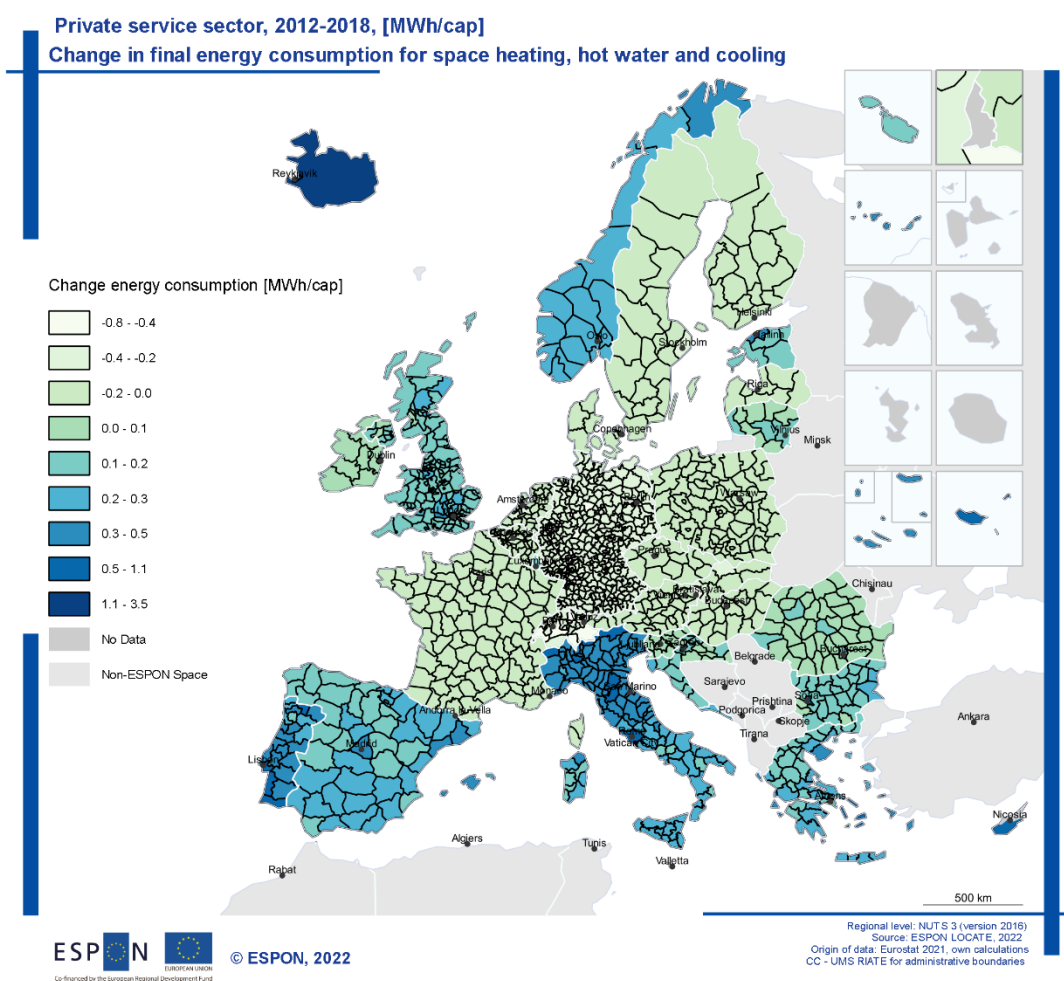
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## Set 4: Final energy consumption for space heating, domestic hot water and cooling in buildings of the private service sectors and public sector (MWh/capita, 2002, 2012, 2018, changes)

Only one map is shown here as an example, but the description below applies to all the maps of this set, please refer to Table 1 for the full list of maps included in set 4.



