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Contributions of water saving to a climate resilient Europe

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Key messages

There is a significant water saving potential in different economic sectors, but it differs across the EU

- In the economic sectors investigated in this report (agriculture, electricity production, three sub-sectors of the manufacturing industry, public water supply and tourism) there is a substantial water saving potential.
- Overall, the EU abstracts around 200,000 million m³ of freshwater annually. Of this, 20,000 - 80,000 million m³ or 10-40% of the total abstraction could be saved with effective implementation of water saving measures and incentives.
- This study points to a theoretical water saving potential[1] of 5-20% of the abstracted volume in agriculture, 45-95% in electricity production, 30-50% in the manufacturing industry, and 20-50% in the public water supply (including 10-30% in tourism). In all sectors, the potential water savings depend strongly on the local circumstances and technologies already in place.
- The main water users in the EU differ per region: agriculture and tourism in Southern Europe, electricity production in Eastern and Western Europe, manufacturing in Northern Europe, while public water supply is relevant in the whole of the EU.

Technical and operational water saving measures must be implemented in close conjunction with tailor-made enabling measures

- The implementation of technical and operational water saving measures must be accompanied by enablers, such as raising awareness among water users and the wider public, water metering, enforcement of abstraction regulations, incentive water pricing, application of the cost recovery and the polluter/user pays principles.

Water saving measures should be designed to increase environmental and socio-economic resilience

- Achieved water savings should be used to reduce the impacts from low flows on ecosystems and increase the resilience of economic sectors and societies against unpredictable fluctuations of water availability that result from climate change.
- Legal and governance arrangements for water saving, including those arising from the EU water policy, should manage the competitive interests among different economic sectors and between economic growth and environmental protection, ultimately securing that sufficient water is available for human and environmental welfare.

The most promising water-saving measures per sector

- In agriculture: reduce evaporation and leakages by using canal lining and closed pipes for water transfer and distribution, expand drip or subsurface irrigation, apply smart and precision farming, select drought-resistant or less water consuming crops or cultivars[2].
- In electricity production: shift to renewable energy sources from combustible fuels, use air cooling in power plants, use waste heat from power plants in adjacent housing areas or industries.
- In manufacturing: increase water recycling and reuse, apply a plethora of available branch-specific water saving measures.

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[1] From the review conducted under this study, the stated water saving potential is considered technically feasible in theoretical terms. Thereby, the stated amounts and percentages refer to possible envelope conditions for water saving. In practice, this theoretical potential may be limited, due to socio-economic factors, including lack of funding, lack of political engagement, changing consumption patterns, rebound effects, intensity of climate change impacts, etc.

[2] As each case is individual, the balances of upstream and downstream impacts of projects should always be assessed, as required by the Environmental Impact Assessment (EIA) Directive (2011/92/EU as amended by 2014/52/EU) and relevant national legislation.

- In public water supply: maintain and upgrade water transfer and distribution pipes, enhance the installation of water saving household appliances, promote water saving practices, reduce non-revenue water.
- In tourism: reduce evaporation from open-space green areas, reduce water use for snowmaking in skiing resorts, reduce water use in hotels, pools and restaurants.
- Across sectors: diversify the water supply sources through desalination of sea / brackish water, water reuse and rainwater harvesting, where feasible.

Executive Summary

Water scarcity, droughts, climate change and the need to save water

Water is essential for life; our ecosystems and economy rely heavily on water. The EU alone abstracts more than 200 000 million m^3 of water per year on average to sustain its economy. Economic sectors such as agriculture, cooling water for electricity generation, manufacturing, and drinking water supply rely on adequate water availability, but also exert pressures on Europe's renewable freshwater resources. These sectors also hold potential in saving large volumes of water by improving the water use efficiency. This report explores the water saving options in five economic activities, namely irrigated agriculture, cooling water for electricity production, three segments of the manufacturing industry (the food and beverages industry, the steel industry, and the pulp and paper industry), public water supply and tourism. However, other sectors not included within the scope of this report can also implement water-saving measures.

