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High-resolution energy atlas

Methodology and data

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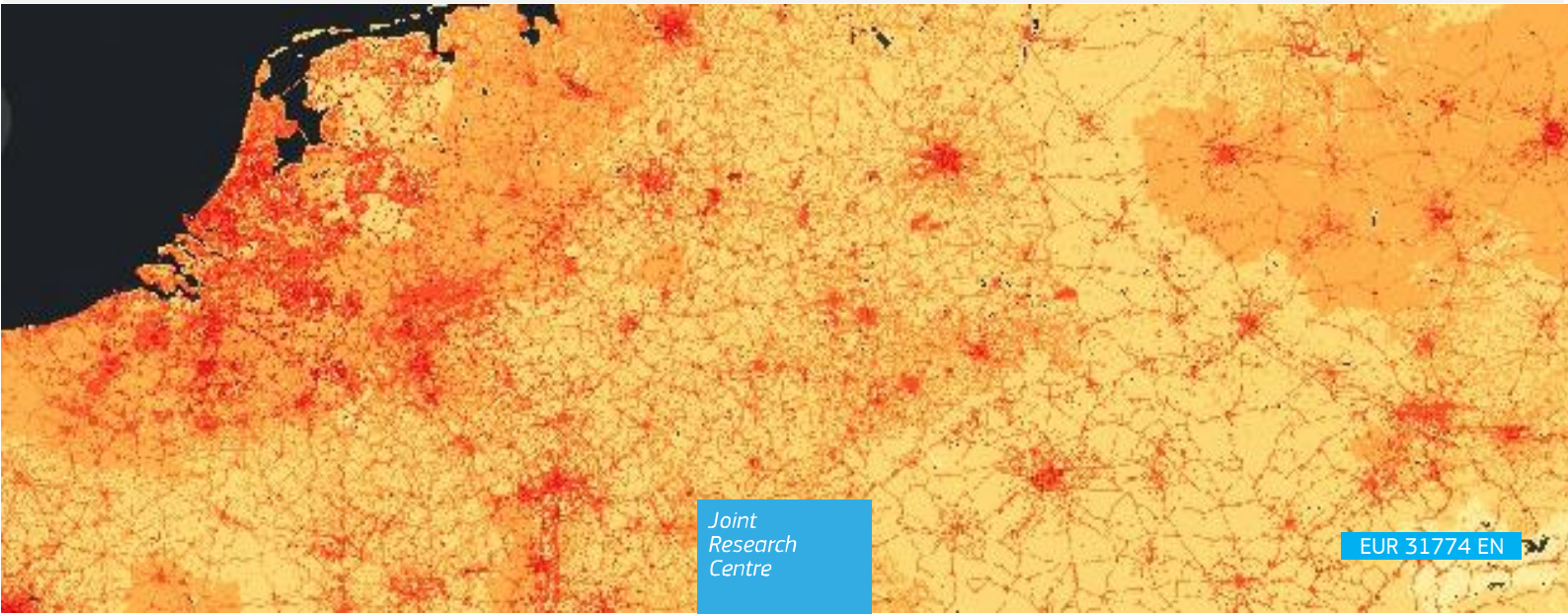

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Contents

Abstract

This report describes the assumptions and methodology used to break down national energy balances and energy scenarios and produce high-resolution gridded maps on a 1x1 km scale. The report shows, as an example, the results corresponding to the demand of natural gas for Portugal in 2019, based on public data available from EUROSTAT and the JRC's Energy and Industry Geography Lab. Those results consist of seven gridded maps of Portugal showing an estimation of the natural gas demand in 1x1 km cells for the main headings of EUROSTAT's 2019 energy balance: overall consumption for all purposes, demand for transformation input (use in power and heating plants, and refineries), and final consumption by industry, transport, commercial & public services, households and agriculture, forestry & fishing.

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1 Introduction

The European Union is committed to a radical decarbonisation of its energy system by 2050. This goal will partly be achieved through increased electrification, improvements in energy efficiency, and the use of hydrogen and other low-carbon energy carriers. This radical transformation of the ways we use and produce energy will require significant developments in our energy infrastructures. Those changes should be based on a sound understanding of the geographical distribution of the energy supply and demand and its plausible evolution. To that purpose, the Energy and Industry Geography Lab (EIGL) of the Joint Research Centre (European Commission - Joint Research Centre, 2023a) has produced a high-resolution atlas of energy demand across the EU, the first of its kind, that shows at an unprecedented 1x1 km resolution how energy is consumed throughout the EU.

This technical report describes the data and the methodology used to produce the high-resolution atlas, and it is organised as follows:

— Section 2 introduces the data inputs used to break down the energy balances and scenarios, namely: the energy balances from the statistical office of the European Union (EUROSTAT) and energy scenarios from the Directorate-General for Energy (ENER), extended data on demand for non-energy uses, energy inputs and geographical locations of individual facilities from the industrial reporting dataset, hydrogen production projects, CO_2 emission data from the European Union Transaction Log, data from the JRC power plant database, regional statistics from EUROSTAT, and land cover data and projections from the LUISA Territorial Modelling Platform (Land Use-based Integrated Sustainability Assessment).

— Section 3 explains the three steps of the methodology used to downscale energy consumption data at national level to 1x1 km cells, which consists of:

1. Splitting the energy demand data, from the energy balances or from scenarios, into the energy consumption at geographically located points and the amount of energy demand that is not yet linked to specific locations
2. The latter is then distributed at regional level using a selection of publicly available datasets at regional level.
3. Finally, the regional energy demand calculated is distributed across 1x1 km cells according to data and projections on population and land cover.

— Section 4 shows some illustrative results at EU level

— Section 5 closes the report with some conclusions and proposals for next steps.

The report contains additional information in two annexes.

2 Inputs

2.1 Energy balances and scenarios

The energy balances published by EUROSTAT[1] are the main input used to produce the high-resolution energy atlas. They are the most complete statistical accounts of energy products and their flow in the economy. An energy balance is the natural starting point for studying the energy sector because it allows users to see the total amount of each energy product extracted from the environment, traded, transformed and used by different types of end-user.

The balances include, for each country, all statistically significant energy products (more than 60, consistent with the Standard International Energy Product Classification – SIEC of the UN's International Recommendations for Energy Statistics (United Nations, 2018)) along with their production, transformation and consumption by economic category (such as industry and transport; the list of economic activities is in accordance to NACE Rev.2 (European Commission - EUROSTAT, 2008)[2]. The energy balances therefore contain a huge amount of information, at national level only, that can be organised in a table (Figure 1, or a Sankey diagram, Figure 2) where columns represent energy products and rows represent flows of the balance (production, transformation, and consumption sectors):

- Products[3] (columns of the energy balance):
    - Total: sum of the main subtotals corresponding to groups of energy products, namely solid fossil fuels, manufactured gases, peat and peat products, oil shale and oil sands[4], oil and petroleum products, natural gas, renewables and biofuels, non-renewable waste, nuclear heat, heat, and electricity. The totals are used in the simplified energy balances whereas the individual energy products are used in the complete energy balances.
    - Solid fossil fuels: anthracite, coking coal, other bituminous coal, sub-bituminous coal, lignite, patent fuels, coke oven coke, gas coke, coal tar, brown coal briquettes and peat briquettes.
    - Manufactured gases: gas works gas, coke oven gas, blast furnace gas and other recovered gases.
    - Oil shale and oil sands
    - Peat and peat products: peat, peat products.
    - Oil and petroleum products: crude oil, natural gas liquids, refinery feedstocks, additives and oxygenates (excluding biofuel portion), other hydrocarbons, refinery gas, ethane, liquefied petroleum gas, motor gasoline (excluding biofuel portion), aviation gasoline, gasoline-type jet fuel, kerosene-type jet fuel (excluding biofuel portion), other kerosene, naphtha, gas oil and diesel oil (excluding biofuel portion), fuel oil, white spirit and special boiling point industrial spirits, lubricants, bitumen, petroleum coke, paraffin waxes, other oil products not elsewhere specified.
    - Natural gas.
    - Renewables and biofuels: hydro power, tide, wave and ocean, wind power, solar photovoltaic, solar thermal, geothermal, primary solid biofuels, charcoal, biogases, renewable municipal waste, pure biogasoline, blended biogasoline, pure biodiesels, blended biodiesels, pure bio jet kerosene, blended bio jet kerosene, other liquid biofuels, ambient heat (heat pumps).
    - Non-renewable waste: industrial waste (non-renewable), non-renewable municipal waste.
    - Nuclear heat.
    - Heat.
    - Electricity.

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1 https://ec.europa.eu/eurostat/cache/infographs/energy_balances/enbal.html
2 NACE stands for "nomenclature statistique des activités économiques dans la Communauté européenne".
3 See (International Energy Agency, 2004) for precise definitions of products and flows.
4 Note that oil shale and oil sands, natural gas, nuclear heat, heat and electricity do not belong to any group.

— Flows (rows of the energy balance), divided into three blocks:
    - Top block: representing the energy supply, defined as the sum of primary energy production, recovery, imports, and stock draws minus the sum of exports, stock build, and maritime and aviation bunkers.
    - Medium block: this refers to energy sector facilities (e.g. power and heat plants, refineries, gas works, patent fuel plants, brown coal briquette plants) and some industrial installations (coke ovens, blast furnaces, petrochemical plants) where primary energy carriers (e.g. oil crude, natural gas and coal) are transformed into final energy products (e.g. gasoline and electricity).
    - Bottom block: this represents the demand of energy products for non-energy purposes (e.g. used as feedstocks in the chemical industry, building materials, or lubricants) and the demand of energy products for final users (e.g. industry, transport and other sectors)[5].

Energy products are used for energy and non-energy purposes, as feedstocks in different industrial processes and other activities (see Table 1). This demand for non-energy uses accounts for a significant share of the total energy use in the industry (between 4% and 55% depending on the MS, 28% on average for the EU). Since EUROSTAT only provides the demand aggregated for all industry, transport and other sectors, the disaggregation of the non-energy use demand for each individual industrial sector considered in the energy balances is done according to the "memo items" available from the IEA's Extended World Energy Balances (International Energy Agency, 2020), which are compatible with EUROSTAT.

Table 1. Possible non-energy uses of energy carriers (non-exhaustive)

Energy product	**Purpose**
Gas/diesel oil	Production of ammonia and petrochemicals
LPG, gasoline	Production of petrochemicals
Naphtha	Production of ethylene and petrochemicals
Lubricants, solvents, paraffin waxes, greases	For engines and machinery used by industries, transport, commercial and public services, households
White spirit	Solvent for paints and varnishes
Oil products	Production of ammonia
Coke, coal	Production of titanium dioxide, carbide, aluminium, and ferroalloys
Coke	Production of lead, zinc, food and beverages
Natural gas	Production of ammonia, methanol, carbon black, nitric acid, petrochemicals, and hydrogen
Bitumen	Construction of buildings and roads
Refinery gas	Production of petrochemicals
Petroleum coke	Production of carbide, electrodes, graphite, and chemicals

Source: JRC, 2023, adapted from Annex 8A.2, Table 2.12, in (Eggleston et al., 2006).

The methodology used to break down the national energy balances to 1x1 km cells is also used, with some additional assumptions, to break down energy scenarios (European Commission, 2023c). The energy scenarios are, in effect, energy balances with additional energy products that are projected into the future as result of a modelling exercise. They provide the European Commission with key tools for policy analysis in energy, transport and climate action. These scenarios allow policymakers to analyse the long-term economic, energy, climate and transport outlook based on the policy framework in place. This can provide them with a comprehensive analytical basis against which they can assess new policy proposals.

The energy scenarios are structured as the energy balances, the only difference being the addition of new energy products: hydrogen, clean gas (grouped together with natural gas), methanol and synthetic fuels (grouped with oil and petroleum products), and ethanol (grouped with renewables and biofuels).

