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SCIENCE FOR POLICY BRIEF

Preparing for water resilience: Mapping the water needs of the EU energy system

HIGHLIGHTS

→ The EU energy sector used 56.2 billion m^3 of freshwater (23 % of the total freshwater abstraction per year in the EU [1]) and 75.2 billion m^3 of non-freshwater in 2022, of which 6.7 billion m^3 of freshwater and 0.8 billion m^3 of non-freshwater were consumed.

→ The decarbonisation of the energy sector reduced freshwater needs by 10.8% with respect to 2015.

→ The electricity sector accounted for 97% of all energy-related withdrawals.

→ The highest freshwater withdrawals took place near thermal power plants along major rivers. .

OVERALL TRENDS

Introduction

The EU energy sector's water needs are a critical aspect of its operations, with significant implications for water resources management and policymaking. With droughts and heatwaves expected to become more frequent and intense due to the effects of climate change, exacerbating water stress in the EU, it is important to quantify the water needs of the energy sector now and in the future.

This brief provides an estimation of the water required by all the activities related to the supply of energy in the EU. This includes the water used to:

— extract primary energy products from the environment (e.g. oil crude, natural gas, coal, solid biomass, and electricity from renewable sources); and

— transform them into final energy products (e.g. non-renewable electricity, petroleum products such as gasoline, and biofuels).

Primary energy products are extracted in coal mines, oil and gas fields, or hydropower plants, among others. Transformation into final energy products takes place at facilities such as thermal power and heat plants or oil refineries, but also at industrial sites such as coke oven plants and blast furnaces. Water is used for many purposes such as washing and transport of mined materials, and mainly for cooling.

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The estimation of water requirements includes the water withdrawals (resources taken from the environment and returned, mostly at higher temperatures after use in cooling devices), and the water consumption (the proportion of the water withdrawals not returned to the local environment, due to evaporation or other reasons).

The current analysis builds upon the assumptions described in previous JRC reports [2, 3], but this update is also based on the latest energy balances from EUROSTAT [4], with data from 2022, and the ongoing work to develop the EU Energy Atlas of the Energy and Industry Geography Lab [5]. The detailed results are at 1x1 km resolution and consider both freshwater and non-fresh water resources. They are summarised in a number of maps available from the JRC Data Catalogue [6].

Water withdrawal

In 2022, the EU energy sector withdrew 56.2 billion m^3 of freshwater (23 % of the total freshwater abstraction per year in the EU [1]), and 75.2 billion m^3 of non-fresh water (mostly seawater).

The power sector was by far the most water-intensive part of the energy system, withdrawing almost 97% of all water resources (54.5 billion m^3 of freshwater and 72.4 billion m^3 of non-freshwater) mostly for the cooling of thermal power plants.

The refining of petroleum products required 2.1% of the resources (0.1 billion m^3 of freshwater and 2.7 billion m^3 of non-freshwater, since the majority of the crude oil refining capacity is located on the coast).

The operation of coke oven plants and blast furnaces needed 0.52% of the water withdrawals (0.7 billion m^3 of freshwater). Coal mining was the fourth most water-intensive activity, accounting for 0.44% of the water withdrawals (0.6 billion m^3 of freshwater). The production of primary solid biomass, such as energy crops and fuelwood, required the withdrawal of 0.2% of the resources (0.3 billion m^3 of freshwater).

Other activities such as the extraction of crude oil, natural gas, peat and oil shales, or the production of charcoal, biofuels, or energy products from waste, also needed water resources, but in much smaller quantities (less than 0.1% altogether).

Water consumption

Some of the withdrawn water resources were consumed, mainly due to evaporation in cooling devices and water reservoirs. Water consumption amounted to 6.7 billion m^3 of freshwater (approximately 3 % of the total freshwater abstraction per year in the EU [1]) and 0.8 billion m^3 of non-fresh water in 2022.

The power sector consumed more than 95% of all water resources (6.5 billion m^3 of freshwater and 0.7 billion m^3 of non-freshwater). About two thirds of this consumption was due to the evaporation of water in reservoirs. Most reservoirs are used for multiple purposes in addition to hydropower generation (such as irrigation, water supply, navigation and recreation) and there are neither enough data nor a straightforward methodology to allocate evaporative losses to the different activities. Thus, this figure rather represents an upper bound of the actual amount of water consumed by hydropower.