Climate change exacerbates the increasing frequency of too much water and not enough water in the same river basin even within a year. This trend of increasing hydro-climatic extremes is confirmed recently by the IPCC (IPCC, 2023). Europe is already facing the impacts of climate change in different forms of socio-economic damage and ecosystem degradation, and experiences record-breaking heat waves not only in southern countries but also almost everywhere towards the north. Annually, an average of 4% of the EU territory is estimated to be affected by drought. The severe droughts experienced in 2022 have impacted approximately 16% of the EU territory (EEA, 2024a). Economic damage from droughts is estimated to be in the order of EUR 2-9 billion annually, not including the damage to ecosystem services (EEA, 2020a; Maes, et al., 2020). River basins affected by water scarcity conditions at least during one quarter of the year between 2000 and 2022 take up approximately 30% of the EU territory (EEA, 2024c). According to the 3rd RBMPs reported by EU Member States[3], water abstraction was identified as a significant pressure for 36% of total groundwater bodies and 8% of total surface water bodies by 2021 (EEA, 2024d).

Various aspects of efficient water use and water savings are addressed in EU environmental and water-related policies. The EU Biodiversity Strategy 2030 emphasizes restoring freshwater ecosystems for ecosystem health and water allocation. The EU Strategy on Adaptation to Climate Change and the Circular Economy Action Plan underline the importance of resource efficiency and reducing water use. The EU Water Framework Directive mandates ecological flow implementation for aquatic ecosystems and sustainable water resource use. However, to make the impacts more noticeable, there is a need for an impetus in the implementation of the current policy provisions (EEA, 2021b).

It is worth noting that the EU Member States have already decreased annual water abstraction by 19% from 2000 to 2022. Despite this accomplishment, uncertainties in water availability are increasing due to the impacts of climate change, leading to a decline in water availability during peak demand seasons. Model-based studies indicate further exacerbation of such risks and uncertainties under the different warming scenarios (Feyen, et al., 2020; De Roo, et al., 2023). This emphasizes the need for prolonged efforts in water saving.

The focus in this report is on the available technical and operational management measures to save water. A clear message from almost all of the reported case studies, however, is that technical measures are only effective if combined with supporting measures and embedded in an effective governance. Only such a constellation can be effective in such matters as the proper use of technical equipment, the enforcement of the agreed abstraction limits, and the use of the water saved to improve environmental and societal resilience rather than additional economic production.

[3] By the time of drafting this report, electronic data from the 3rd RBMPs were available only for 19 out of 27 EU Member States: Austria, Belgium, Croatia, Czechia, Denmark, Estonia, France, Germany, Italy, Latvia, Lithuania, Luxembourg, Netherlands, Poland, Portugal, Romania, Slovakia, Spain, Sweden.

This report brings together information on technical and operational management water saving options, as investigated and implemented in the field, and reported in published and grey literature. In addition, the responses to a questionnaire among Eionet members and several dedicated interviews were used.

The report's overarching conceptual approach is to assess the efficiency of sector-based technical measures, aiming to explore the feasibility of achieving maximum water savings. Additionally, it seeks to compare the best-performing sectors and countries on a regional scale to identify the potential range for water savings in the near future. While this approach may introduce some uncertainties in providing precise quantitative figures, it proves valuable in developing an overview of priority sectors at the EU, regional, and country levels for implementing water-saving measures and understanding their potential contribution to enhancing water resilience.

Operational and technical measures for water saving in economic activities

The ***agricultural sector*** is, with 50% of the EU-27’s total, the largest consumer of water in the EU, and therefore a key sector in water saving strategies. The current focus point of such strategies is Southern Europe, which is responsible for 74% of the EU-27’s total consumption for agriculture. Under the impact of climate change, an increasing percentage of the total agricultural area in Europe is expected to require irrigation in the future. Nevertheless, there is a significant remaining potential in water saving by the agricultural sector by means of further prevention of losses, improved management practices and improved application technologies. Theoretically, the water saving potential in irrigated agriculture is estimated to be up to 20% of the total water abstraction. In practice, the achievable saving can be much lower (e.g. 5%) due to technical and economic constraints. Literature points to several cases where the regional water use was not reduced after the implementation of these measures, because the saved water was used to enlarge the irrigated area or to grow crops with a higher water consumption. To avoid these so-called rebound effects, water saving measures must be accompanied by awareness campaigns to foster behavioural change or even be embedded in an adequate governance structure that ensures that the saved water is used for increased environmental resilience.

A decreasing but still considerable share of Europe’s ***electricity production*** relies on water for cooling. Some 36% of the abstracted and 20% of the consumed freshwater is used for cooling water for electricity production. The water demand of the sector will be reduced strongly by the anticipated energy transition in the coming decades. Technologies like wind and solar power will reduce the total volume of water required, but biofuels require more water than the currently used fossil fuels, if the water needed for crop production is included. These developments in combination with changes in cooling systems could theoretically reduce cooling water abstraction by 45-95%.