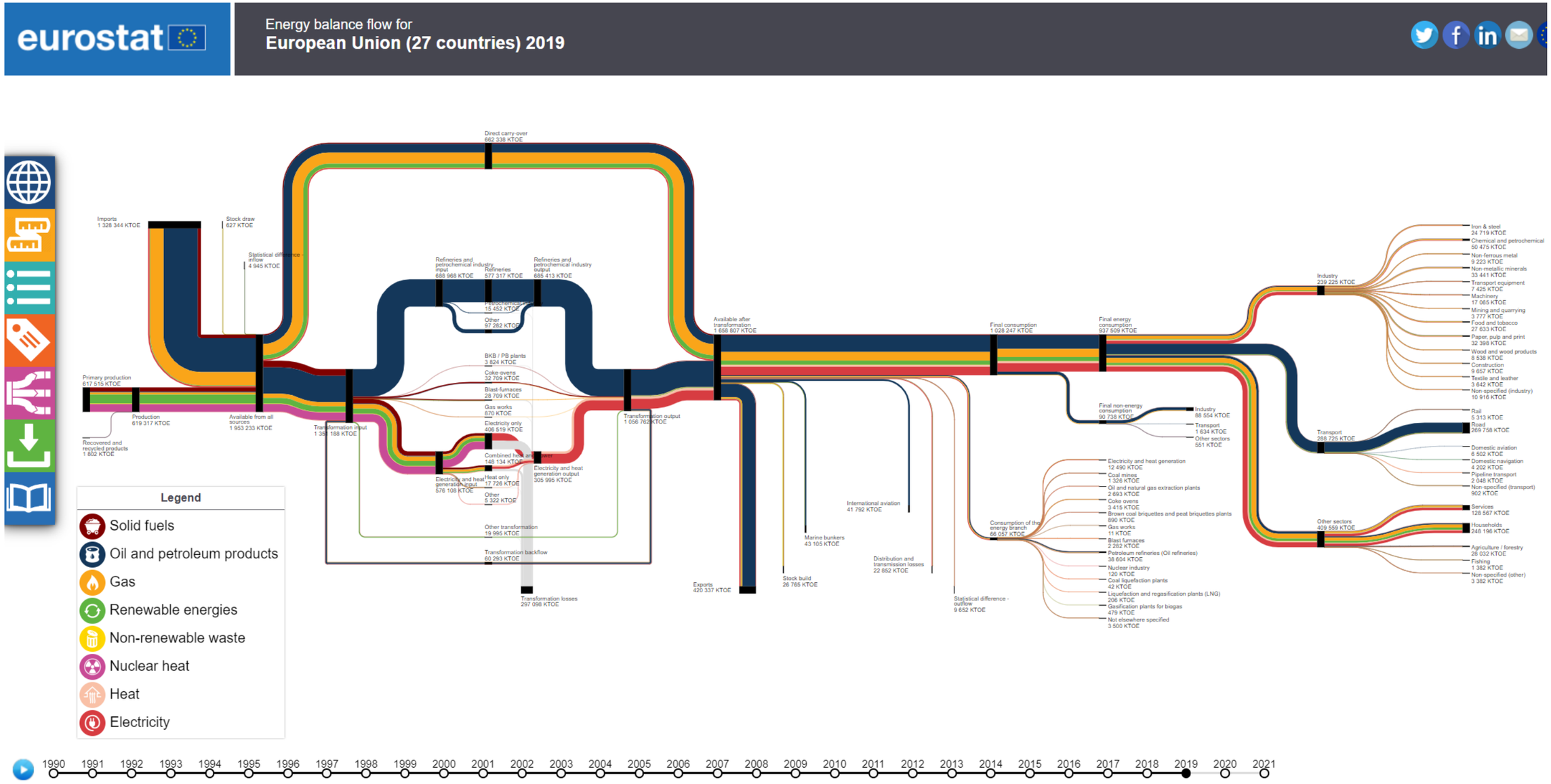
[5] See the annex for further details about the definition of the sectors considered in the energy balance.

Figure 1. Simplified EUROSTAT energy balance for the EU

European Union (28 countries) ktoe 2017	Total	Solid fossil fuels	Manufac-tured gases	Peat and peat products	Oil shale and oil sands	Oil and petroleum products	Natural gas	Renewables and biofuels	Non-renewable waste	Nuclear heat	Heat	Electricity
+ Primary production	758 209	124 466	Z	1 604	4 147	73 390	103 091	226 586	14 201	210 724	Z	Z
+ Recovered & recycled products	1 627	468	Z	0	0	1 160	Z	0	Z	Z	Z	Z
+ Imports	1 528 083	115 370	0	58	0	968 451	392 136	18 493	487	Z	6	33 081
- Exports	580 306	15 016	0	15	0	425 156	96 029	11 844	37	Z	5	32 204
+ Change in stock	11 810	3 098	0	527	55	8 680	-788	241	-3	Z	Z	Z
= Gross available energy	**1 719 424**	**228 386**	**0**	**2 174**	**4 202**	**626 525**	**398 411**	**233 476**	**14 648**	**210 724**	**1**	**877**
- International maritime bunkers	44 499	0	0	0	0	44 472	27	0	Z	Z	Z	Z
- International aviation	51 158	Z	Z	Z	Z	51 158	Z	0	Z	Z	Z	Z
= Total energy supply	**1 623 766**	**228 386**	**0**	**2 174**	**4 202**	**530 894**	**398 384**	**233 476**	**14 648**	**210 724**	**1**	**877**
Transformation input	**1 528 381**	**231 542**	**8 505**	**1 874**	**4 136**	**786 331**	**125 258**	**144 558**	**10 724**	**210 724**	**775**	**3 954**
+ Electricity & heat generation	665 619	157 823	8 504	1 764	2 494	16 279	123 327	129 251	10 724	210 724	775	3 954
+ Coke ovens	36 454	36 027	0	0	16	399	11	0	Z	Z	Z	Z
+ Blast furnaces	33 150	33 090	0	0	0	27	33	0	Z	Z	Z	Z
+ Gas works	721	518	0	0	185	0	18	0	Z	Z	Z	Z
+ Refineries & petrochemical industry	769 433	Z	Z	Z	Z	769 433	Z	Z	Z	Z	Z	Z
+ Patent fuel plants	208	145	0	0	0	63	Z	0	0	Z	Z	Z
+ BKB & PB plants	3 807	3 696	0	111	0	Z	Z	0	0	Z	Z	Z
+ Coal liquefaction plants	1 440	0	0	0	1 440	Z	Z	Z	Z	Z	Z	Z
+ For blended natural gas	599	Z	0	Z	Z	130	Z	469	Z	Z	Z	Z
+ Liquid biofuels blended	14 503	Z	Z	Z	Z	Z	Z	14 503	Z	Z	Z	Z
+ Charcoal production plants	244	Z	Z	Z	Z	Z	Z	244	Z	Z	Z	Z
+ Gas-to-liquids plants	0	Z	Z	Z	Z	Z	0	Z	Z	Z	Z	Z
+ Not elsewhere specified	2 201	241	1	0	0	0	1 870	90	0	Z	Z	Z
Transformation output	**1 175 554**	**31 255**	**19 888**	**77**	**Z**	**766 501**	**501**	**14 260**	**Z**	**Z**	**59 391**	**283 680**
+ Electricity & heat generation	343 071	Z	Z	Z	Z	Z	Z	Z	Z	Z	59 391	283 680
+ Coke ovens	33 926	27 315	6 611	Z	Z	Z	Z	Z	Z	Z	Z	Z
+ Blast furnaces	12 762	0	12 762	Z	Z	Z	Z	Z	Z	Z	Z	Z
+ Gas works	468	0	468	Z	Z	Z	Z	Z	Z	Z	Z	Z
+ Refineries & petrochemical industry	763 656	Z	Z	Z	Z	763 656	Z	0	Z	Z	Z	Z
+ Patent fuel plants	137	137	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z
+ BKB & PB plants	3 880	3 803	Z	77	Z	Z	Z	Z	Z	Z	Z	Z
+ Coal liquefaction plants	955	Z	Z	Z	Z	955	Z	Z	Z	Z	Z	Z
+ Blended in natural gas	501	Z	Z	Z	Z	Z	501	Z	Z	Z	Z	Z
+ Liquid biofuels blended	14 174	Z	Z	Z	Z	Z	Z	14 174	Z	Z	Z	Z
+ Charcoal production plants	86	Z	Z	Z	Z	Z	Z	86	Z	Z	Z	Z
+ Gas-to-liquids plants	1 644	Z	Z	Z	Z	1 644	Z	Z	Z	Z	Z	Z
+ Not elsewhere specified	294	0	47	0	Z	247	Z	Z	Z	Z	Z	Z
Energy sector	**79 194**	**653**	**5 125**	**20**	**2**	**30 098**	**16 614**	**666**	**75**	**Z**	**4 866**	**21 075**
+ Own use in electricity & heat generation	15 183	19	15	0	0	30	66	23	8	Z	1 160	13 862
+ Coal mines	1 467	301	32	0	2	72	31	0	0	Z	123	905
+ Oil & natural gas extraction plants	8 315	Z	Z	Z	Z	700	6 911	0	Z	Z	17	687
+ Patent fuel plants	0	0	0	0	0	Z	Z	0	0	Z	0	0
+ Coke ovens	3 417	123	3 046	0	0	0	29	0	0	Z	93	127
+ BKB & PB plants	1 019	187	0	20	0	Z	Z	18	0	Z	367	427
+ Gas works	14	0	0	0	0	0	0	4	0	Z	0	10
+ Blast furnaces	2 236	1	1 996	0	0	1	37	0	39	Z	11	150
+ Petroleum refineries (oil refineries)	43 104	21	25	0	0	29 067	8 538	40	0	Z	2 246	3 167
+ Nuclear industry	102	Z	Z	Z	Z	Z	Z	Z	Z	Z	0	102
+ Coal liquefaction plants	26	0	0	0	0	Z	Z	Z	Z	Z	8	18
+ Liquefaction & regasification plants (LNG)	199	Z	Z	Z	Z	Z	197	Z	Z	Z	0	2
+ Gasification plants for biogas	538	Z	Z	Z	Z	Z	Z	535	0	Z	3	0
+ Gas-to-liquids (GTL) plants	0	Z	Z	Z	Z	Z	0	Z	Z	Z	0	0
+ Charcoal production plants	0	Z	Z	Z	Z	Z	Z	0	0	Z	0	0
+ Not elsewhere specified (energy)	3 573	0	10	0	0	229	805	47	28	Z	838	1 617
Distribution losses	**25 892**	**30**	**905**	**1**	**0**	**30**	**1 937**	**66**	**0**	**Z**	**5 186**	**17 736**
Available for final consumption	**1 165 852**	**27 416**	**5 354**	**356**	**64**	**480 936**	**255 076**	**102 445**	**3 849**	**0**	**48 565**	**241 792**
Final non-energy consumption	**102 208**	**1 660**	**17**	**0**	**53**	**85 372**	**15 105**	**0**	**Z**	**Z**	**Z**	**Z**
Final energy consumption	**1 060 037**	**25 609**	**5 247**	**433**	**19**	**394 125**	**239 278**	**102 366**	**3 847**	**Z**	**48 528**	**240 585**
+ Industry	261 037	14 443	5 233	154	19	26 833	82 617	23 042	3 538	Z	16 122	89 035
+ Iron & steel	27 860	3 656	4 976	0	0	610	8 343	7	3	Z	486	9 780
+ Chemical & petrochemical	52 696	3 107	78	3	0	7 267	18 783	316	481	Z	6 859	15 801
+ Non-ferrous metals	10 323	297	34	0	0	309	3 573	2	11	Z	158	5 939
+ Non-metallic minerals	34 184	4 176	81	1	19	5 847	13 310	1 768	2 736	Z	227	6 020
+ Transport equipment	8 697	241	37	0	0	388	2 783	16	0	Z	577	4 655
+ Machinery	19 565	111	13	0	0	994	7 110	100	7	Z	593	10 637
+ Mining & quarrying	3 516	172	12	0	0	880	601	49	2	Z	119	1 681
+ Food, beverages & tobacco	29 948	1 366	1	1	0	1 792	14 198	1 142	7	Z	1 309	10 131
+ Paper, pulp & printing	34 356	869	0	148	0	700	6 835	13 438	140	Z	2 138	10 088
+ Wood & wood products	8 859	43	0	1	0	231	677	5 029	33	Z	584	2 261
+ Construction	7 505	45	0	0	0	3 746	1 772	93	1	Z	40	1 808
+ Textile & leather	4 245	57	0	0	0	218	2 033	21	1	Z	147	1 768
+ Not elsewhere specified (industry)	18 988	303	1	0	0	3 852	2 598	766	118	Z	2 885	8 466
+ Transport	326 872	12	0	0	0	303 031	3 383	14 891	0	Z	Z	5 557
+ Rail	6 532	12	0	0	0	1 932	Z	28	0	Z	Z	4 560
+ Road	306 247	Z	Z	Z	Z	289 576	1 687	14 855	0	Z	Z	129
+ Domestic aviation	6 139	Z	Z	Z	Z	6 139	Z	0	Z	Z	Z	Z
+ Domestic navigation	5 052	0	0	0	0	5 047	Z	4	0	Z	Z	Z
+ Pipeline transport	1 807	Z	Z	Z	Z	9	1 638	0	Z	Z	Z	160
+ Not elsewhere specified (transport)	1 095	0	0	0	0	328	57	3	0	Z	Z	707
+ Other	472 128	11 153	14	279	0	64 261	153 279	64 434	310	Z	32 405	145 994
+ Commercial & public services	154 041	896	3	9	0	16 003	45 206	10 060	303	Z	9 632	71 928
+ Households	287 975	9 201	11	207	0	32 371	103 789	50 500	7	Z	22 443	69 445
+ Agriculture & forestry	24 282	1 012	0	62	0	12 872	3 418	2 390	0	Z	250	4 278
+ Fishing	1 493	0	0	0	0	1 297	1	47	0	Z	0	148
+ Not elsewhere specified (other)	4 338	44	0	0	0	1 718	864	1 437	0	Z	80	194
Statistical differences	**3 607**	**147**	**90**	**-77**	**-8**	**1 440**	**692**	**78**	**2**	**0**	**37**	**1 206**
Gross electricity production	283 260	56 910	2 804	451	852	5 216	57 034	86 467	2 182	71 343	Z	Z
Gross heat production	57 628	13 378	908	722	46	2 342	21 699	15 271	3 108	108	Z	46

Source: figure from EUROSTAT 2023

Figure 2. Sankey diagram of the EU energy balance



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Source: EUROSTAT, 2023

2.2 Data on individual industrial installations

Data on industrial installations are crucial to allocate part of the demand reported in the energy balances and scenarios to specific locations. The main sources of this kind of information are the industrial reporting dataset from the European Industrial Emissions Portal (European Environment Agency, 2023a) and the European Union Transaction Log (EUTL).