The refining of petroleum products accounted for 3.4% of the consumption (0.1 billion m^3 of freshwater and 0.1 billion m^3 of non-freshwater).

The operation of coke oven plants and blast furnaces consumed 0.9% of the water resources (0.07 billion m^3 of freshwater). Coal mining consumed 0.28% of the resources (0.02 billion m^3 of freshwater). The water consumed by all other activities was negligible.

Comparison with previous estimations and available data

Table 1 shows that the current estimation is in line with previous JRC analysis [2]. The latest results show that the freshwater requirements for energy production reduced by 10.8% between 2015 and 2022, which is consistent with the observed long-term trend of decreasing water requirements originated by the spread of wind and solar energy and the closure of thermal power plants.

EUROSTAT provides some statistics on water use [7, 8, 9] but the reporting is very irregular, data for key countries such as Germany, France and Italy are missing, and EUROSTAT only considers freshwater resources. Although EUROSTAT data are not fully comparable with JRC estimations for these reasons, Table 1 shows that the JRC results are plausible and within a similar order of magnitude.

Table 1 – Comparison of freshwater withdrawals for energy purposes in the EU in various years (billion m^3)

EUROSTAT use categories	JRC 2022 [current]	JRC 2015 [1]	EUROSTAT 2020 (6)	EUROSTAT 2022 (6)
Agriculture, forestry and fishing (1)	0.3	1.3	24.8	1.1
Mining and quarrying (2)	0.6	0.9	0.5	0.4
Production and distribution of electricity (3)	54.5	60.7	31.9	8.1
Basic metals (4)	0.1	0.0	0.9	0.3
Coke, refined petroleum products, and chemical products (5)	0.7	0.1	6.3	2.0
Total	56.2	63.0	64.5	12.0

Source: JRC and EUROSTAT

Notes:

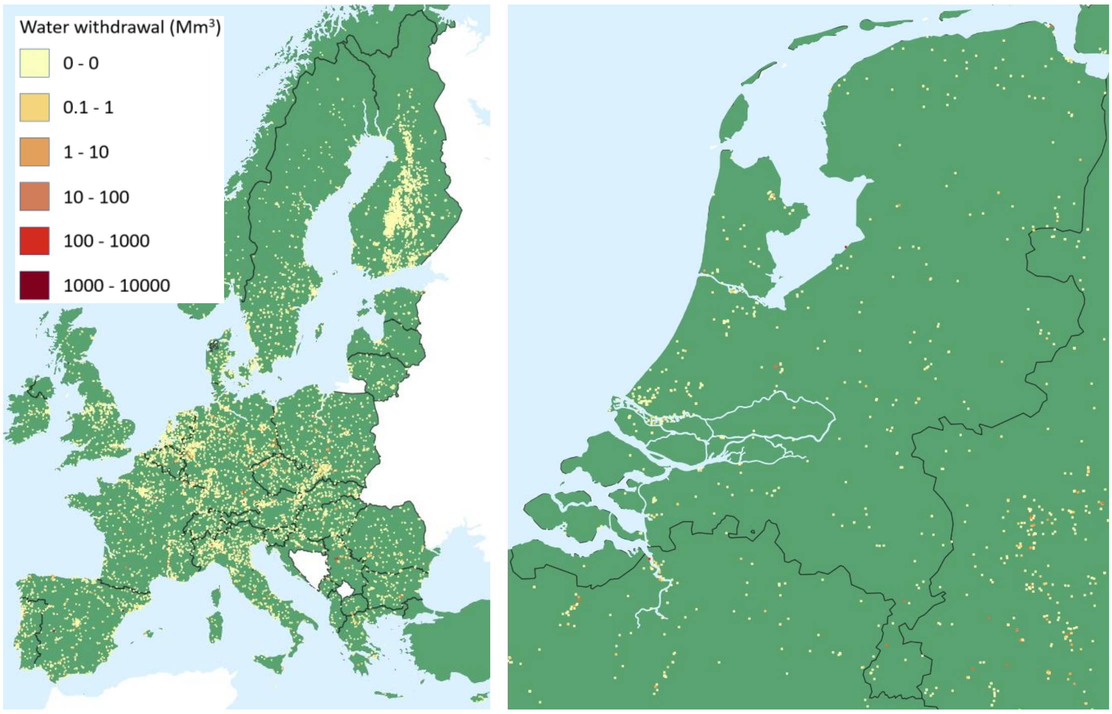
1. "Agriculture, forestry and fishing" includes all related activities, while the JRC figures take into account only the energy-related ones.
2. "Mining and quarrying" includes all mining activity, while the JRC figures take into account only the extraction and mining of energy products, mainly fossil fuels.
3. JRC figures include all water needs for "Production and distribution of electricity" while EUROSTAT only reports cooling needs. It is not clear whether EUROSTAT includes the water needs of industrial autoproducers of electricity.
4. "Basic metals" covers all the uses of water for the production of iron and steel as well as non-ferrous metals (e.g. quenching), but the JRC figures only reflect the operation of coke oven plants and blast furnaces, the only energy-producing facilities of those industries.
5. "Coke, refined petroleum products, and chemical products" includes the water needs of the chemical industry, while the JRC figures only take into account the energy-producing facilities (coke ovens and oil refineries).
6. The EUROSTAT figures are calculated with the values present in the statistics. The huge decline between 2020 and 2022 is due to the gaps in the historical time series.