The ***manufacturing industry*** is an extremely diverse sector, producing a wide range of goods in a wide range of production processes. Hence a comprehensive overview of manufacturing is outside the scope of this report. Instead, three categories with considerable water use are analysed in more detail: the food and beverages industry, the steel industry, and the pulp and paper industry. The analysis shows that considerable savings, in the order of 30-50%, are possible, if the necessary investments are made. Water reuse and recycling are key measures for water saving in these sectors.

The analysis of water saving options in the ***public water supply*** sector suggests that more than 30% of water abstraction for public water supply is lost between the point of abstraction and the point of supply, while further water losses occur during water use. Water abstraction and use in the public water supply sector can be reduced by 20-50% by improving water infrastructure, upgrading monitoring equipment, optimising water billing and reducing water demand by individual users and households.

Tourism relies on water for various purposes, including hotels, restaurants, and recreational activities like swimming pools and golf courses. As the tourism sector in Europe is expected to grow up to 7.5 % until 2034, the demand for water in tourism activities will also grow, exerting pressure on local water supplies and ecosystems. The overall direct water use by the European tourism sector is estimated at about 5% of the total water abstraction by public water supply in the EU. This may seem like a minor figure, but it often places additional stress on already water-scarce areas, such as small Mediterranean islands and coastal areas. Plenty of water-saving measures have been implemented in the past. Yet, the level of implementation should be increased. Given the many uncertainties, the resulting rough overall figure for the water-saving potential in the tourism sector of 10-30% shall be handled with caution.

The table below provides a summary of the annual water abstraction volume and the estimated percentage of potential water savings in each sector for the EU-27.

EU-27	Agriculture	Cooling water in electricity production	Manufacturing, including cooling water in industry	Public water supply, including tourism and other services	Others (e.g., mining, quarrying and construction)
Annual water abstraction (million m³)	59,300	72,300	28,200	38,700	3,000
Theoretical potential saving in water abstracted (%)	5-20%	45-95%	30-50%	20-50% (10-30% in tourism)	*Not assessed in this report*

Diversifying water supply through alternative water sources

Water saving measures are often combined with the exploitation of alternative water sources: rainwater harvesting, water reuse and desalination. Using these alternative sources does not reduce water consumption but can help relieve abstraction pressures on surface and groundwater bodies.

Alternative water sources are, with variable intensity, applied in all economic sectors. Rainwater harvesting has been applied in agriculture for centuries and is also applied in industry, urban water supply and tourism. An example from the tourism sector: rainwater harvesting options were modelled for meeting non-potable water demand at Amsterdam-Schiphol Airport. With sufficient storage, all non-potable water demand of the airport can be supplied, reducing freshwater abstraction for drinking water by some 60%.

Water reuse has significantly increased over the past decade in the EU. Water reuse for irrigation remains the most common application of reclaimed water in Europe, followed by water reuse in industry / manufacturing and water reuse for recreational purposes. The annual volume of reclaimed water in the EU-27 accounts for 2.4% of the urban wastewater receiving tertiary treatment annually, but Cyprus and Malta already reuse more than 90% and 60% of their wastewater, respectively.

Desalination is the only one of the measures discussed in this report that increases the volume of freshwater available for use. At present it represents only around 1% of the total volume of water use in Europe. Between 2017 and 2021, there has been a significant increase in desalination for public water supply (the main user of desalinated water) in some Mediterranean countries. Especially in Cyprus and Malta, desalination exceeds 50% of total public water supply. In agriculture, desalination is an option that was traditionally restricted to capital-intensive crops, but technical development, with cost price of water production well below 1 €/m^3 as well as significant subsidies continue to broaden the field of application considerably. Sustainable solutions are needed for the supply of clean and renewable energy to meet the high demands of the desalination process, as well as for the management of desalination by-products (e.g. brine) to reduce risks to the environment.

Importance of enablers in water saving

To make sure that water saving measures contribute to increased societal and environmental resilience, technical and operational management water saving measures must always be implemented in close coordination with economic measures, financial arrangements, awareness raising or market development, and be embedded in an adequate governance structure.

For a future regionalized assessment of water-saving options, a comprehensive overview of water-dependent economic activities is crucial. Including details on current water saving measures and estimating remaining potential, along with assessing the economic viability of selected measures over an extended time horizon, will inform strategic opportunities. This holistic approach contributes to a more informed and forward-looking regional water management strategy.