The industrial reporting dataset from the European Industrial Emissions Portal (European Environment Agency, 2023a) contains the location and administrative data for the largest industrial complexes in Europe, releases and transfers of regulated substances to all media, transfers of waste, and more detailed data on energy input and emissions for large combustion plants (LCPs). The dataset contains information over 60 000 industrial sites from 65 economic activities across Europe (as defined by Directive 2010/75/EU[6], Regulation (EC) No 166/2006[7] and Commission Implementing Decision 2019/1741[8]), including sectors covered by the energy balances such as energy, production and processing of metals, mineral industry, chemical industry, or paper and wood production and processing. For this work we have used the version released on March 2023.

The European Union Transaction Log (EUTL) (European Commission, 2023b) is the central reporting and monitoring tool of the European Emissions Trading System (EU ETS) (European Commission, 2023a). The EUTL provides detailed information on the compliance of each installation covered by the EU ETS, as defined in the ETS Directive[9]. Since the EUTL has major usability problems (Abrell, 2023a), we used the processed data provided by EUETS.INFO (Abrell, 2023b). The dataset contains details on compliance for each installation included in annex I of the ETS Directive[10]. For this work we have used the version dated May 2022 in order to estimate the energy demand from individual installations in combination with default emission factors for stationary combustion in manufacturing industries and construction (Gómez *et al.*, 2006) and the shares of process vs. combustion emissions derived from the national emission inventories (European Environment Agency, 2023b).

A significant share of the energy used in the EU is consumed by electric utilities or by industrial sites that also have power and heat plants. The JRC-PPDB-OPEN (Kanellopoulos, De Felice, Hidalgo González and Bocin, 2019; Kanellopoulos, De Felice, Hidalgo González, Bocin Dumitriu, *et al.*, 2019) is a EU-wide power plant database at generation unit level based on publicly available information from ENTSO-E (ENTSO-E, 2023) and other open datasets (Global Energy Observatory *et al.*, 2018; Gotzens *et al.*, 2019; European Environment Agency, 2023a; Gupta and Shankar, 2023). The database contains, among others, data on geographical coordinates, installed capacities, unit status, commissioning and decommissioning dates, and fuel type, and it is used whenever possible to complement the information provided by the industrial reporting dataset from the European Industrial Emissions Portal (European Environment Agency, 2023a).

The JRC has prepared a dataset, not yet published, that harmonises and consolidates information about the location and capacity of current and future projects for the production of new energy carriers (e.g. hydrogen, methanol), based on diverse open and commercial sources (Yamaguchi *et al.*, 2020; International Energy Agency, 2021; Pacific Northwest National Laboratory, 2021; Patel, 2021). This dataset is used to break down the energy scenarios.

2.3 Other inputs

The available information on individual industrial installations is not enough to allocate the whole energy balance to specific geographic locations. The part for which there is no geographical information available is distributed to specific 1x1 km cells using a 2-step approach. The first breaks down the national figures to

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6 Directive 2010/75/EU of the European Parliament and of the Council of 24 November 2010 on industrial emissions.

7 Regulation (EC) No 166/2006 of the European Parliament and of the Council of 18 January 2006 concerning the establishment of a European Pollutant Release and Transfer Register and amending Council Directives 91/689/EEC and 96/61/EC.

8 Commission Implementing Decision (EU) 2019/1741 of 23 September 2019 establishing the format and frequency of data to be made available by the Member States for the purposes of reporting under Regulation (EC) No 166/2006 of the European Parliament and of the Council concerning the establishment of a European Pollutant Release and Transfer Register and amending Council Directives 91/689/EEC and 96/61/EC.

9 Directive 2003/87/EC of the European Parliament and of the Council of 13 October 2003 establishing a system for greenhouse gas emission allowance trading within the Union and amending Council Directive 96/61/EC.

10 Including, among others, combustion installations with a rated thermal input above 20 MW, refining of mineral oil, production of coke, metal roasting or sintering, production and processing of ferrous and non-ferrous metals, manufacture of glass and ceramics, production of cement and lime, production of pulp and paper, or production of basic chemical products.

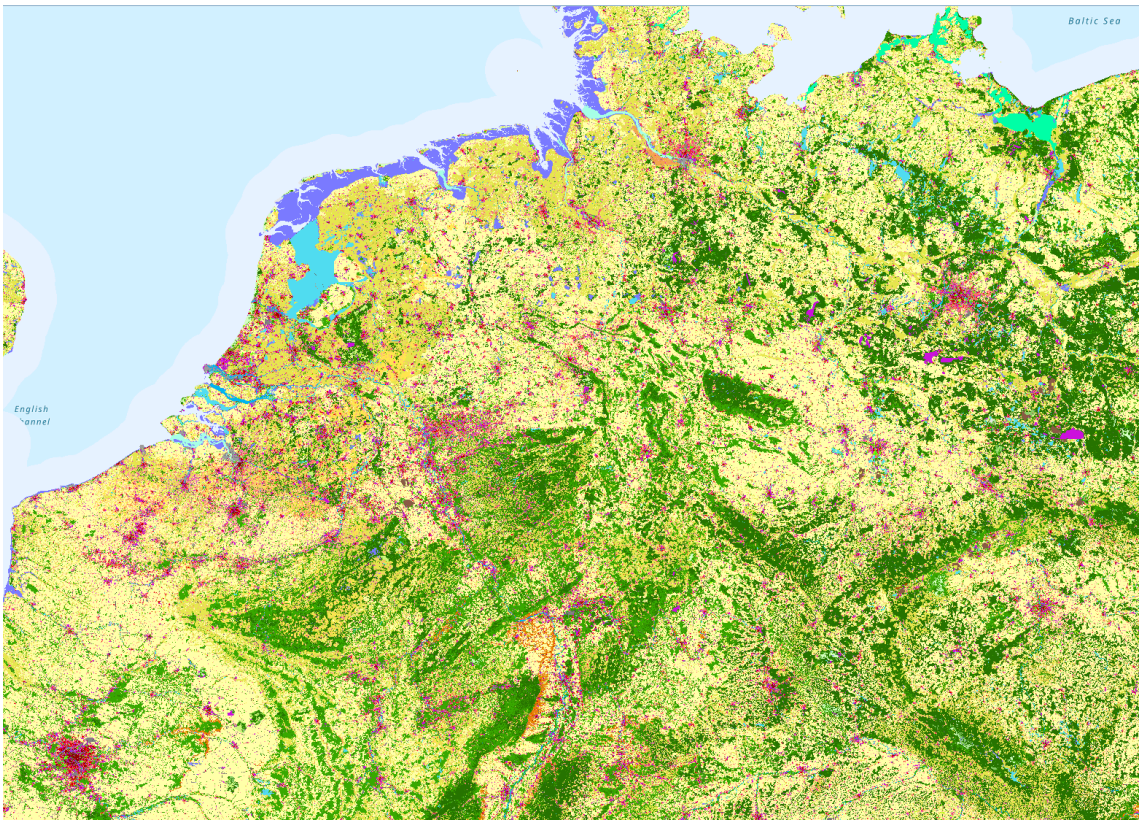
NUTS3 region level, and the second allocates the regional demands to individual grid cells. For the first step different regional datasets from EUROSTAT are used:

- Gross value added per NACE divisions and NUTS3 regions (European Commission - EUROSTAT, 2023c) and employment information from the structural business statistics data by NUTS2 regions and NACE Rev. 2, (European Commission - EUROSTAT, 2023f), to distribute the regional energy demand across economic sectors.
- Population data per NUTS3 region (European Commission - EUROSTAT, 2023e), to allocate the national energy demand from households per region (European Commission - EUROSTAT, 2022, 2023d).
- Heating and cooling degree days (European Commission - EUROSTAT, 2023a) are weather-based technical indexes designed to describe the energy requirements of buildings in terms of heating or cooling. They are used to adjust the energy demand from commercial and public services and households.

The second step (from NUTS3 to 1x1 km cells) distributes the regional energy demands according to the EUROSTAT reference grid. This dataset contains grid cells covering the European land territory, for various resolutions from 1 km to 100 km (European Commission - EUROSTAT, 2023b). Base statistics such as cell coordinates, population figures, land shares, or identifiers of the NUTS regions intersected by the cells are provided.

Since certain activities can only take place at specific locations, the break down from NUTS3 regions to cells take into account land use and land cover data from the JRC's LUISA Territorial Modelling Platform (European Commission - Joint Research Centre, 2023b). The land cover dataset used for the energy balance is the LUISA Base Map 2018 (Batista and Pigaiani, 2021) a high-resolution land use/land cover map that improves the CORINE Land Cover 2018 map providing a higher overall spatial detail and finer thematic breakdown of artificial land use/cover categories (17 instead of 11 in CORINE). In the case of the energy scenarios, possible changes in the land cover are taken into account using projections for 2030, 2040 and 2050 resulting from an update of LUISA reference scenario 2017 (Lavalle *et al.*, 2017) especially run for this project.

Figure 3. Land cover view of the Benelux and parts of France and Germany in 2018



Source: JRC's LUISA, 2018

3 Methodology

The process to break down the national energy demands under the different sections of an energy balance or a scenario consists of the two steps explained in the following sections:

- The first step determines the part of the national energy demand that can be allocated to specific 1x1 km cells, usually large combustion plants used in the transformation and industrial sectors, either because that information is known from the available datasets or because it can be estimated through proxies.
- The second step distributes the remaining national demand (that is, the national energy demand minus the amounts calculated in the first step) among the NUTS3 regions of each country according to regional statistics, and then down to 1x1 km cells according to land cover and population data and projections (in the case of the energy scenarios).

Figure 4 provides a graphical overview of the steps described below. The methodology is applied only to the categories of the energy balances and scenarios corresponding to stationary energy demands (e.g. energy and industrial infrastructure, households) or network-based transportation (road, rail and pipeline transport). Aviation and maritime transport, distribution losses and the statistical differences reported in the energy balances are not taken into account in this methodology since it is not possible to allocate them to individual sectors or geographical locations.

3.1 Energy demand from individual installations

From the available statistics (European Environment Agency, 2023a) the energy demand from individual installations can be known, in particular for large combustion plants used in the transformation and industrial sectors subject to Directive 2010/75/EU on industrial emissions[11].

For many other installations covered by the ETS Directive[12], it is possible to estimate their energy demands combining their CO_2 emission data from the EUTL (Abrell, 2023a) with information about the type of energy products that they consumed (from the energy balances and other datasets available at the EIGL), the default emission factors per energy product (Gómez et al., 2006), and the shares of process vs. combustion emissions derived from the national emission inventories (European Environment Agency, 2023).

The process used to calculate the energy demand from individual installations consists of the following steps:

1. Assign to all the possible installations listed in the EUTL (Abrell, 2023a) the energy demand by product from the industrial emissions portal (European Environment Agency, 2023a).
2. Assign NACE codes and EUROSTAT sectors (as defined in the energy balances) to the installations listed in the EUTL (Abrell, 2023a).
3. Map the installations in the EUTL (Abrell, 2023a) to the power plant dataset (Kanellopoulos, De Felice, Hidalgo González and Bocin, 2019) to determine the specific energy products that they use and their corresponding CO_2 emission mixes.
4. Determine for each country the energy mix at sector level (that is, the percentages of each energy product in the total demand from each sector) using the energy balance or scenario.
5. Determine for each country the CO_2 emission mix at sector level (that is, the percentages of each energy product in the total emissions from each sector) converting the results of step 10 into CO_2 emissions with the IPCC default emission factors (Gómez *et al.*, 2006).
6. Split the CO_2 emission data for each of the installations between emission from processes and emissions from combustion, using the shares derived from the national emission inventories (European Environment Agency, 2023b).
7. Distribute, for each installation, the CO_2 emissions from combustion by energy product using the emission mix from step 3 (if the installation is mapped to a power plant) or from step 5 (if the

[11] Directive 2010/75/EU of the European Parliament and of the Council of 24 November 2010 on industrial emissions.

[12] Directive 2003/87/EC of the European Parliament and of the Council of 13 October 2003 establishing a system for greenhouse gas emission allowance trading within the Union and amending Council Directive 96/61/EC.

installation is not mapped to a power plant then the average emission mix from the corresponding sector, according to the energy balance or the scenario, is used).

8. For each installation, if there is energy consumption data, take the demand of each energy product directly from step 1. If not, estimate the demand of each energy product (except nuclear heat, heat and electricity) from the emissions from fuel combustion calculated in step 7 (dividing the emissions by the corresponding emission factor for each energy product).

9. For all installations except power plants, calculate the demand of nuclear heat, heat and electricity is taking into account that:

$$Total\ energy\ demand = \frac{\sum_{other\ products} Demand_{other\ products}}{\sum_{other\ products} Share_{other\ products}} = \frac{Heat\ demand}{Share\ heat} = \frac{Electricity\ demand}{Share\ electricity}$$

   Where all the shares are known from step 4, and the demand from other energy products has been calculated in step 8.

10. For all installations the energy demands per product are grouped according to the subtotals of the energy balances (see 2.1).

11. For each installation, the energy demands calculated in step 10 are mapped to specific 1x1 km cells (European Commission - EUROSTAT, 2023b). The results are then grouped by cell since more than one installation may be located within the same cell.