**Map 4. Change in energy demand for heating, DHW, private services per capita (2018 - 2012) [MWh/cap]**

Theme: Environment and Energy

Project: Updating and integrating LOCATE datasets and maps

Programme: ESPON 2020 Cooperation Programme implemented by the ESPON EGTC

Publication: Final delivery



- **Final energy consumption per capita in this sector differs strongly across regions in Europe due to different climates, buildings' status and economic circumstances.**
- **The change of this indicator in both periods of observation (2002-2012, 2012-2018) is very diverse across regions. This is only partly due to different demographic developments and mostly driven by policies affecting the growth of the service sector, related demand of floor area per capita and buildings' energy performance.**
- **Energy consumption in buildings of the private service sector is less strongly decreasing (or even increasing) compared to the residential sector. In both observation periods, a lot of regions show increasing demand for space heating, hot water and cooling in the service sector. This calls for efficiency policies and sufficiency measures specifically addressing this sector.**
- **Heating and Cooling are essential parts of the European decarbonization policy. Mapping the heat and cold demand is essential for energy management and planning, zoning, and identifying areas with potential for district networks.**

## Observations for policy

Heating and cooling are crucial for the European transition to a clean and carbon-neutral economy by 2050. Heating and cooling in buildings and industry account for about half of the EU's energy consumption, being the biggest energy end-use sector, ahead of transport and electricity. Approximately 3/4<sup>th</sup> of heating and cooling is generated using fossil fuels with only the remaining part produced with renewable energy. Therefore, significantly reducing energy consumption, fossil fuel dependency and emissions in this sector is essential to achieving the EU's climate and energy goals.

Space heating and hot water production represent a large part of the service sector's final energy consumption. While the cooling demand is still smaller than the heating demand, it becomes more and more important – not only in southern Europe but also in central and even northern European countries. It is generally expected the heating demand will decrease due to energy efficiency measures and rising temperatures, while space cooling demand is expected to increase. In opposite to the residential demand, the highest demand per capita is located in densely populated areas, as these indicators correlate with the number of businesses and employees per area.

Again, consistent comprehensive data is difficult to find, this is even more valid for the non-residential sector. Here we do not only lack solid data on the heated floor area and its historical development, but also the national energy consumption data provided by statistical bureaus are more prone to uncertainties and methodological changes.

Overall, it can be observed that the energy consumption of the service sector does not decrease as strongly as it is the case for residential buildings. The reason for that is not fully clear. One plausible reason could be the employment shift from industrial sectors toward the service sector, which leads to a disproportionately strong increase in heated floor space. However, at this stage, we cannot rule out that some of this effect might be driven by how statistical bureaus assigned the energy consumption to the different sectors.



## Policy context

Heating and cooling are a key sector of the European decarbonization agenda, affected by all energy and climate targets according to the Green Deal and the Fit-for-55 package of the European Commission: GHG emissions reduction, increasing the share of renewable energy, and increasing energy efficiency. The obligation to submit and regularly update a national Comprehensive Assessment of efficient heating and cooling was introduced with the Energy Efficiency Directive (2012/27/EU). In 2016 the Commission proposed a first heating and cooling strategy, then advanced by a series of roundtables. In 2019 the European Green Deal included a Sustainable Europe Investment Plan and the Just Transition Mechanism. In the context of long-term decarbonization of the heating and cooling sector, in 2020 the Commission adopted the EU strategy on energy system integration and the renovation wave strategy. Also, A Clean Planet for All set out in 2021 the strategic long-term vision for a prosperous, modern, competitive and climate-neutral economy by 2050. This also involves the targets for energy efficiency improvements set out in the Energy Efficiency Directive, which would also need to be taken up in the building sector. The proposed Energy Performance of Buildings Directive foresees measures like minimum energy performance standards and other instruments like renovation passports or digital building logbooks. Still, they have to be implemented stringently to avoid lock-in effects. Finally, the Cohesion Policy, the Territorial Agenda 2030 and the 2030 Agenda for Sustainable Development (SDGs 7 and 12) aim all at a greener and climate-resilient Europe, supporting the low-carbon transition, investing in renewable energy and energy efficiency, and reducing emissions.

## Map interpretation

Looking at the maps, the highest final energy consumption per capita for space heating, domestic hot water and space cooling can be seen in Iceland, Norway, Finland, Germany and the alpine regions of Austria and Italy, in metropolitan areas for private services as well as in central Europe for public services. The lowest values can be seen in the eastern and southern regions.

Between 2012 and 2018, both private and public services saw a strong increase in energy demand per capita for heating and cooling in Iceland, Norway, Italy, Spain, and Portugal and a strong decrease in Germany, more moderate in the rest of central Europe. On the one hand, building codes, standards and regulatory frameworks need to be strengthened accordingly and specifically for the service sector. On the other hand, the development shows that the trend is also strongly triggered by economic growth and that a decoupling of economic growth and energy consumption has not yet occurred in this sector. Where data was not available or could not be estimated, the region was indicated as “No Data”, such as some overseas French territories for instance.