1 Setting the scene

Water is vital for life, and both our ecosystems and economy depend heavily on it. The EU alone abstracts more than 200 000 million m^3 of water per year on average to sustain its economy, excluding hydropower. However, water availability fluctuates in time and varies throughout Europe, whereas water demand as affected by socio-economic and climate drivers (such as drought and rising temperature) is highly variable from season to season (Feyen, et al., 2020).

Annually, an average of 4 % of the EU territory is estimated to be affected by drought. The severe droughts experienced in 2022 have impacted approximately 16% of the EU territory (EEA, 2024a). Economic damage from droughts is estimated to be in the order of EUR 2-9 billion annually, not including the damage to ecosystem services (EEA, 2020a; Maes, et al., 2020). River basins affected by water scarcity conditions at least during one quarter of the year between 2000 and 2022 take up approximately 30% of the EU territory (EEA, 2024c). According to the 3rd RBMPs reported by EU Member States[4], water abstraction was identified as a significant pressure for 36% of total groundwater bodies and 8% of total surface water bodies by 2021 (EEA, 2024d). It is worth noting that the EU Member States have already decreased annual water abstraction by 19% from 2000 to 2022. Despite the overall decreasing trend between 2000 and 2022, water abstraction for agriculture, industry, and public water supply has shown an increasing trend since 2010, indicating the need for increased efforts to improve overall water use efficiency.

Addressing uncertainties about current and future water availability and their impact on freshwater ecosystems and the economy is a complex challenge. Improving resilience is essential to reduce vulnerability in these areas. Key components of water resilience include reducing water demand, diversifying supply sources, and ensuring ecological flow. The EU's environmental policy, particularly its water policy, offers ample provisions (EEA 2021b) for improving resilience against the impacts of climate change. The new EU Strategy on Adaptation to Climate Change (EC, 2021b) is addressing the availability and sustainability of freshwater as fundamental for climate resilience, stating, 'We also need to sharply reduce water use'. Similarly, the European Green Deal (EC, 2019b) underlines the threat of over-exploitation of natural resources and requires actions towards sustainable management of clean freshwater provision for maintaining economic development and ecosystem health. The EU Biodiversity Strategy prominently calls for the restoration of freshwater ecosystems and the implementation of e-flows and revision of the water allocation scheme.

The EU Water Framework Directive 2000/60/EC (WFD), as the EU key policy provision for integrated management of water resources, promotes sustainable water use based on a long-term protection of available water resources and calls for the implementation of adequate incentives for efficient use of water resources to achieve the environmental objectives of the Directive. It also introduced the "polluter-pays" principle, encouraging cost recovery for water services and promoting economic instruments to incentivize sustainable water use.

Concept of water saving

Overall, water saving refers to the amount of water that can be conserved in a socio-economic system by adopting one or more combined efficiency approaches under certain socio-economic conditions (Wu, et al., 2019). Resilience is 'the ability of a system, community or society exposed to hazards to resist, absorb, accommodate, adapt to, transform and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions through risk management' (UNDRR, 2017).

[4] By the time of drafting this report, electronic data from the 3rd RBMPs were available only for 19 out of 27 EU Member States: Austria, Belgium, Croatia, Czechia, Denmark, Estonia, France, Germany, Italy, Latvia, Lithuania, Luxembourg, Netherlands, Poland, Portugal, Romania, Slovakia, Spain, Sweden.

Implementing water-saving measures — ranging from major technical upgrades to promoting individual behavioural changes — is essential for strengthening the resilience of both ecosystems and socio-economies. By reducing the demand for renewable water resources, these measures can help economic sectors become more resilient to water scarcity. Additionally, allocating the water resources saved from economic use for environmental purposes can significantly enhance the resilience of ecosystems.

Water saving, water scarcity, drought risk and climate resilience

Resilience building against climate change is addressed in several recent publications that present holistic overviews of planning principles, possible actions and related indicators (UNDRR, 2021; World Bank, 2019; World Bank, et al., 2021). Applied to drought, increased resilience is understood as the result of the implementation of a coherent and future-oriented set of measures to reduce drought risks for society, environment and economy. In the current report the scope is narrowed down to the contribution that water saving measures can make in this transition.

Increased drought resilience implies the development of strategies to cope with lower average levels and higher variability of water availability in the future. This needs to be quantified, in time, in space, and by water user.

Due to the absence of a conceptual framework linking water-saving measures and resilience, this report adopts the assumption that any amount of water saved contributes to increased resilience. There are two major caveats, however:

- first, water availability is projected to decrease in many parts of Europe (at least during summers, in some regions even year-round); resilient plans should include those future conditions;
- second, there are examples where water savings were only used to fuel economic growth (cf. Chapter 3, section on Regulatory and legal measures), not leaving room for flexibility in water use during droughts and not increasing drought resilience.