12. Finally, for each country the results from step 10 are aggregated by sector to see whether they are lower or equal than the values reported in the energy balances (see annex 2 for a comparison between the aggregation of the estimated energy demand from individual installations and the 2019 energy balances). This is not always the case due to existing inconsistencies such as:

    (a) different reporting of the economic activities across datasets (e.g. autoproducers of electricity and heat that may appear either in the transformation block or in the final consumption block of the balances are reported under other economic activities in other datasets),

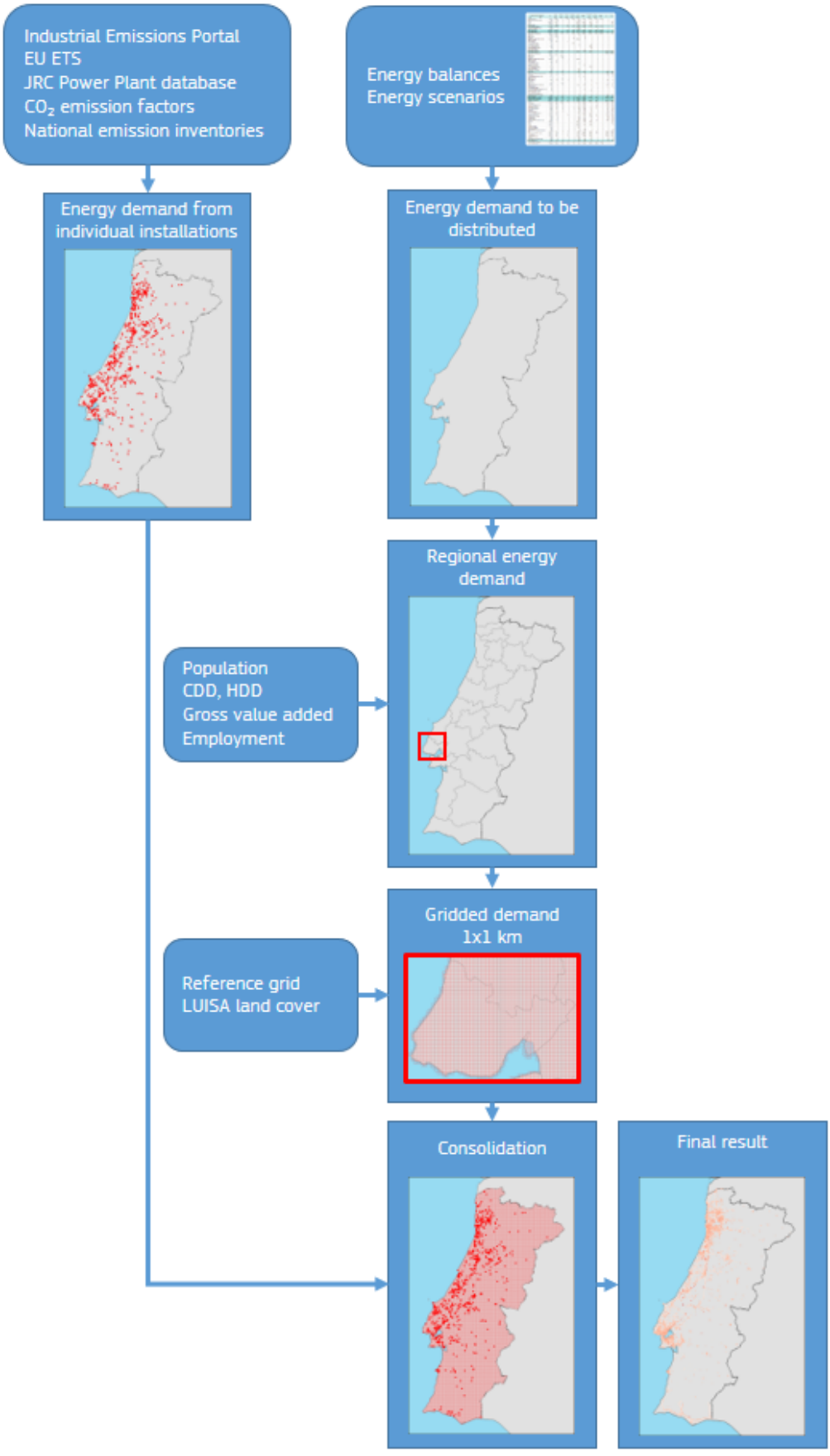
    (b) the existence of some industrial sites that are related to more than one activity (e.g. integrated lead and zinc works that produces sulphuric acid, so part of the energy input is reported under “chemical and petrochemical” in the energy balance, or installations with NACE codes for “transport equipment” wrongly reported under “machinery” in the energy balances),

    (c) differences between the amounts of energy consumed according to the industrial emission portal (European Environment Agency, 2023a) and the energy balances,

    (d) wrong reporting of energy products (e.g. “other recovered gases” as “natural gas”, “natural gas” instead of “oil shale” or “refinery gas”, different types of coal) in the industrial emission portal.

   Note that this final validation is only possible in the case of the energy balances. By design, the disaggregation process has no inconsistencies when applied to an energy scenario.

Figure 4. Graphical overview of the methodology



Source: JRC, 2023

3.2 Distribution of the remaining demand

Once the energy demand from individual installations is known, the remaining demand (that is, the national energy demand reported in the energy balances minus the amounts calculated according to the steps defined in section 3.1) has to be distributed among the 1x1 km cells of each country. This is done in two parts:

1. First the national values are broken down by NUTS3 region according to certain sector-specific hypotheses and regional datasets from EUROSTAT.
2. Then the regional energy demands are distributed among the 1x1 km cells conforming each NUTS3 region, taking into account the population present in each cell and assuming that certain activities may take place only in certain areas (e.g. energy demand from households is only possible in urban areas).

3.2.1 From national level to NUTS3

The process used to break down the national energy demand values consists of the following steps:

1. For all the sectors within each country, the energy demands are distributed to the regional level according to the gross value added of the corresponding activity in the different regions. To that purpose it is necessary to calculate the share of each NUTS3 region in each of the national energy demands to be distributed. These shares are calculated in various steps using data on gross value added per NACE divisions and NUTS3 regions (European Commission - EUROSTAT, 2023):
   (a) Relate the categories used in the energy balances to the NACE divisions through these equivalences:
      i. "Mining": NACE divisions B-E minus F.
      ii. "Industry": NACE division C.
      iii. "Construction": NACE division F.
      iv. "Commercial and public services": NACE divisions G-J, K-N, and O-U.
      v. "Agriculture and forestry": NACE division A.
      vi. "Households", "Fishing" and "Not elsewhere specified (other)" are set equal to 0.
   (b) Calculate for each sector the shares of each NUTS3 region in the national gross value added.
   (c) Calculate for each NUTS3 region the share of employment for all the industries considered in the energy balance, based on the structural business statistics data by NUTS2 regions and NACE Rev. 2 (European Commission - EUROSTAT, 2023f).
   (d) Calculate the gross value added for each combination NUTS3-industry as the product of the values for "industry" from step (a) by the employment shares from (c).
   (e) Group the results from (d) by NUTS3 and calculate the shares per NUTS3 and industrial sector.
2. Calculate the energy demand (for non-energy and energy uses) per NUTS3 region and sector (row of the energy balance) as the product of the total national energy demands per sector and the corresponding shares from step 1(e) assuming that:
   (a) The average share for the industry from step 1(b) applies to the transformation input and energy sector.
   (b) The average share for "commercial and public services" from step 1(b) applies to the transport sector and other activities not elsewhere considered.
   (c) The demand from households is distributed among NUTS3 regions according to their populations (European Commission - EUROSTAT, 2023e), corrected by deviations of the heating and cooling degree days (European Commission - EUROSTAT, 2023a) with respect to the national averages

3.2.2 From NUTS3 to 1x1 km cells

The demand of gas within each NUTS3 region is then allocated to individual 1x1 km cells according to the population density and land cover data and projections. This process is done according to:

1. Merge the EUROSTAT reference grid (European Commission - EUROSTAT, 2023b) with the LUISA land cover data and projections (Batista and Pigaiani, 2021; European Commission - Joint Research Centre, 2023b).
2. Calculate for each 1x1 km cell its shares of land use and population in each of the intersecting NUTS3 regions, using the following assumptions:
    (a) Transformation input takes place only in industrial and commercial sites.
    (b) Non-energy uses are possible in residential areas (weighted by the population) and industrial and commercial sites.
    (c) Final consumption in industry occurs in industrial and commercial sites.
    (d) Final consumption in transport takes place in residential areas (weighted by the population) and across transport infrastructures.
    (e) Final consumption for other uses is distributed across residential (weighted by the population), agriculture and permanent crop areas
    (f) Other land cover classes (urban green areas, forests, other vegetated of natural areas, wetlands and water bodies) are excluded from the distribution.

    The shares differ in time, according to the land cover projections.
3. Calculate the energy demand per sector for each 1x1 km cell as the product of the regional energy demand and the shares calculated in step 2.
4. Add to each cell the energy demand from individual installations grouped by cells calculated in step 11 of section 3.1

4 Results

This section shows the results of applying the methodology to the energy balance of natural gas in Portugal in 2019, the year with most recent data from Eurostat[13] . In that year, total energy supply of natural gas in Portugal amounted to 5302.7 ktoe[14]. according to EUROSTAT's energy balances That amount included the use of natural gas for energy transformation (including power generation), support operations of the energy sector itself, transmission and distribution losses, final energy consumption (industry, transport, households, services, agriculture, …) and the use or non-energy purposes (e.g. in the chemical industry)[15]. As described in previous sections, some minor items such as distribution losses, or statistical differences, are ignored since they cannot be allocated to specific sections of the energy balance. In 2019 natural gas was used as follows (see a graphical representation of the natural gas balance in Figure 5).

1. Input for transformation in power and CHP plants (3375.9 ktoe):
   (a) Power plants: Main activity producer electricity only (1886.4 ktoe)
   (b) Industrial and commercial autoproduction of power and heat: Autoproducer electricity only (5.5 ktoe) and autoproducer CHP (1261.7 ktoe)
   (c) Not elsewhere specified: uncategorised consumption (222.3 ktoe)
2. Own use in the energy sector:
   (a) Petroleum refineries (oil refineries) (94.7 ktoe)
3. Distribution losses (6.3 ktoe)
4. Use as fuel by final consumers (1825.8 ktoe) ([16]):
   (a) Industry (1258.1 ktoe):
      i. Iron and steel (50.0)
      ii. Chemical and petrochemical (175.8 ktoe)
      iii. Non-ferrous metals (16.0 ktoe)
      iv. Non-metallic minerals (456.2 ktoe)
      v. Transport equipment (25.4 ktoe)
      vi. Machinery (35.5 ktoe)
      vii. Mining and quarrying (2.6 ktoe)
      viii. Food, beverages & tobacco (161.8 ktoe)
      ix. Paper, pulp & printing (157.8 ktoe)
      x. Wood and wood products (9.3 ktoe)
      xi. Construction (14.0 ktoe)
      xii. Textile and leather (141.4 ktoe)
      xiii. Not elsewhere specified (industry) (12.1 ktoe)
   (b) Transport (17.5 ktoe)
   (c) Other sectors (539.3 ktoe) ([17])
      i. Commercial and public services (247.5 ktoe)
      ii. Households (285.3 ktoe)
      iii. Agriculture and forestry (6.5 ktoe)
5. Statistical differences (10.9 ktoe)

According to the industrial emissions portal (European Environment Agency, 2023a), the large combustion plants, for which the precise geographical location is known (31 points), consumed 2513.8 ktoe in 2018[18],

[13] 2021 is the most recent year with available annual energy data (annual energy statistics are published two years after the reporting period) but that year energy consumption was still affected by the consequences of the COVID pandemic
[14] Thousand tonnes of oil equivalent.
[15] In the case of other energy carriers this also excludes international aviation and maritime bunkers (which do not use natural gas)
[16] This also includes the use of natural gas as feedstock, mainly in the chemical industry, but this is 0 ktoe in the case of Portugal.
[17] This item includes fishing as well, but it is 0 ktoe in the case of Portugal.
[18] 2018 is the latest available year in this dataset.