The data does not provide evidence that the public service sector performed significantly better than the private service buildings, although specific policies for improving the energy performance of public buildings are in place. Thus, the efforts for improving the energy performance of public buildings need to be further enhanced.

While the consumption per capita in residential buildings in metropolitan areas tends to be lower than in other regions, for service buildings it is the other way round, due to the higher concentration of economic activities. This asks for specific measures to address the growth and energy performance of service buildings in these areas.

Overall, the data support the conclusion that the development of energy consumption in this sector in the observation periods is not in line with policy targets set in the fit-for-55 package.

## Concepts and methods

For non-residential buildings, the national demand for space heating, DHW and cooling as well as the share of energy carriers (2012) were built on own data sets. The share of total sectoral energy consumption per energy carrier, used for space heating, DHW and cooling was kept constant. Using the Energy balance sheets provided by Eurostat (April 2022 edition (Eurostat, 2022d), except for the United Kingdom, where the June 2021 version (Eurostat, 2021) was used), a consistent data series for the energy consumption per energy carrier group was created for the period 2000 to 2019 (natural gas, oil, coal, district heating, electricity and renewable energy carriers). For Switzerland, we draw on data provided by Prognos (2021).

The national energy consumption was broken down to the NUTS 3 level for the year 2012 by using the open data set of the Hotmaps project, which provides heat density maps on the hectare level for residential and non-residential buildings (Müller and Fallahnejad, 2018b). The Hotmaps dataset is built with a top-down approach: starting from data at the country level (NUTS 0) and estimating data down to the hectare level using a series of regional indicators (Müller et al., 2019).

The data refers to the total final energy consumption for space heating, hot water production and space cooling in residential buildings in megawatt hour per capita (MWh per capita) for the years 2002, 2012 and 2018. To estimate deviating developments in different NUTS 3 regions within a country for the energy consumption analysed here, the population growth (Eurostat, 2022a) was used as an indicator. To differentiate between public and private service sectors, the country-specific share published by Schremmer et al. (2018) within the Territories and low-carbon economy (ESPON Locate) project was used. For the conversion of the dataset with different NUTS 3 definitions (NUTS 2013, NUTS 2021 into NUTS 2016 version), the data on the hectare level was resampled using the population layer of the Hotmaps project (Müller, 2018b).

## Keywords

*Heating and Cooling Demand, Final Energy Consumption, Residential Private and Public Buildings, Sustainable Development*

## Literature

Eurostat 2021, Energy Balances in the MS Excel file format (2021 edition), Accessed on 14/4/2022, <https://ec.europa.eu/eurostat/documents/38154/4956218/Energy-balance-sheets-February-2021-edition.zip/4b1d6665-f303-be7d-a7e5-1e0da16ec0d9?t=1612709565471>

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Müller Andreas and Fallahnejad Mostafa 2018b, Heat density map (final energy demand for heating and DHW) of non-residential buildings in EU28 + Switzerland, Norway and Iceland for the year 2015. Open dataset created within the Hotmaps project, [https://gitlab.com/hotmaps/heat/heat\\_non-res\\_curr\\_density](https://gitlab.com/hotmaps/heat/heat_non-res_curr_density)