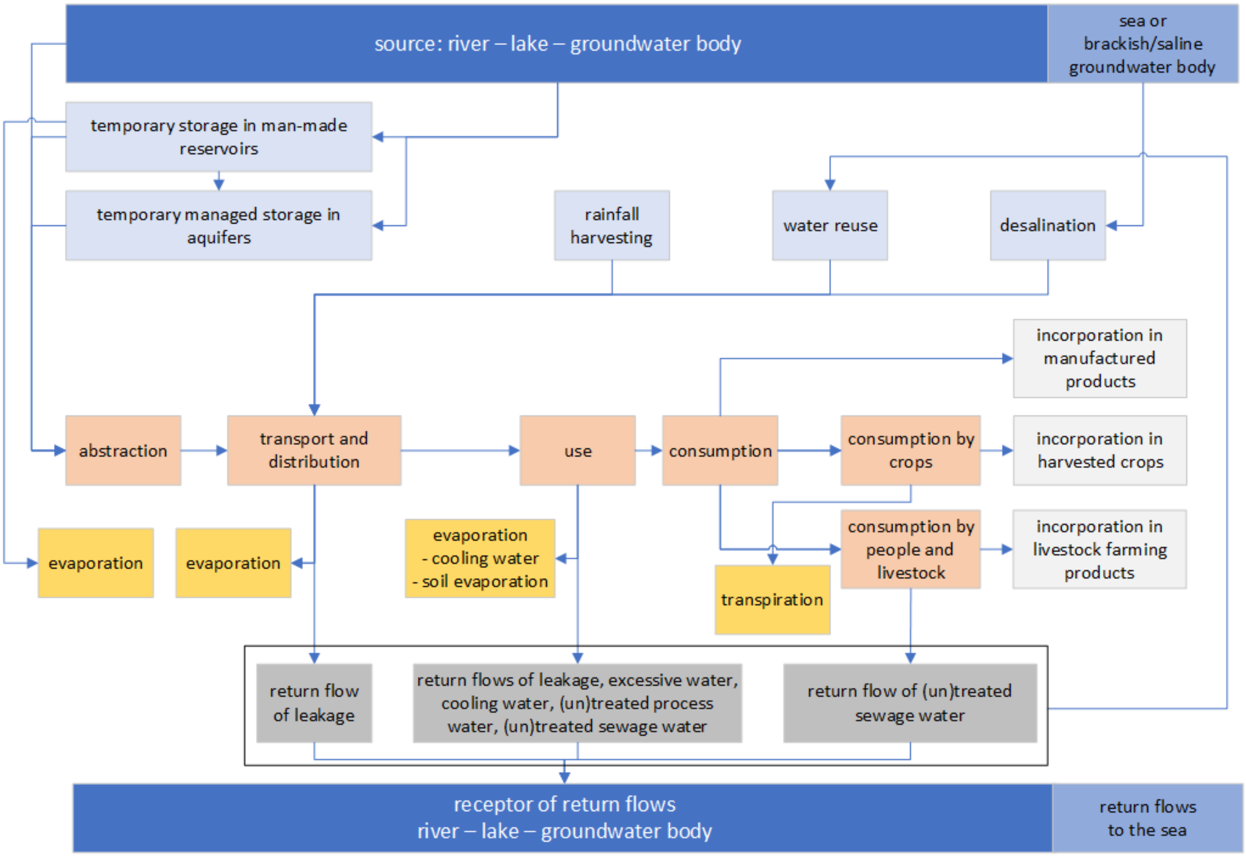
Water savings in the stages of the water use chain

The water use chain consists, in its basic linear form, of the consecutive abstraction from a water source, transport, distribution, use and consumption of water, ending with the discharge of the used water back into the environment. In this process, part of the water is lost to the local water cycle by evaporation or crop transpiration, and part is captured in products. These together constitute water consumption. The definitions of each of these stages as used in this report are included in the Glossary.

Water saving measures can be directed towards reduction of the volume of abstracted water, leakage losses, more efficient use of water and enhanced circularity, and reduction of evaporation or transpiration losses. Figure 1.1 presents these elements in a simplified schema.