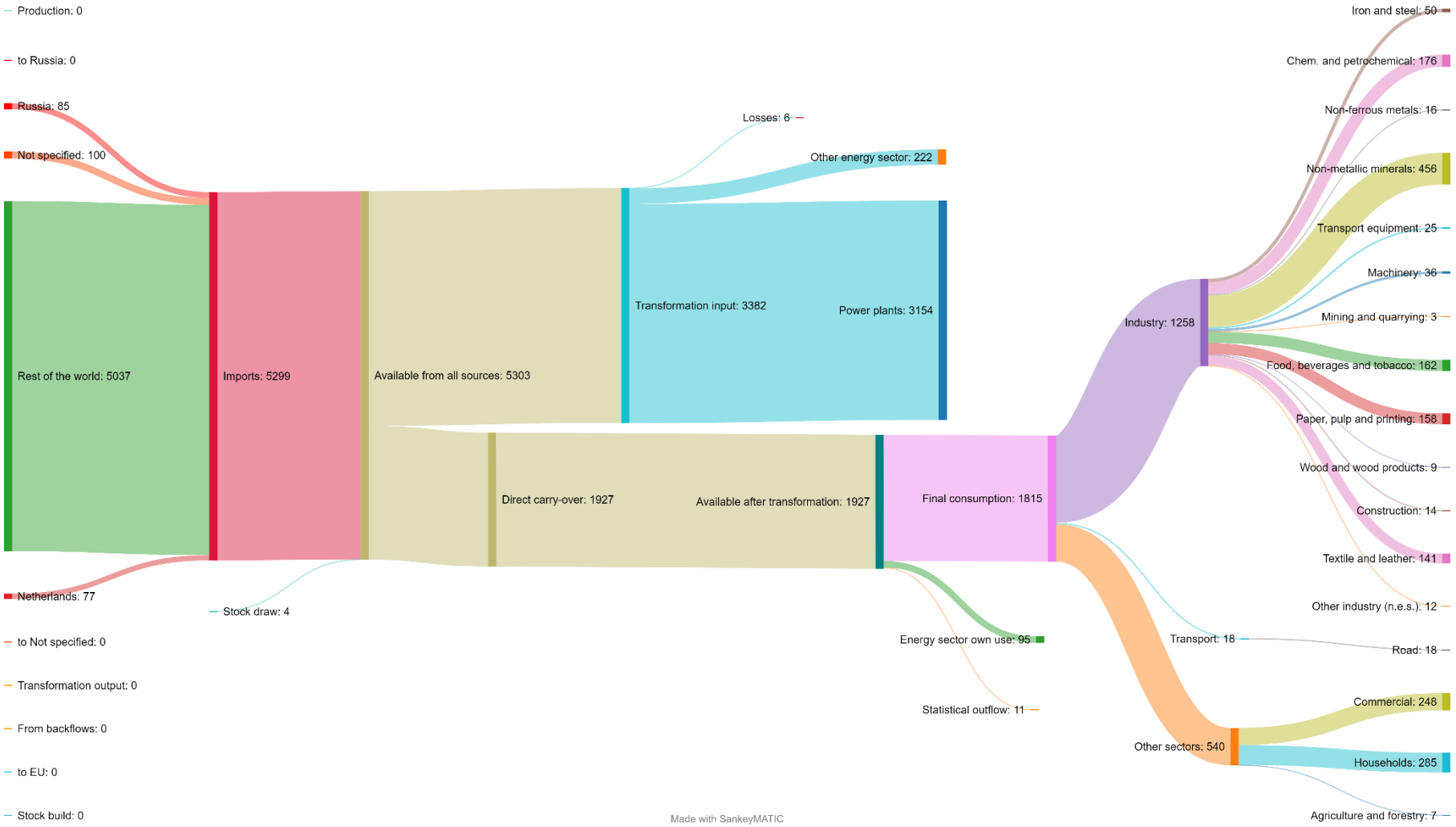
detailed in Table 3, which represents approximately half of the gas demand in 2019. The geographical location of the remaining consumption amounts to 2766.1 ktoe. Table 4 shows the distribution of the national gas demand across NUTS3 regions.

Table 2. Elements of the energy balance in Portugal to be broken down (natural gas, 2019, ktoe)

Energy balance heading		Of which	Total	Geographically located (large combustion plants)	Remainder
Transformation input		Main activity producer electricity only	1886.4	1608.5	277.8
		Autoproducer electricity only	5.5	0	5.5
		Autoproducer CHP	1261.7	611.3	650.4
		Not elsewhere specified	222.3	0	0.0
Energy sector		Petroleum refineries (oil refineries)	94.7	224.8	92.2
Final non-energy consumption			0	0	0
Final energy consumption	Industry	Iron & steel	1258.1	69.2	1189.0
		Chemical & petrochemical	50.0	0	50.0
		Non-ferrous metals	175.8	0	175.8
		Non-metallic minerals	16.0	0	16.0
		Transport equipment	456.2	0	456.2
		Machinery	25.4	0	25.4
		Mining & quarrying	35.5	0	35.5
		Food, beverages & tobacco	2.6	0	2.6
		Paper, pulp & printing	161.8	0	161.8
		Wood & wood products	157.8	0	157.8
		Construction	9.3	0	9.3
		Textile & leather	14.0	0	14.0
		Not elsewhere specified (industry)	141.4	0	141.4
	Transport	Road	17.5	0	17.5
	Other sectors	Commercial & public services	247.5	0	247.5
		Households	285.3	0	285.3
		Agriculture & forestry	6.5	0	6.5
		Fishing	0.0	0	0.0
		Not elsewhere specified (other)	0.0	0	0.0
TOTAL			5285.4	2513.8	2771.6

Source: JRC, based on EUROSTAT data, 2022

Figure 5. Sankey diagram of the energy balance of PT, natural gas, 2019 (ktoe)



Source: JRC, based on EUROSTAT data, 2022

Table 3. Demand of natural gas from large combustion plants in Portugal (2018, ktoe)

Category	Site name *	Latitude	Longitude	Gas consumption 2018 (ktoe)
Production of electricity	Sítio - Celbi	40.052	-8.87674	0.1
	Sítio - Central de Ciclo Combinado da Tapada do Outeiro	41.0630696	-8.4615053	240.6
	Sítio - Central de Ciclo Combinado da Tapada do Outeiro	41.069958	-8.458923	212.1
	Sítio - Central de Ciclo Combinado da Tapada do Outeiro	41.070338	-8.459226	187.3
	Sítio - Central Termoeléctrica de Lares	40.12412	-8.7743	115.4
	Sítio - Central Termoeléctrica de Lares	40.1242	-8.77444	168.0
	Sítio - Central Termoeléctrica do Pego	39.466	-8.11198	0.5
	Sítio - Central Termoeléctrica do Pego	39.46706	-8.11129	186.1
	Sítio - Central Termoeléctrica do Pego	39.46806	-8.11119	130.1
	Sítio - Central Termoeléctrica do Ribatejo	39.0115	-8.95025	102.4
	Sítio - Central Termoeléctrica do Ribatejo	39.0118	-8.95035	165.5
	Sítio - Central Termoeléctrica do Ribatejo	39.0121	-8.95045	100.3
Refining/Chemicals	Sítio - Petrogal-Refinaria do Porto	41.2031	-8.71459	102.0
	Sítio - Petrogal-Refinaria do Porto	41.2034	-8.71559	101.7
	Sítio - Refinaria de Sines	37.96105	-8.80085	21.1
Autoproducer CHP	Sítio - Indorama Ventures Portugal PTA (Fábrica de PTA)	37.9802	-8.82033	3.6
	Sítio - Indorama Ventures Portugal PTA (Fábrica de PTA)	37.9804	-8.82023	43.9
	Sítio - Kraft Viana	41.700008	-8.711935	58.7
	Sítio - Kraft Viana	41.7037	-8.7124	60.2
	Sítio - Navigator Figueira	40.058772	-8.857196	39.8
	Sítio - Navigator Figueira	40.058972	-8.857296	32.9
	Sítio - Navigator Setúbal	38.4937	-8.80599	119.5
	Sítio - Refinaria de Sines	37.96342	-8.80024	5.7
	Sítio - Refinaria de Sines	37.9639	-8.80064	104.9
	Sítio - Refinaria de Sines	37.96392	-8.80054	103.2
	SITIO-SGL Composites	38.6781	-9.0504	38.9
Industry	Sítio - Celbi	40.051916	-8.875081	1.5
	Sítio - CELTEJO	39.66152	-7.671087	6.1
	Sítio - Navigator Aveiro	40.68293	-8.586243	6.9
	Sítio - Navigator Figueira	40.058793	-8.856643	31.4
	Sítio - Repsol Polimeros , Lda.	37.984	-8.83216	23.4

* Repeated rows refer to different installations or parts of installations located at the same site

Source: JRC, based on (European Environment Agency, 2023a)

Table 4. Natural gas demand in Portugal by NUTS3 region and energy balance heading (2019, ktoe)

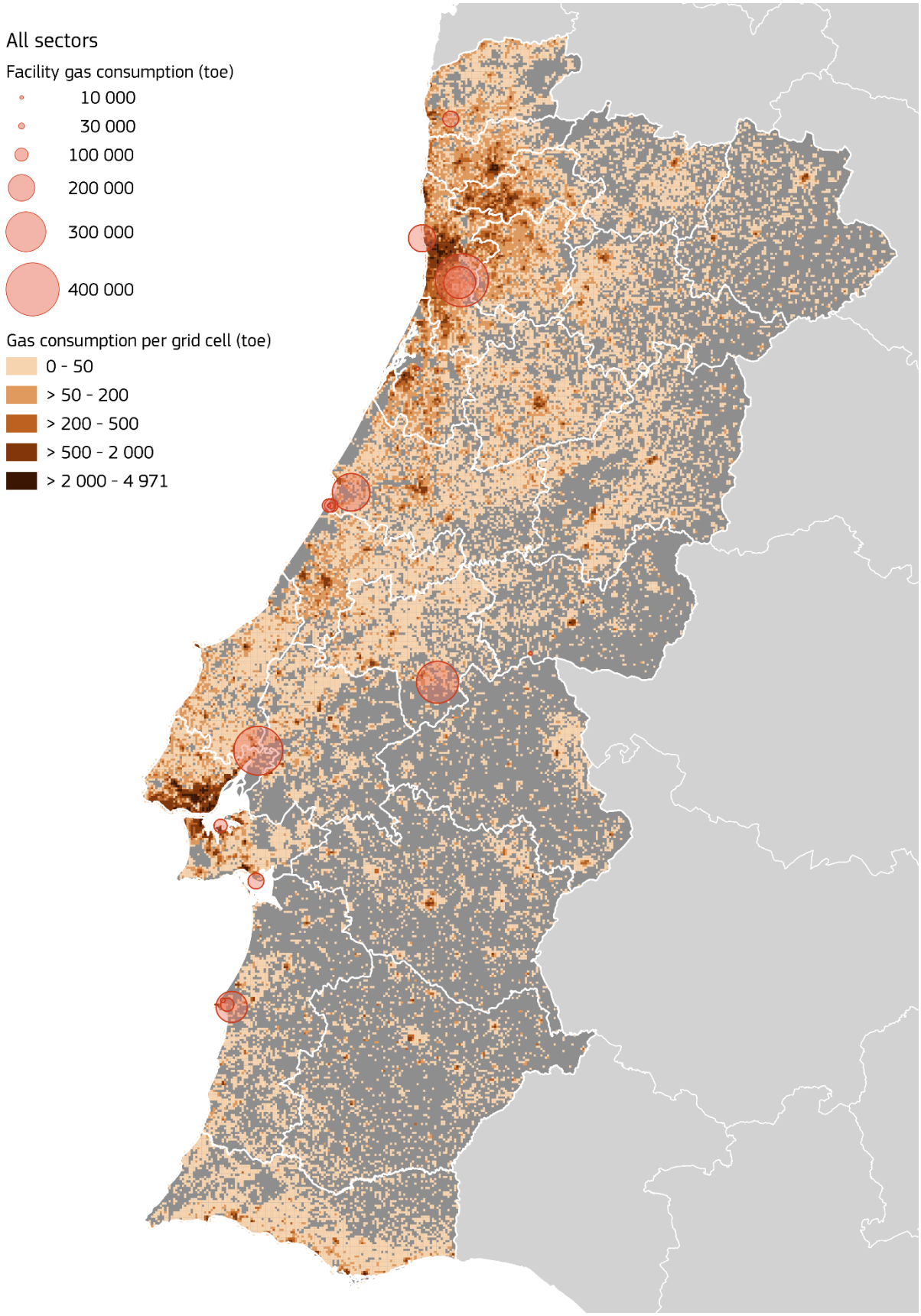
NUTS2	NUTS2 name	NUTS3	NUTS3 name	Industry	Commercial & public services	Agriculture & forestry & fishing	Not elsewhere specified (other)	Households	Transport	Transformation input (power, CHP, ref.)
PT11	Norte	PT111	Alto Minho	34.1	3.5	0.1	0.0	9.2	0.2	29.4
PT11	Norte	PT112	Cávado	65.0	7.0	0.1	0.0	14.8	0.5	56.1
PT11	Norte	PT119	Ave	84.7	5.6	0.1	0.0	17.6	0.4	73.1
PT11	Norte	PT11A	Área Metropolitana do Porto	223.1	38.7	0.3	0.0	58.7	2.7	192.5
PT11	Norte	PT11B	Alto Tâmega	8.2	1.2	0.1	0.0	5.1	0.1	7.1
PT11	Norte	PT11C	Tâmega e Sousa	55.8	4.6	0.1	0.0	15.7	0.3	48.2
PT11	Norte	PT11D	Douro	18.5	3.0	0.3	0.0	8.5	0.2	15.9
PT11	Norte	PT11E	Terras de Trás-os-Montes	11.0	1.7	0.2	0.0	5.8	0.1	9.5
PT15	Algarve	PT150	Algarve	26.2	13.4	0.5	0.0	8.5	0.9	22.6
PT16	Centro (PT)	PT16B	Oeste	39.1	6.4	0.5	0.0	6.5	0.5	33.7
PT16	Centro (PT)	PT16D	Região de Aveiro	72.8	6.6	0.2	0.0	12.3	0.5	62.8
PT16	Centro (PT)	PT16E	Região de Coimbra	53.7	9.0	0.3	0.0	13.1	0.6	46.3
PT16	Centro (PT)	PT16F	Região de Leiria	53.4	5.5	0.2	0.0	7.5	0.4	46.1
PT16	Centro (PT)	PT16G	Viseu Dão Lafões	28.7	4.2	0.2	0.0	10.1	0.3	24.8
PT16	Centro (PT)	PT16H	Beira Baixa	11.1	1.5	0.1	0.0	2.5	0.1	9.6
PT16	Centro (PT)	PT16I	Médio Tejo	26.6	4.0	0.2	0.0	5.8	0.3	22.9
PT16	Centro (PT)	PT16J	Beiras e Serra da Estrela	18.5	3.4	0.2	0.0	9.5	0.2	16.0
PT17	Área Metropolitana de Lisboa	PT170	Área Metropolitana de Lisboa	249.2	102.7	0.4	0.0	57.6	7.3	215.0
PT18	Alentejo	PT181	Alentejo Litoral	16.7	2.1	0.4	0.0	1.9	0.1	14.4
PT18	Alentejo	PT184	Baixo Alentejo	17.2	2.0	0.4	0.0	2.9	0.1	14.8
PT18	Alentejo	PT185	Lezíria do Tejo	24.9	4.2	0.6	0.0	4.4	0.3	21.5
PT18	Alentejo	PT186	Alto Alentejo	8.4	1.8	0.2	0.0	3.0	0.1	7.2
PT18	Alentejo	PT187	Alentejo Central	13.6	3.1	0.3	0.0	4.2	0.2	11.7
PT20	Região Autónoma dos Açores	PT200	Região Autónoma dos Açores	12.7	5.5	0.5	0.0	0.0	0.4	11.0
PT30	Região Autónoma da Madeira	PT300	Região Autónoma da Madeira	15.7	6.8	0.1	0.0	0.0	0.5	13.6