Spatial patterns of water use for energy purposes

At national scale, five countries withdrew almost two thirds of the freshwater resources: France (19%), Germany (16%), Poland (10%), Belgium (10%) and Bulgaria (9%). About 70% of the freshwater consumption took place in five countries: Germany (18%), France (17%), Sweden (17%), Austria (7%) and Spain (7%). Just three Member States withdrew 67% of non-freshwater resources: France (29%), Sweden (26%) and Italy (12%). Three quarters of the non-freshwater resources (0.6 billion m^3) were consumed by five Member States: France (18%), Sweden (18%), Spain (16%), Italy (12%) and the Netherlands (11%). This distribution is mainly explained by the location of thermal power plants, refineries and hydropower plants.

The current results cover the EU and the neighbouring countries (Figure 1, left), but they are provided at a much finer 1x1 km resolution (Figure 1, right, detail for NL).

Figure 1 – Water withdrawals for energy purposes in 2022 (Million m³)



Source: JRC, Energy and Industry Geography Lab, 2025

Figure 2 shows heatmaps based on the detailed results to highlight the most water-stressed areas. The colour scale represents increasing levels of water use from green, through yellow to red. The highest freshwater withdrawals took place near thermal power plants, often along major rivers such as the Rhine, the Rhone and the Danube (Figure 2 a). The pattern of freshwater consumption differs from the withdrawal. Figure 2 b shows higher consumption in mountain areas with significant hydropower capacity such as the Alps, and areas where power plants use cooling devices that produce significant evaporation.

As regards non-freshwater resources, withdrawals (Figure 2 c) and consumption (Figure 2 d) were concentrated near coastal refineries and thermal power plants, especially in the area Rotterdam-Antwerpen between the Netherlands and Belgium, the area Calais-Le Havre in France, and the Swedish nuclear plant in Forsmark.

CLOSING REMARKS

Thermal power generation continues to stress water resources due to the significant amount of withdrawals needed for cooling purposes. Nevertheless, due to the decarbonisation of the energy system, water withdrawals have decreased by 10.8% in seven years.