In addition to the conventional sources of water supply and use chain, there are three main types of so-called alternative water sources: harvested rainwater, water from WWTP's and desalinated water (indicated in light blue in Figure 1.1). Measures to exploit these alternative water sources are supply-side rather than demand-side measures. Hence, they do not reduce water use per unit production. Similar to water abstraction from surface and groundwater, alternatively sourced water may be temporarily stored in reservoirs or aquifers. For reasons of readability the corresponding arrows have not been included in Figure 1.1.

Figure 1.1 Schematic overview of the concepts of water abstraction, use, return and consumption[5]



Note: blue boxes = water sources; salmon boxes = supply chain; orange boxes = losses to the atmosphere; dark grey boxes = leakage and return flows, light grey boxes = incorporation in livestock, crops and manufactured products.
Source: Authors' elaboration.

Scope and objectives of the report

Water saving is a very broad topic that encompasses not only efficiency measures in water use but also interlinkages between ecosystem and economy, water allocation and stakeholder management, financing, governance, etc. Addressing all aspects of water saving within the given scope of this report was not possible. The report addresses mainly the envelope potential water saving in economic sectors based on the case studies compiled for this report and a cross-comparison of best-performing countries within the same region for the same economic sectors. The underlying data is a compilation from various sources, including EEA WISE State of Environment data, Eurostat and an OECD joint questionnaire, and many others, which can be found in the list of references at the end of this report.

This report aims to provide quantitative and qualitative assessments of the water saving potential in five prominent water-dependent economic activities in Europe: irrigated agriculture, cooling water for

[5] _Note on terminology_: *Understanding the differences in the definitions of 'water abstraction', 'water use' and 'water consumption' (See Glossary).*
Water abstraction: extraction of water from the environment for human and socio-economic purposes; usually assuming that this occurs with the use of artificial means (e.g. canals, pipes, diversions, pumping).
Water use = Water abstraction minus returns before site of use (e.g. conveyance losses).
Water consumption = Water abstraction minus returns before site of use (e.g. conveyance losses) minus returns on site of use (e.g. application losses) = Water abstracted and not in liquid form returned to the environment (frequently also mentioned as 'net abstraction').

electricity production, manufacturing, public water supply and tourism[6]. Specific sectoral measures proposed in this report may require detailed analyses to assess their suitability and viability at local scales.

The development of a standard typology for water saving measures which can be applied across Europe is beyond the scope of this report. The practical classification that is adopted here is the following:

- Enabling measures, including economic, financial, legal, regulatory, governance and institutional measures, as well as monitoring, data and information provision across all sectors.
- Operational (optimizing the use of available resources) and technical measures for water savings in economic activities
- Diversifying water supply through alternative water sources

Enabling measures (economic incentives, regulatory and legal measures, governance, raising awareness, education and training, market development and certification and data provision) are presented briefly in this report. The aim is not to be complete or to present them in their full depth, but rather, to emphasise the need to address them thoroughly when planning water saving measures. The report provides detailed analyses and assessment on technical and operational management water saving measures from a European perspective.

Assessing the water saving potential in Europe is not a new topic. A report on water savings was published by the EC in 2007 (Dworak, et al., 2007). That report provides a large number of quantitative assessments of water saving potential in various economic sectors. The findings of the 2007 report were used in the EEA report on water stress (EEA 2021b), which concluded (among others) that since 2007 no comprehensive update of the water saving potential in Europe has become available. However, the current report should not be regarded as an updated version of the 2007 report, neither a catalogue of water saving measures at sectoral level, but rather as an overview of where large water saving potentials exist, and which sectors could be prioritized in which parts of Europe[7]. The report provides quantitative assessments and explains where the data and information are available. It suggests actions to be prioritized.

[6] Assessment of the share of the five selected economic activities in the water abstraction and use of the broader groups of which they are part of is a challenge, due to gaps in the reported data. A rough estimate by the authors, based on expert judgment and an elaboration of reported data, indicates that the water abstraction share of irrigated agriculture, cooling for electricity and public water supply is in the order of 90% or more of the respective sector data (Agriculture, Energy supply and Public water supply/Services). The three manufacturing industries presented in this report together represent 16% of the manufacturing sector in terms of GVA (Eurostat), however, there is no data available on their proportion of total water abstraction. Tourism represents a small fraction of total water use in the EU with high level concentration in certain areas such as small Mediterranean islands, coastal areas and mountains.

[7] The Climate-ADAPT database (https://climate-adapt.eea.europa.eu/#t-database) contains a wide range of water-saving measures. The EDORA project (Benitez Sanz, et al., 2023) also provide a catalogue of a wide range of sectoral adaptation measures.