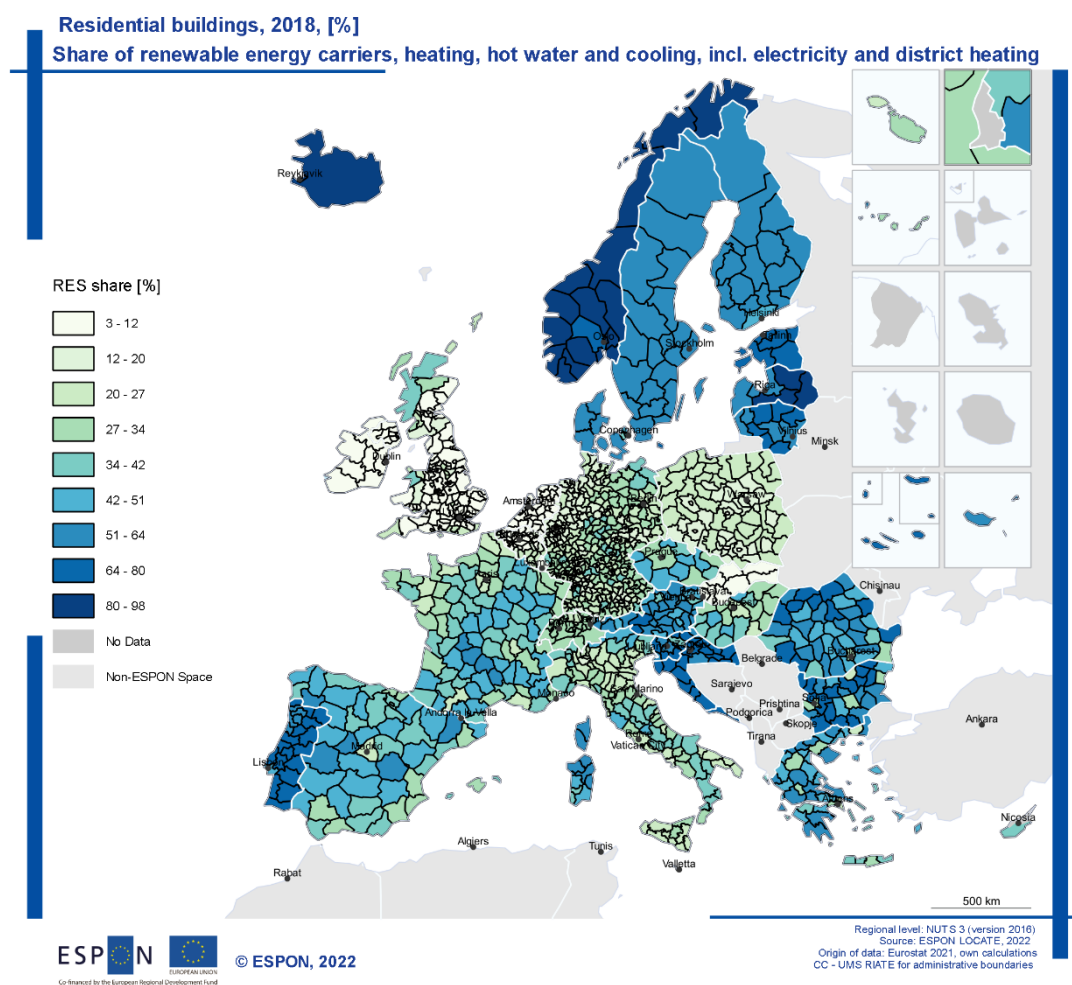
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## Set 5: Share of renewable energy carriers in final energy consumption for space heating, domestic hot water production and cooling in buildings of the residential sector (in %, 2002, 2012, 2018, changes)

Only one map is shown here as an example, but the description below applies to all the maps of this set, please refer to Table 1 for the full list of maps included in set 5.



**Map 5. Share of renewable energy carriers for heating, DHW and cooling, residential buildings 2018 [%]**

Theme: Environment and Energy

Project: Updating and integrating LOCATE datasets and maps

Programme: ESPON 2020 Cooperation Programme implemented by the ESPON EGTC

Publication: Final delivery

- **The highest share of renewable energy carriers in final energy consumption for heating and cooling can be seen in Scandinavia and the Baltic Countries, followed by an uneven distribution across the rest of Europe.**
- **Most NUTS3 regions are not yet in line with the policy ambitions set out in the Green Deal and the Fit-For-55 package regarding the absolute share of renewables (49% by 2030 in the building sector, with an annual increase of 1.1%).**
- **Metropolitan areas face particular challenges in increasing the share of renewables in buildings. This can be addressed by integrated solutions, spatial energy planning and zoning policies for renewable district heating.**

## Observations for policy

Heating and cooling are crucial for the European transition to a clean and carbon-neutral economy by 2050. Accounting for about half of the EU's energy consumption, they are the biggest energy end-use sector, ahead of transport and electricity. Approximately 3/4<sup>th</sup> of heating and cooling is still generated from fossil fuels and only the remaining part comes from renewable energy. Significantly reducing energy consumption, fossil fuel dependency and emissions in this sector is essential to achieving the EU's climate and energy goals.