Source: JRC, 2022

The results consist of seven gridded maps of Portugal showing an estimation of the natural gas demand in each 1x1 km cell for the main headings of EUROSTAT's 2019 energy balance: overall consumption for all purposes (Figure 6), demand for transformation input (Figure 7, use in power and heating plants, and refineries), and final consumption by the industry (Figure 8), transport (Figure 9), commercial and public services (Figure 10), households (Figure 11), and agriculture, forestry and fishing (Figure 12).

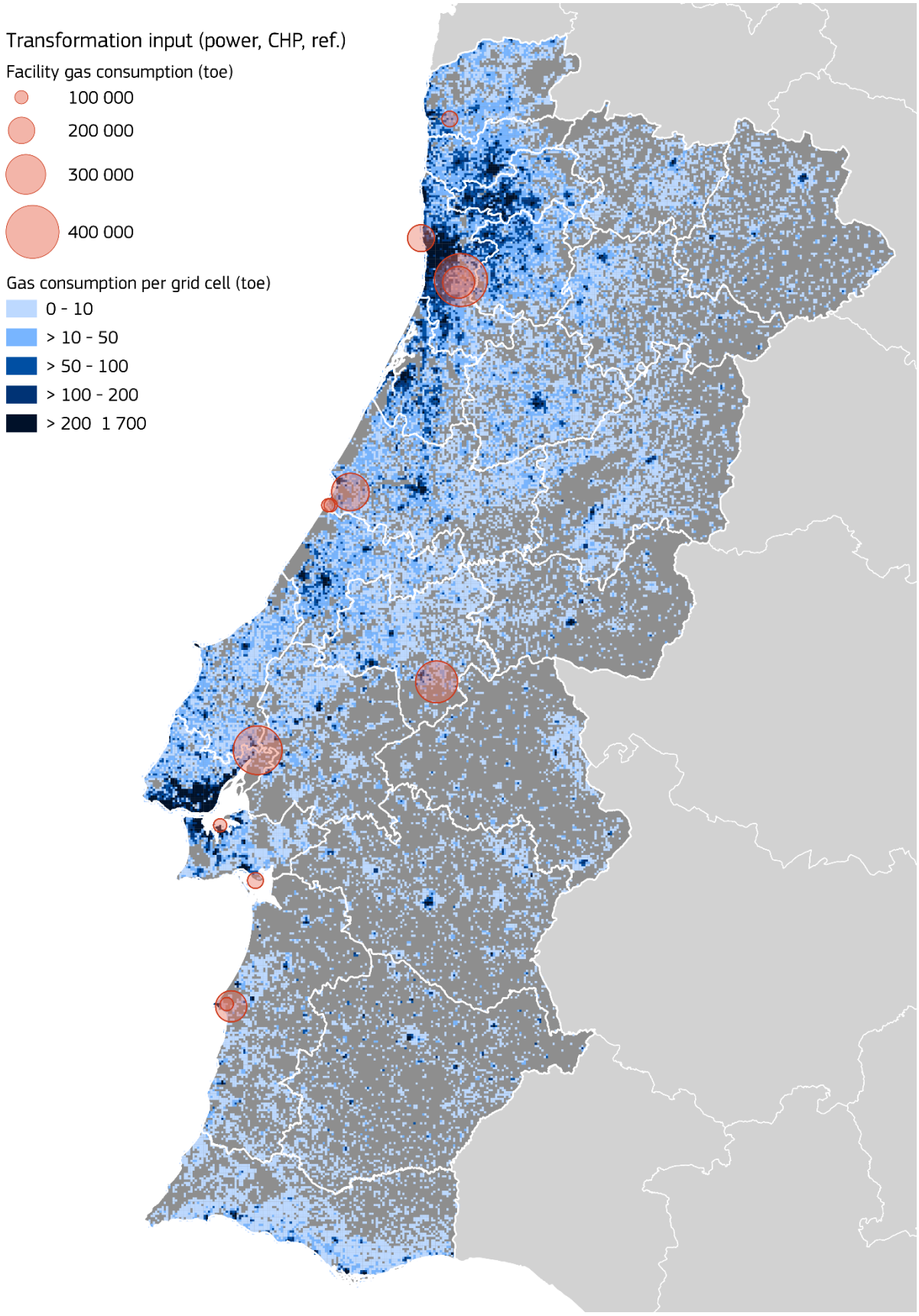
The gas demand per cell is colour-coded in different shades of orange (overall consumption) or blue (rest of the results) split into consumption bands (e.g. 0-10 toe, >10-50 toe, >50-100 toe, >100-200 toe, >200 toe), except in the cases where the location of the consumption sites is known (large combustion plants: power and heating plants and some industrial sites), which are represented by red circles. Industrial sites at the same locations were aggregated.

Figure 6. Natural gas consumption of PT in 2019 per 1x1 km, all sectors (toe)



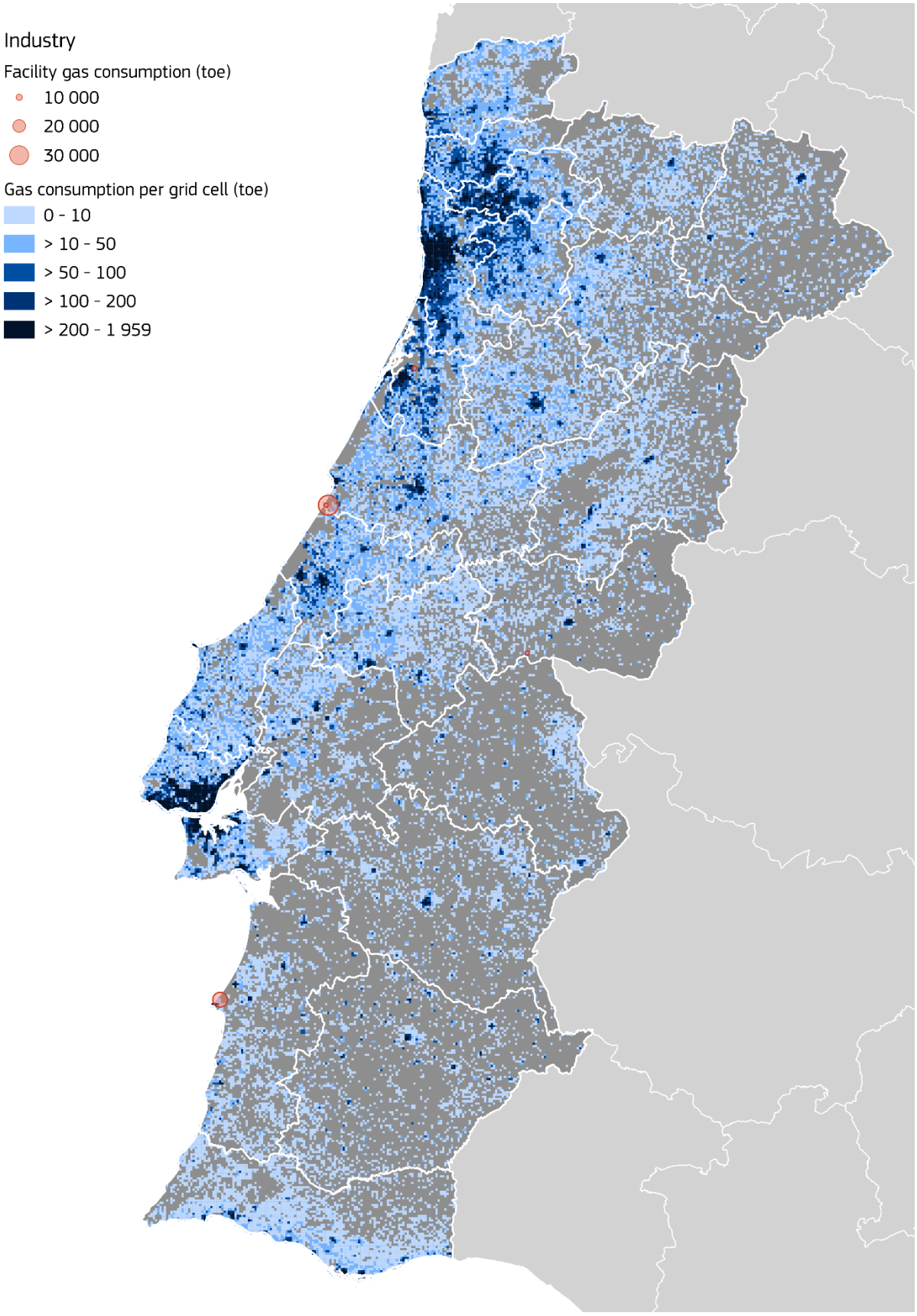
Source: JRC 2023, EUROSTAT, Eurogeographics

Figure 7. Natural gas consumption for transformation input in PT in 2019 per 1x1 km (toe)



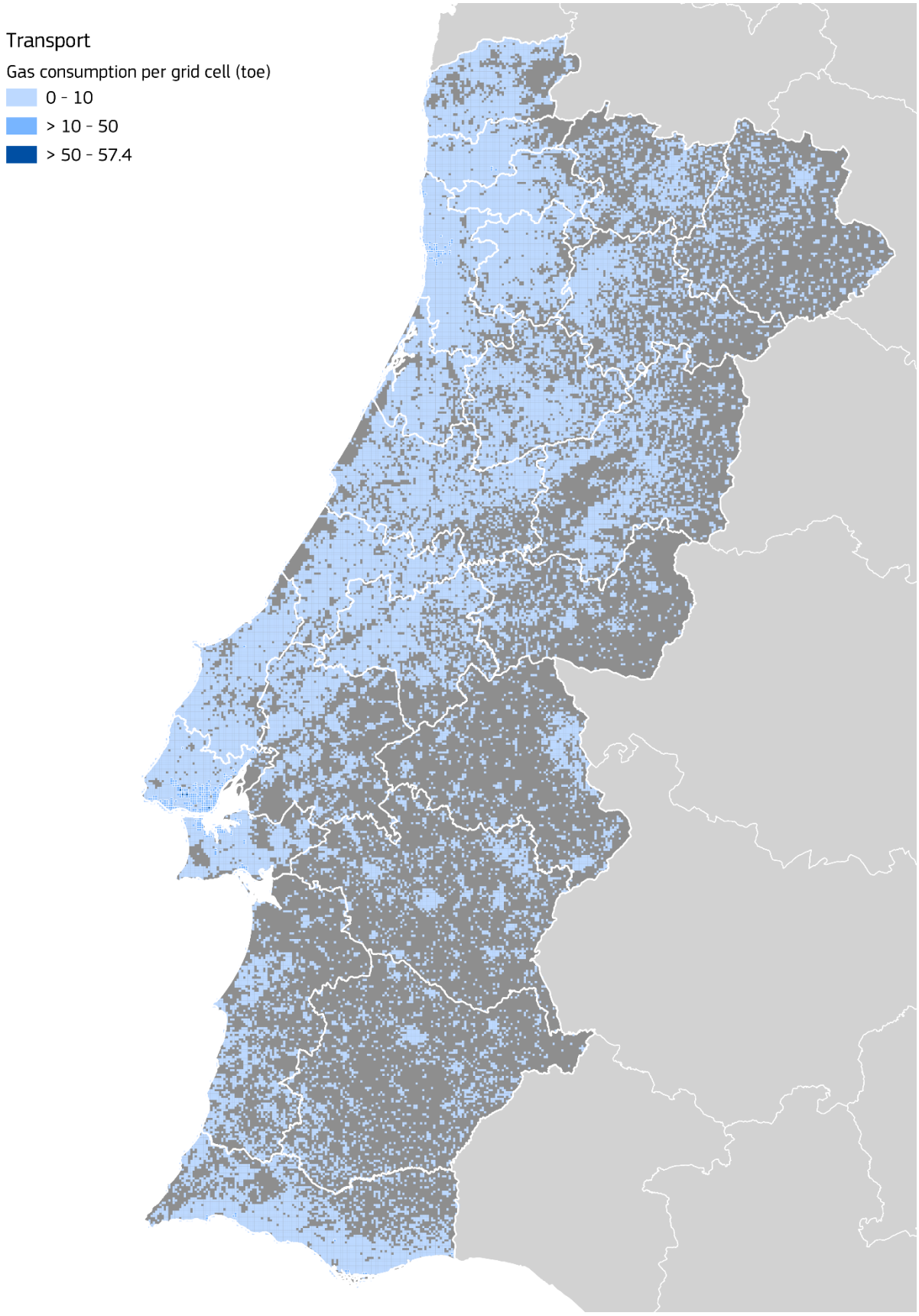
Source: JRC 2023, EUROSTAT, Eurogeographics