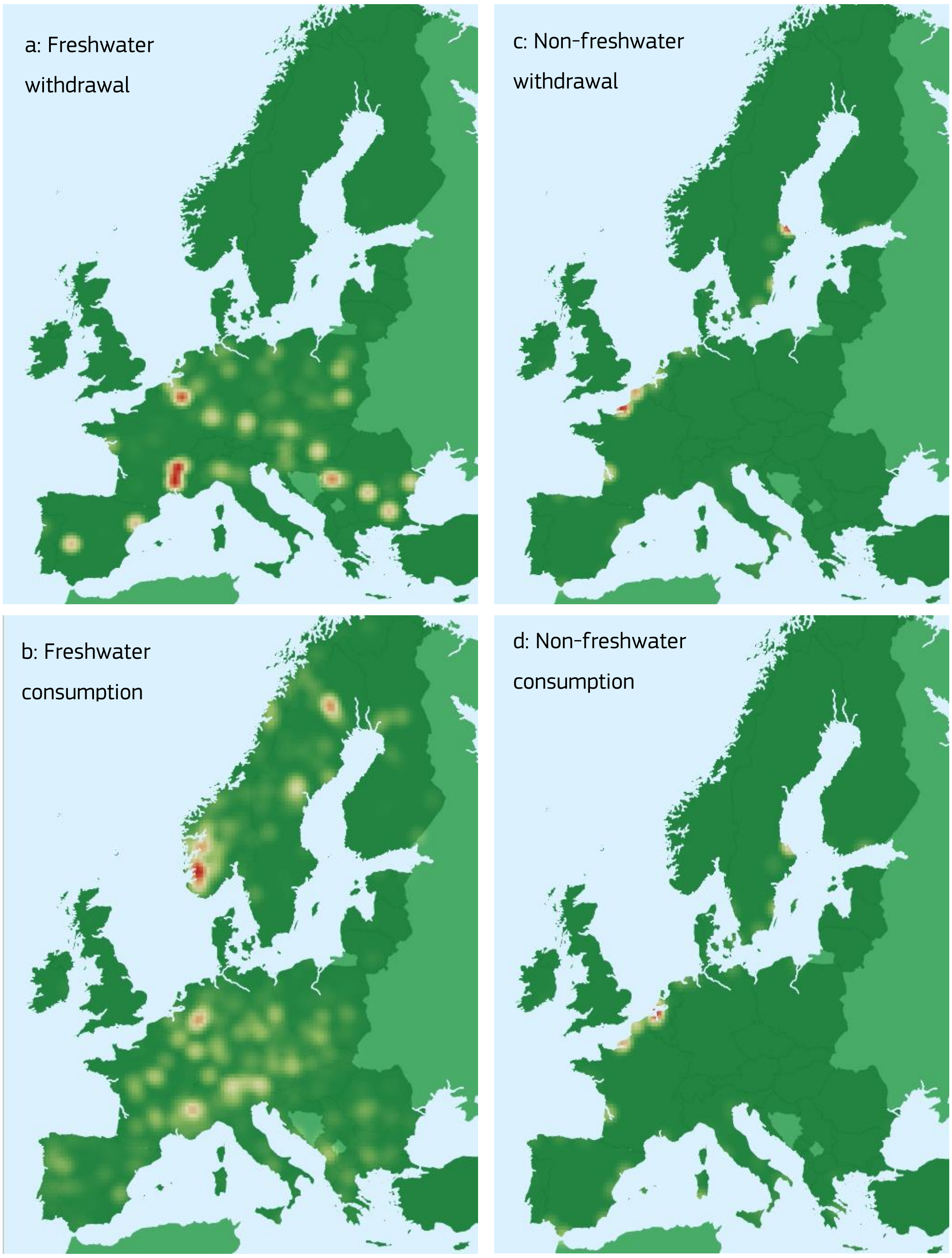
This result is in line with previous studies [9] which expect that water stress will continue to decrease due to the transition to a decarbonised energy sector. This is largely due to the fact that wind and solar power make very little demand on water.

However, some net-zero technologies are water-intensive. In the case of conventional nuclear power, this is due to cooling needs; with carbon capture and storage, biomass and hydrogen, it is due to intrinsic production processes. In an era of mass electrification, and growing energy demand in areas such as data centres and desalination, it is vital that clean energy technology choices are made with care and attention to local water scarcity.

At EU scale, the energy system's water demand is expected to reduce in the long term. However, this will not necessarily eliminate water stress at regional and local levels. It is important to map local specificities and to take these geographical issues into account with detailed spatial analysis when planning future energy infrastructure.

Finally, improved data collection across water uses remains an unresolved issue. Accurate data are essential to understand the interdependencies between water and energy, but the available statistics are affected by significant limitations due to gaps in the time series and the incomplete coverage of the energy sector in the water accounts.

Figure 2 – Water use heatmaps



Source: JRC, Energy and Industry Geography Lab, 2025

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