Space heating and hot water production represent the greatest part of households' final energy consumption. Cooling demand is much smaller, but on a growing trend, also because of rising temperatures. Renewable energy carriers, largely neglected for a long time in heating and cooling supply, have seen an expansion in the last decades. Renewable energy will play a crucial role in decarbonizing the heating and cooling sector. However, to exploit the untapped potential, further adaptation measures and policies are needed to integrate distributed generation, coping with the specific features of renewable energy carriers. This includes simplified and faster permitting procedures for new installations, adequate financial incentives, enhanced grid access through the strengthening of local distribution grids, and stronger policy signals, including clearer and long-term regulations about various environmental impacts.

In fact, the highest share of renewable energy carriers in heating and cooling demand does not correspond to the highest potentials of the same renewable energy sources, but rather where the strongest policies and market conditions favoured their development. In this sense, public policies supporting the deployment and integration of renewable energy sources are especially needed where the lowest energy costs are combined with limited disposable income. Mapping the share of renewable energy carriers in heating and cooling consumption is an essential step to understanding how to identify the most successful condition for further deployment.

Overall, it can be seen that the speed of the development in most NUTS3 areas is not in line with the targets proposed in the Fit-for-55 package (i.e., an annual increase of RES-H&C by 1.1 ppt by 2030 and reaching 49% of RES in buildings' final energy consumption by 2030). In particular, metropolitan areas face specific challenges in increasing the RES-share in buildings' energy consumption. This needs to be addressed by spatial energy planning policies like district heating zoning policies.

## Policy context

Heating and cooling are a key sector of the European decarbonization agenda, affected by all energy and climate targets: emissions reduction, renewable energy, and energy efficiency. The obligation to submit and regularly update a national Comprehensive Assessment of efficient heating and cooling potentials was introduced with the Energy Efficiency Directive (2012/27/EU). In 2016 the Commission proposed a first heating and cooling strategy, then advanced by a series of roundtables. In 2019 the European Green Deal included a Sustainable Europe Investment Plan and the Just Transition Mechanism. In the context of long-term decarbonization of the heating and cooling sector, in 2020 the Commission adopted the EU strategy on energy system integration and the renovation wave strategy. Also, A Clean Planet for All set out in 2021 the strategic long-term vision for a prosperous, modern, competitive and climate-neutral economy by 2050. Also, the Commission proposal presented in 2021 could raise the current target for renewable energy from 32% to 40% by 2030. In particular, the proposed renewable energy directive includes an indicative target of 49% of RES in buildings' final energy consumption and an annual increase of RES-H&C by 1.1 ppt. Finally, the Cohesion Policy, the Territorial Agenda 2030 and the 2030 Agenda for Sustainable Development (SDGs 7 and 12) aim all at a greener and climate-resilient Europe, supporting the low-carbon transition, investing in renewable energy and energy efficiency, and reducing emissions.

## Map interpretation

Looking at the maps, the highest share of renewable energy carriers in final energy consumption for space heating, domestic hot water and space cooling can be seen in Iceland, Portugal, Scandinavian and Baltic regions, with the highest results by far in the residential sector, followed by private and public services.

Between 2012 and 2018, the residential sector shows the greatest increase in the share of renewable energy in heating and cooling final energy demand in Finland, Lithuania, Portugal, Greece, and Denmark, while in the service sector, strong increases took place in Portugal, Italy, and Greece. A decrease in the share of renewable energy in final energy consumption for space heating, domestic hot water and space cooling was registered in Norway, Finland and the Czech Republic. Where data was not available or could not be estimated, the region was indicated as "No Data", such as some overseas French territories for instance.

Only a few areas and countries have shown significant progress in both observed periods (2002-2012; 2012-2018), in particular Finland, Denmark, Portugal and parts of Scotland. Most regions show differences in the pace at which renewables in residential buildings have increased. These differences cannot be explained by the status of RES development in a certain area, nor by the related RES potentials.