2 Key figures of water use by economic sectors in the European Union

2.1 Water abstraction and water consumption by sector and region

The EU Member States (EU-27) abstracted annually around 200,000 million m^3 of fresh surface water and groundwater on average between 2000 and 2022 (excluding temporary abstraction for hydropower). Cooling water for electricity production and agriculture show the highest levels of water abstraction in the EU-27, representing 36% and 29% of the total annual water abstraction, respectively. However, agriculture is responsible for the highest water consumption in the EU-27, as it accounts for 50% of the total water consumption from all sectors. A large portion of cooling water is returned to the environment after use, so cooling water consumption represents only 20% of the total water consumption in the EU-27 (EEA, 2024c). In general, water abstraction and consumption vary significantly both across sectors and regions in the EU-27 (Table 2.1).

Table 2.1 Distribution of water abstraction and water consumption of different economic sectors at regional and EU level (average 2000-2022)

	Agriculture	Cooling water in electricity production	Manufacturing, including cooling water in industry	Public water supply, including tourism and other services	Mining, quarrying and construction
EU-27					
Water abstraction	29%	36%	14%	19%	2%
Water consumption	50%	20%	19%	9%	2%
Eastern Europe (BG, CZ, HU, PL, RO, SK)					
Water abstraction	13%	54%	12%	20%	1%
Water consumption	22%	45%	20%	11%	2%
Northern Europe (DK, EE, FI, IE, LT, LV, SE)					
Water abstraction	8%	33%	30%	27%	2%
Water consumption	16%	35%	36%	9%	4%
Southern Europe (CY, ES, EL, HR, IT, MT, PT, SI)					
Water abstraction	60%	10%	11%	19%	<0.1%
Water consumption	74%	9%	9%	7%	<0.1%
Western Europe (AT, BE, DE, FR, LU, NL)					
Water abstraction	6%	58%	16%	18%	3%
Water consumption	16%	26%	36%	14%	8%

Note: ’Agriculture’ stands for Agriculture, forestry and fishing (NACE A); ’Cooling water in electricity production’ stands for Water abstraction for cooling purposes in electricity, gas, steam and air conditioning supply (NACE D); ’Manufacturing’ stands for Manufacturing, including water for cooling purposes in manufacturing (NACE C); ’Mining and quarrying’ stands for Mining and quarrying (NACE B); ‘Construction’ stands for Construction sector (NACE F); ‘Public water supply’ stands for Water collection, treatment and supply (NACE E36); ‘Tourism and other services’ stands for Services (NACE G - U);.

Source: EEA, 2024c

2.2 Contribution of the water-abstracting sectors to Europe's economy

The total GVA of the EU-27 economy amounted to 15.5 trillion EUR, while ca. 205 million people were employed in 2023 (OECD, 2024). By that time, these indicators had recovered from the 2020-2021 COVID-19 pandemic. The economic sectors included in Table 2.2 make up 30 % of the GVA and 34 % of employment in the EU-27, and they are responsible for almost all water abstraction taking place, due to their dependence on water (EEA, 2024b).

Table 2.2 Contribution of the main water abstracting sectors to EU economy

	Agriculture	Energy supply services	Manufacturing	Public water supply services	Tourism
EU-27					
Share in total employment	4%	1%	19%	<1%	6%
Share in total GVA	1%	2%	24%	<1%	2%
Number of farms	9.1 million				
Number of enterprises		188.000	2.2 million	27.000	1.9 million

Note: 'Agriculture' stands for Agriculture, forestry and fishing (NACE A); 'Energy supply services' stands for Water abstraction for cooling purposes in electricity, gas, steam and air conditioning supply (NACE D); 'Manufacturing' stands for Manufacturing, including water for cooling purposes in manufacturing (NACE C); 'Mining and quarrying' stands for Mining and quarrying (NACE B); 'Construction' stands for Construction sector (NACE F); 'Public water supply stands for Water collection, treatment and supply (NACE E36); 'Tourism stands for Accommodation and food services (NACE I);

Sources: Eurostat, 2022, 2024a, 2024b, 2024c, 2024d, 2024e; OECD, 2024; Pernice and Debyser, 2023

2.3 Priority sectors for water savings

Identifying priority sectors for implementing water-saving measures should focus on those with the highest water demand, as these areas are likely to yield significant efficiency gains and positive impacts. According to available data, substantial water-saving potential exists in agriculture and in water abstraction for cooling, particularly for electricity production. Table 2.3 provides an overview of sectors with the largest volumes of water abstraction, highlighting priority areas for potential water savings.