Figure 8. Natural gas consumption for industry in PT in 2019 per 1x1 km (toe)



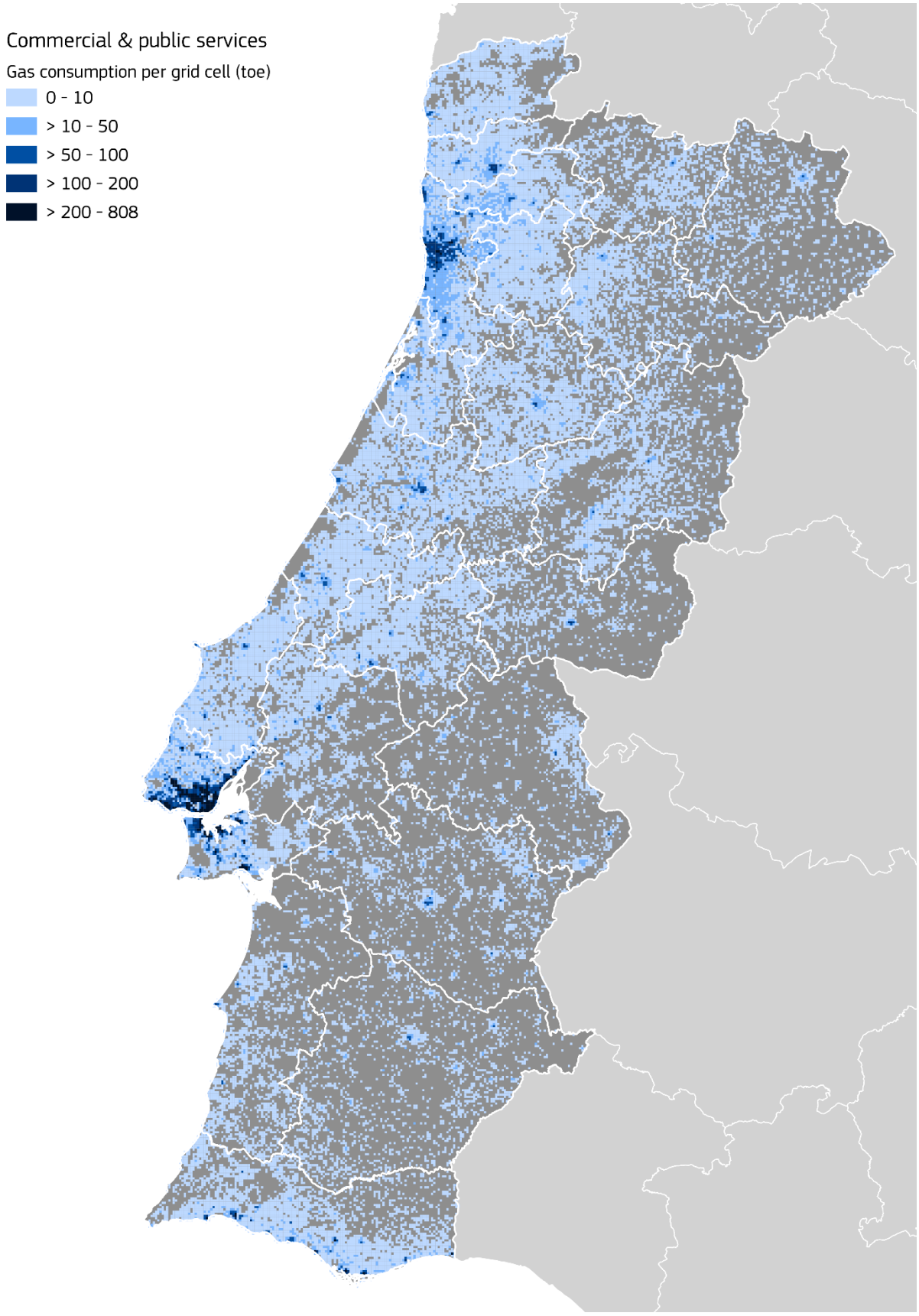
Source: JRC 2023, EUROSTAT, Eurogeographics

Figure 9. Natural gas consumption for transport in PT in 2019 per 1x1 km (toe)



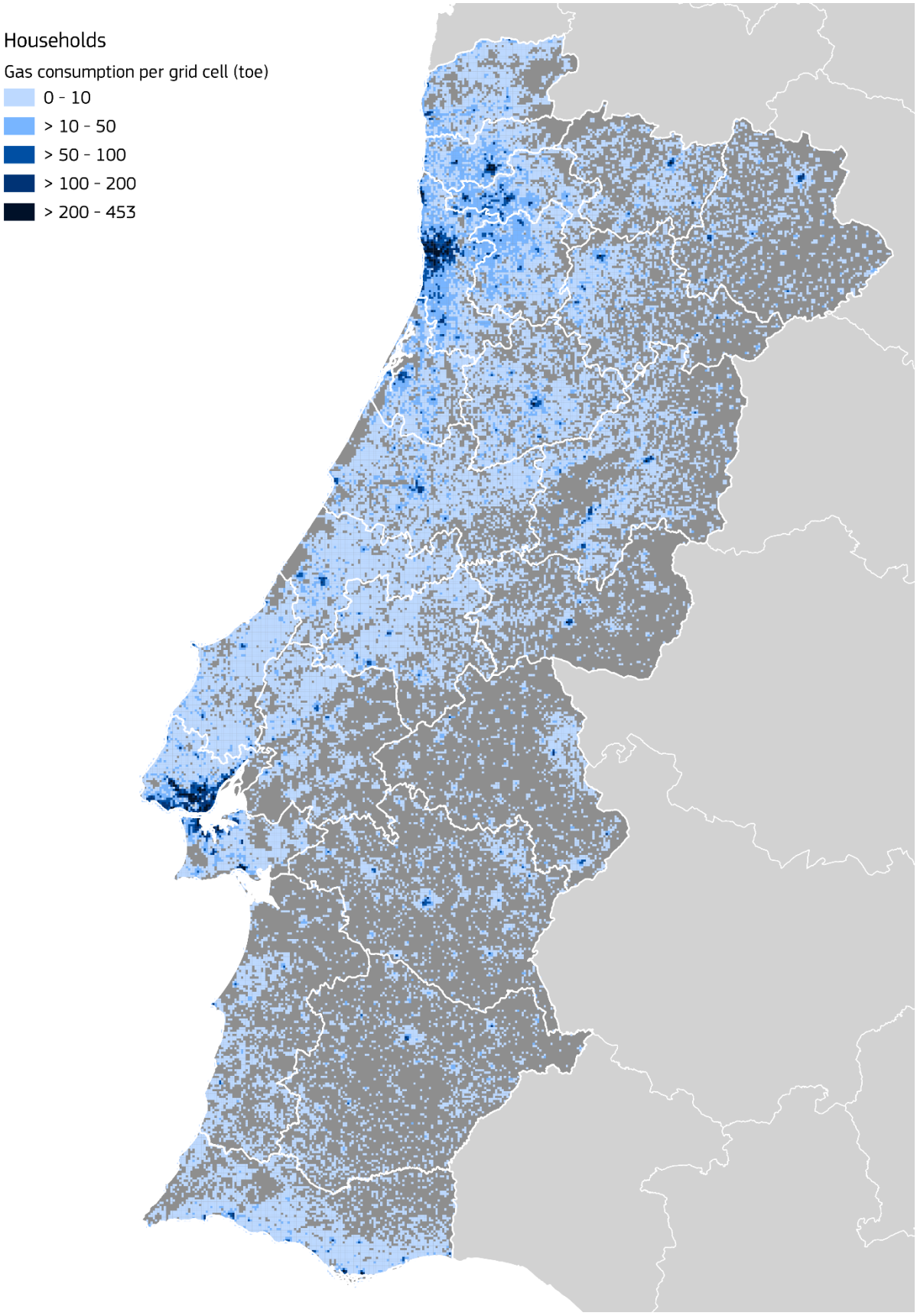
Source: JRC 2023, EUROSTAT, Eurogeographics

Figure 10. Natural gas consumption for commercial and public services in PT in 2019 per 1x1 km (toe)



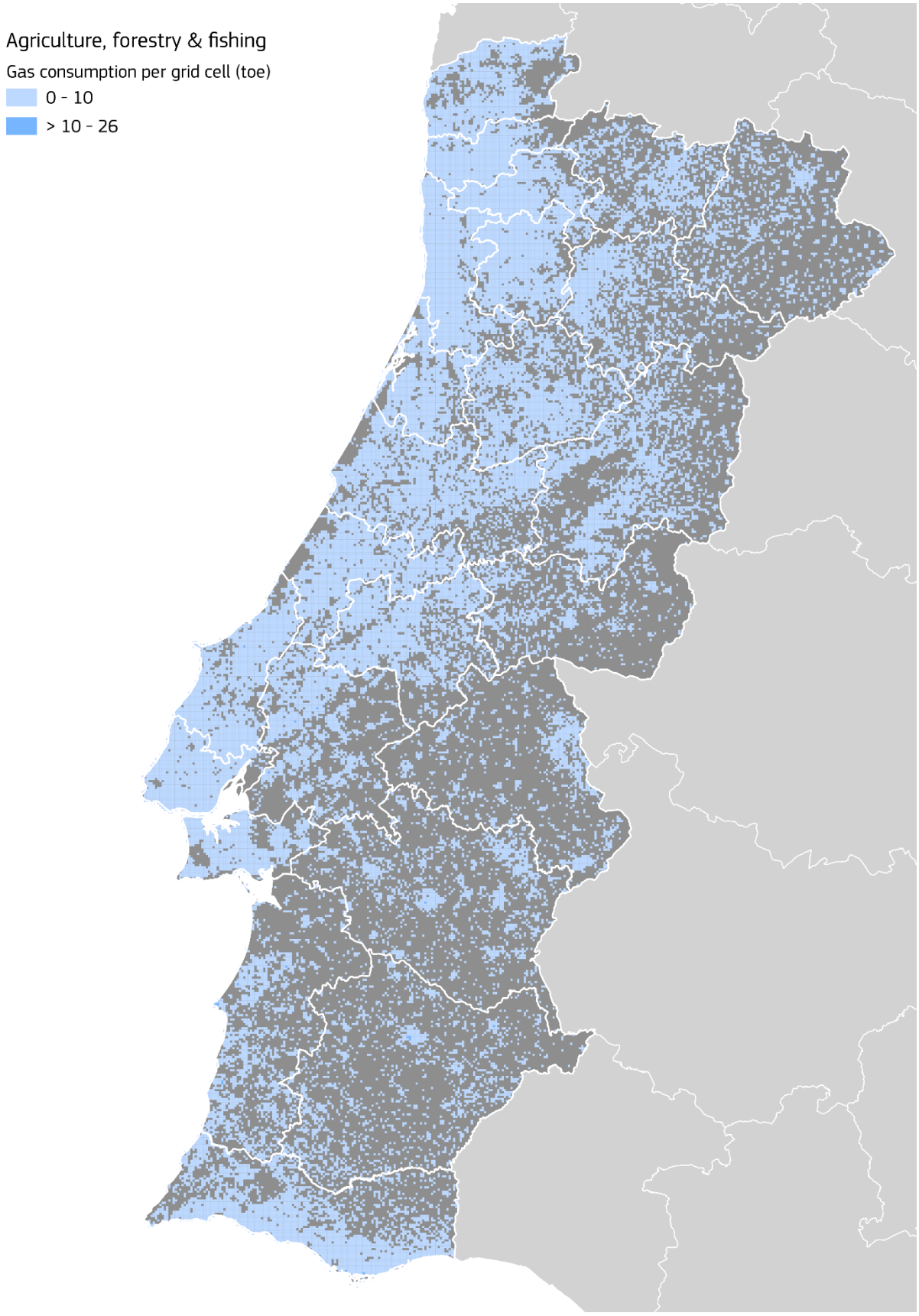
Source: JRC 2023, EUROSTAT, Eurogeographics

Figure 11. Natural gas consumption for households in PT in 2019 per 1x1 km (toe)



Source: JRC 2023, EUROSTAT, Eurogeographics

Figure 12. Natural gas consumption for agriculture, forestry and fishing in PT in 2019 per 1x1 km (toe)



Source: JRC 2023, EUROSTAT, Eurogeographics

5 Conclusions

The methodology presented in this report enables the production of a high-resolution atlas of energy demand across the EU, the first of its kind, at an unprecedented level of detail. There are several possible ways of improving this result, such as:

- Increasing the number of points where a proportion of the national energy demand can be located, but that depends on the availability of real data (that is, the coverage of the industrial emissions portal and the number of installations subject to the ETS).
- Using more detailed regional statistics to improve the distribution of the unallocated energy demand to NUTS3 regions.
- Refining the land-cover data by expanding the number of land-cover types, using higher resolution datasets (e.g. 100 m x 100 m), or using cadastre-level data.
- Developing a breakdown at sub-annual levels in order to take into account seasonal energy consumption patterns.
- Developing similar breakdowns for the supply of energy products.
- Expanding the atlas to non-EU neighbouring countries (e.g. UK, NO, CH, Wester Balkans) which are already connected and integrated into the European energy system.