## Concepts and methods

Data on the final energy consumption for heating and cooling on the NUTS 0 (country) level were taken from Eurostat (Eurostat, 2022c). Using the Energy balance sheets provided by Eurostat (April 2022

edition (Eurostat, 2022d), except for the United Kingdom, where the June 2021 version (Eurostat, 2021) was used), a consistent data series for the energy consumption per energy carrier group was created for the period 2000 to 2019 (natural gas, oil, coal, district heating, electricity and renewable energy carriers). Missing data was extrapolated from time series of energy carrier consumption of at least five years. Where time series of four years or less was available, the energy carrier share of total energy demand was kept constant for missing years. Where no data were available, the average share of all countries (weighted by the square root of the national consumption) was applied per energy carrier to the total sectoral demand of that energy carrier. A dataset was built for non-residential buildings for the national demand for space heating, DHW and cooling as well as the share of energy carriers (2012). The share of the total sectoral energy consumption per energy carrier used for space heating, DHW and cooling was kept constant.

The national share of energy carriers was broken down to the NUTS 3 level for the year 2012 by considering the potential availability of energy carriers within the different NUTS 3 regions. The possible availability of natural gas was estimated as a proximity function to the distance to the European gas transport infrastructure. More on that approach is discussed in (Schremmer et al., 2018). The availability of district heating uses the energy demand for space heating and domestic hot water preparation based on the Hotmaps heat density maps (Müller and Fallahnejad, 2018a, 2018b) on the hectare level in those hectare cells, for which the Heat Roadmap Europe Peta 4.3 indicates that a district heating network exists (Persson et al., 2018) with a weight of 80% and the installed CHP capacity in 2016 (as used by Schremmer et al., 2018) within the different NUTS 3 region with a weight of 20% (100% for those countries, which are not included in the Peta 4.3). The availability or usage of oil, renewables (mostly biogenic energy carriers in most countries) and coal were estimated depending on the degree of urbanisation. This reflects the higher utilisation of these energy carriers in more rural areas. The share of urbanisation for each NUTS 3 region was given as an attribute of the NUTS 3 spatial layer provided by Eurostat. In the case of renewable energy carriers and coal, an availability indicator of 50% was given to rural areas, and 20% to urban areas. Oil use was estimated at 80% for rural and 60% for urban areas. Electricity was given an availability weight of 80% for all areas. For each NUTS 3 region, the possible supply options were calculated and scaled the availability up, if either a single region scored a total availability indicator for all energy carriers of less than 200% or if the total country weight utilisation potential for a given energy carrier did not reach at least 125% of national consumption of that energy carrier group.

In consecutive steps, the energy consumption of each energy carrier was assigned to each region according to the availability indicator of that energy carrier compared to the other energy carriers by ensuring that the total consumption of all energy carriers aligns with the total energy demand in each region and that the total energy demand per energy carrier in all regions meets the national consumption of each energy carrier for space heating, domestic hot water preparation and air conditioning in the corresponding year. The share of renewable energy for electricity and district heat production was calculated based on the share of renewable fuel input into the different types of electricity and district



heat supply types and their corresponding heat and electricity output, as stated according to the Energy Balances provided by Eurostat for each year and country (Eurostat, 2021; Eurostat, 2022d). With this methodology, the seasonal change in the renewable energy share was neglected, especially for electricity production, imports and exports and in the case of CHP production, we give the same weight to electricity and district heat, not considering different efficiency factors.

The data refers to the share of renewable energy carriers in total final energy consumption for space heating, hot water production and space cooling in residential buildings in percentage (%) for the years 2002, 2012 and 2018. To estimate deviating developments in different NUTS 3 regions within a country for the energy consumption analysed here, the population growth was used as an indicator. For the conversion of the dataset with different NUTS 3 definitions (NUTS 2013, NUTS 2021 into NUTS 2016), data was resampled on the hectare level using the population layer provided by the Hotmaps project (Müller, 2018b).

## Keywords

*Renewable Energy, Heating and Cooling Final Energy Consumption, Residential Buildings, Sustainable Development*

## Literature

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## **ESPON 2020**

ESPON EGTC  
4 rue Erasme, L-1468 Luxembourg  
Grand Duchy of Luxembourg  
Phone: +352 20 600 280  
Email: [info@espon.eu](mailto:info@espon.eu)  
[www.espon.eu](http://www.espon.eu)

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### **Disclaimer**

This delivery does not necessarily reflect the opinion of the members of the ESPON 2020 Monitoring Committee.