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List of abbreviations and definitions

AT	Austria
BE	Belgium
BG	Bulgaria
CDD	Cooling degree days
CORINE	Coordination of information on the environment
CY	Cyprus
CZ	Czechia
DE	Germany
DK	Denmark
EE	Estonia
EIGL	Energy and Industry Geography Lab
EL	Greece
ENER	Directorate-General for Energy
ENTSO-E	European Network of Transmission System Operators for Electricity
ES	Spain
EU ETS	European Union Emission Trading System
EUROSTAT	Directorate-General Statistical Authority of the European Union
EUTL	European Union Transaction Log
FI	Finland
FR	France
HDD	Heating degree days
HR	Croatia
HU	Hungary
IE	Ireland
IEA	International Energy Agency
IT	Italy
LCP	Large combustion plants
LT	Lithuania
LU	Luxembourg
LUISA	Land Use-based Integrated Sustainability Assessment
LV	Latvia
MT	Malta
NACE	Nomenclature Statistique Des Activités Économiques Dans La Communauté Européenne
NL	Netherlands
NUTS	Nomenclature of territorial units for statistics
PL	Poland
PT	Portugal
RO	Romania

SE	Sweden
SI	Slovenia
SIEC	Standard International Energy Product Classification
SK	Slovakia
toe	Tonne of oil equivalent

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Annexes

Annex 1. Definition of the final consumers used in the energy balance

Table 5. NACE codes of the processes included in the energy balances

Industry	Description
Energy sector	NACE Rev. 2 Divisions 05, 06, 19 and 35, NACE Rev. 2 Group 09.1 and NACE Rev. 2 classes 07.21 and 08.92
Iron and steel	NACE Rev. 2 Groups 24.1, 24.2 and 24.3; and NACE Rev. 2 Classes 24.51 and 24.52 C241: Manufacture of basic iron and steel and of ferroalloys C242: Manufacture of tubes, pipes, hollow profiles and related fittings, of steel C2451: Casting of iron C2452: Casting of steel
Chemical and petrochemical	NACE Rev. 2 Divisions 20 and 21 C201: Manufacture of basic chemicals, fertilisers and nitrogen compounds, plastics, and synthetic rubber in primary forms C202: Manufacture of pesticides and other agrochemical products C203: Manufacture of paints, varnishes and similar coatings, printing ink and mastics C204: Manufacture of soap and detergents, cleaning and polishing preparations, perfumes and toilet preparations C205: Manufacture of other chemical products C206: Manufacture of man-made fibres C21: Manufacture of basic pharmaceutical products and pharmaceutical preparations
Non-ferrous metals	NACE Rev. 2 Group 24.4; and NACE Rev. 2 Classes 24.53 and 24.54 C244: Manufacture of basic precious and other non-ferrous metals C2453: Casting of light metals C2454: Casting of other non-ferrous metals
Non-metallic minerals	NACE Rev. 2 Division 23 C231: Manufacture of glass and glass products C232: Manufacture of refractory products C233: Manufacture of clay building materials C234: Manufacture of other porcelain and ceramic products C235: Manufacture of cement, lime, and plaster C236: Manufacture of articles of concrete, cement, and plaster C237: Cutting, shaping, and finishing of stone C239: Manufacture of abrasive products and non-metallic mineral products n.e.c.
Transport equipment	NACE Rev. 2 Divisions 29 and 30 C29: Manufacture of motor vehicles, trailers, and semi-trailers C30: Manufacture of other transport equipment
Machinery	NACE Rev. 2 Divisions 25, 26, 27 and 28 C25: Manufacture of fabricated metal products, except machinery and equipment C26: Manufacture of computer, electronic and optical products C27: Manufacture of electrical equipment C28: Manufacture of machinery and equipment n.e.c.
Mining and quarrying	NACE Rev. 2 Divisions 07 (excluding 07.21: mining of uranium and thorium ores) and 08 (excluding 08.92: extraction of peat), NACE Rev. 2 Group 09.9 B07: Mining of metal ores B08: Other mining and quarrying B099: Support activities for other mining and quarrying
Food, beverages, and tobacco	NACE Rev. 2 Divisions 10, 11 and 12 C10: Manufacture of food products C11: Manufacture of beverages C12: Manufacture of tobacco products
Paper, pulp, and printing	NACE Rev. 2 Divisions 17 and 18 C171: Manufacture of pulp, paper, and paperboard C172: Manufacture of articles of paper and paperboard C18: Printing and reproduction of recorded media
Textile and leather	NACE Rev. 2 Divisions 13, 14 and 15 C13: Manufacture of textiles C14: Manufacture of wearing apparel C15: Manufacture of leather and related products
Construction	NACE Rev. 2 Division 41, 42 and 43 F41: Construction of buildings F42: Civil engineering

Industry	Description
	F43: Specialised construction activities
Wood and wood products	NACE Rev. 2 Division 16 C161: Sawmilling and planing of wood C162: Manufacture of products of wood, cork, straw, and plaiting materials
Transport	NACE Rev. 2 Divisions 49, 50 and 51
Commercial and public services	NACE Rev. 2 Divisions 33, 36, 37, 38, 39, 45, 46, 47, 52, 53, 55, 56, 58, 59, 60, 61, 62, 63, 64, 65, 66, 68, 69, 70, 71, 72, 73, 74, 75, 77, 78, 79, 80, 81, 82, 84 (excluding Class 84.22), 85, 86, 87, 88, 90, 91, 92, 93, 94, 95, 96 and 99 NACE Rev. 2 Division 49, 50 and 51.
Households	NACE Rev. 2 Divisions 97 and 98
Agriculture and forestry	NACE Rev. 2 Divisions 01 and 02
Fishing	NACE Rev. 2 Division 03

Source: JRC, 2023

Annex 2. Validation of the estimated demand from individual installations

The following table shows the inconsistencies found between the estimation of the energy demand from individual installations (values highlighted in red) and the energy balances (highlighted in green).

Table 6. Comparison between the estimated aggregated demand from individual installations and the 2019 energy balances

Country	Block, activity	Source	Solid fossil fuels	Oil and petroleum products	Natural gas	Others	Renewables and biofuels	Nuclear heat	Heat	Electricity
AT	FEC, pipeline transport	Estimation	0.0	0.0	232.9	0.0	0.0	0.0	0.0	20.7
		Energy balance	0.0	0.0	232.7	0.0	0.0	0.0	0.0	20.7
BG	FEC, industry, non-ferrous metals	Estimation	1.0	16.5	50.8	0.0	0.0	0.0	10.0	69.7
		Energy balance	1.0	15.7	48.3	0.0	0.0	0.0	22.5	89.1
CY	TRI, electricity and heat generation	Estimation	0.0	1010.6	0.0	0.0	0.0	0.0	0.0	0.0
		Energy balance	0.0	1010.5	0.0	0.0	47.5	0.0	0.0	0.0
CZ	FEC, industry, chemical and petrochemical	Estimation	109.2	66.2	36.4	32.6	0.0	0.0	49.5	91.0
		Energy balance	241.9	66.3	244.3	31.3	0.2	0.0	175.6	283.0
DE	TRI, electricity and heat generation	Estimation	41550.2	800.9	17508.3	1512.1	694.1	0.0	0.0	3.7
		Energy balance	38817.4	1079.5	18434.2	5321.1	28106.7	19332.0	0.0	703.4
EE	TRI, electricity and heat generation	Estimation	0.0	2.6	201.0	1115.0	341.3	0.0	0.0	0.0
		Energy balance	0.0	13.0	122.7	1384.8	744.8	0.0	0.0	0.0
EL	TRI, electricity and heat generation	Estimation	3076.9	1028.4	2614.7	0.0	0.0	0.0	0.0	0.0
		Energy balance	2998.2	1297.2	3015.2	42.0	1457.8	0.0	0.0	6.3
HR	TRI, electricity and heat generation	Estimation	345.9	1.1	790.1	0.0	5.6	0.0	0.0	0.0
		Energy balance	338.6	11.8	629.1	0.0	969.8	0.0	0.0	13.1
HU	TRI, electricity and heat generation	Estimation	985.6	14.6	2493.5	170.5	413.7	0.0	0.0	0.0
		Energy balance	986.9	17.8	2113.4	255.0	963.8	4106.0	0.0	2.0
IT	FEC, industry, transport equipment	Estimation	0.0	0.0	19.5	0.0	0.0	0.0	5.9	64.9
		Energy balance	0.0	0.0	0.0	0.0	0.0	0.0	94.9	315.0
MT	TRI, electricity and heat generation	Estimation	0.0	2.3	346.3	0.0	0.0	0.0	0.0	0.0
		Energy balance	0.0	9.8	305.6	0.0	17.5	0.0	0.0	0.0
NL	FEC, industry, non-ferrous metals	Estimation	0.0	5.8	182.5	0.0	0.0	0.0	0.0	624.4
		Energy balance	0.0	2.2	67.8	0.0	0.0	0.0	0.0	232.0
PL	TRI, electricity and heat generation	Estimation	30280.1	279.3	2934.6	995.9	1863.8	0.0	0.8	1.7
		Energy balance	30714.1	371.1	2723.3	1111.4	3485.6	0.0	41.9	88.8
SI	FEC, industry, paper, pulp, and printing	Estimation	32.3	0.6	26.2	0.0	28.1	0.0	0.2	18.7
		Energy balance	21.4	1.2	77.5	0.0	10.9	0.0	1.0	60.8

Source: JRC, 2023

The reasons behind the inconsistencies resulting from the analysis of the input data are explained below:

1. AT: the energy demand from some gas compressor stations ("Gas Connect Austria - WAG Baumgarten", "Gas Connect Austria - WAG Kirchberg", "Gas Connect Austria - WAG Rainbach", "Trans Austria Gasleitung – Baumgarten", "Trans Austria Gasleitung – Eggendorf", "Trans Austria Gasleitung – Ruden", "Trans Austria Gasleitung – Weitendorf", and "Trans Austria Gasleitung – Grafendorf"), are reported under "commercial & public services" (NACE code 52.10) in the energy balances.
2. BG: the installation "KCM SA Plovdiv" is an integrated lead and zinc works (NACE 24.43) that produces sulphuric acid, so part of the energy input is reported under "chemical and petrochemical" in the energy balance.
3. CY: there is a minor difference between the amounts reported in industrial emissions portal and the energy balance (0.012%).
4. CZ: there is a small difference (4%) corresponding to "ORLEN UNIPETROL – AGROCHEMIE", possibly part of "other recovered gasses" is reported under "natural gas" in the energy balance.
5. DE: there is a 7% difference in the consumption of solid fossil fuels in "electricity and heat generation" with respect to the energy balance, several power plants are LCPs but there are no data reported to industrial emissions portal. Part of this demand could correspond to power plants in iron and steel mills, coke ovens, or the energy sector (blast furnaces).
6. EE: the installation "AS Kunda Nordic Tsement" consumes oil shale instead of natural gas, reported under "others" in the energy balance.
7. EL: there is a small discrepancy in the consumption of lignite for "electricity and heat generation" between industrial emissions portal and the energy balance (2.62%).
8. HR: there is higher consumption of solid fossil fuels for "electricity and heat generation" (2.15%) reported to the industrial emission portal for "TE Plomin 2". "Petrokemija d.d. tvornica gnojiva" linked to "KUTINA PETROCHEMICAL", part of the consumption falls under "chemical and petrochemical" in the energy balance.
9. HU: the discrepancy in the consumption of natural gas for "electricity and heat generation" between the industrial emissions portal and the energy balance is due to the use of refinery gas from "MOL Nyrt. Dunai Finomító" in "Dunamenti Erőmű Zrt.".
10. IT: some installations included in the EUTL with NACE codes for "transport equipment" are reported under "machinery" in the energy balance.
11. MT: there is a discrepancy between the industrial emissions portal and the energy balance.
12. NL: some non-ferrous metals installations ("Aluminium & Chemie Rotterdam B.V.", "Century Aluminum Vlissingen BV", "Zalco B.V.", "DAMCO Aluminium Delfzijl Coöperatie U.A.", "E-max Remelt", "Nyrstar Budel B.V.") possibly with their own power plants and reported under "electricity and heat generation" in the energy balance.
13. PL: the installations "KGHM Polska Miedź S.A. Oddział Huta Miedzi Głogów" and "KGHM Polska Miedź S.A. Oddział Huta Miedzi Legnica" linked respectively to "HUTA MIEDZI GLOGOW" and "HUTA MIEDZI LEGNICA", reported under "electricity and heat generation" in the energy balance, possibly using "other gases" instead of "natural gas".
14. SI: the installations "Vipap Videm Krško d.d." and "Količevo karton, d.o.o.." are paper mills with their own power plants, reported under "electricity and heat generation" in the energy balance, possibly using some "primary solid biofuels" instead of coal.

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