It is important to note that these priority sectors vary significantly across countries, even within the same region (see Annex 1 for country-level distribution data). For example, agriculture, though not a major water user in much of Eastern Europe, is a priority in Romania, due to its large volume of water abstraction. Conversely, while agriculture is the primary water-demanding sector in Southern Europe, cooling water takes precedence in Slovenia.

Table 2.3 Priority sectors for identification of water saving options at regional scale (EU-27)

Region	Agriculture	Cooling water in electricity production	Manufacturing, including cooling water in industry	Public water supply, including tourism and other services
Eastern Europe (BG, CZ, HU, PL, RO, SK)		X		X
Northern Europe (DK, EE, FI, IE, LT, LV, SE)			X	X
Southern Europe (CY, ES, EL, HR, IT, MT, PT, SI)	X			X
Western Europe (AT, BE, DE, FR, LU, NL)		X		X

Note: Based on the share (%) of each sector in the total water abstraction of each region. Current uptake of water saving / efficiency measures or proportion in total consumption are not assessed. The country grouping is adapted from UN Geo schema M49 (UNSD, 1999).

Source: EEA, 2024b

3 Enabling measures

Technical and operational management measures must be embedded in enabling measures

The water-saving measures that are discussed in chapters 4 to 8 should never be considered as stand-alone options. That is made clear in the cases suggested by the Member States during the preparation of this report and presented here. The measures to be taken in parallel to technical and operational management measures are dubbed ‘enabling measures’. The most prominent categories are introduced in this chapter. The aim is not to be complete or to present them in their full depth, but rather, to emphasise the need to address them thoroughly when planning water saving measures.

Economic incentives

There are two distinct principles incorporated in the EU Water Framework Directive: the polluter-pays/user-pays principle, by which the costs of pollution should be borne by the polluter/user; and the principle of cost recovery of water services to different uses, by which the sound pricing of water will promote awareness on its value, discourage wastage and improve efficient use of the resource. The cost recovery should not only cover the financial costs for investments and management of the service systems, but also include environmental costs and reflect scarcity of the water resource (OECD, 2020; Zetland, 2021). However, the incorporation of these external (environmental and resource) costs into water tariffs is often not applied in a manner representing the true value of the resource. For example, costs of water treatment include the costs of the treatment of the wastewater, but not the costs of the discharge of the treated (but still containing pollutants like residues from medicines) water into the surface water (EEA, 2013). The introduction of pricing instruments is also a source of revenues to finance required investments in infrastructure and pay for operational and management costs (OECD, 2023).

Economic instruments

Imbalances of water demand and supply will occur when the price of water is not set adequately, for example when the price of water is equal to zero and there is not an abundance of supply (Zetland, 2021). Setting a price for water, in the case that water is a scarce resource, can assist in balancing supply and demand. The result of this mechanism is that prices for water should increase with increasing scarcity. However, current practice is that the price of (utility) water is set to cover fixed costs (linked to investments required for infrastructure) and variable costs (linked to operational costs of this infrastructure and the administrative costs for the delivery of the service). The price often does not include the costs of the scarcity of the water, thus undervaluing the price of water and thus not achieving a balance between supply and demand. Furthermore, payment for drinking water services is accepted in all EU Member States, whereas payment for other water services, like the supply of water for agricultural and industrial use is sometimes not priced, causing further imbalance to water supply and demand.

The actual use of water can be excludable (i.e. it is possible to limit or restrict use, e.g. metered water) or non-excludable (i.e. difficult to restrict use, e.g. abstracting water from an aquifer or environmental flows), requiring different mechanisms to manage the resource. Both excludable and non-excludable water use can be rival (i.e. the use of one affects the use of the other) or non-rival (i.e. the use of one does not affect the use of the other), as shown in Table 3.1.

Once the type of water use is defined, then water, as a good, should be managed with either economic or community/ political tools. Where excludable use is best managed through the use of market instruments, e.g. pricing of the resource, non-excludable use is best managed through policy instruments setting requirements and/or limitations on use, e.g. water rights. In the application and design of an effective mix of pricing and non-pricing instruments, the specific features of each country in terms of water availability and water demand challenges should be taken into consideration.

Table 3.1 Typology of water as a good, by assessing excludability and rivalry

	Excludable	Non-excludable
Rival use	Private good *(metered water)*	Common-pool good *(shared aquifer)*
Non-rival use	Club good *(distribution network)*	Public good *(Environmental flows)*
	Market	Policy

Source**:** adapted from Zetland, 2021

Matching supply and demand in case of water scarcity

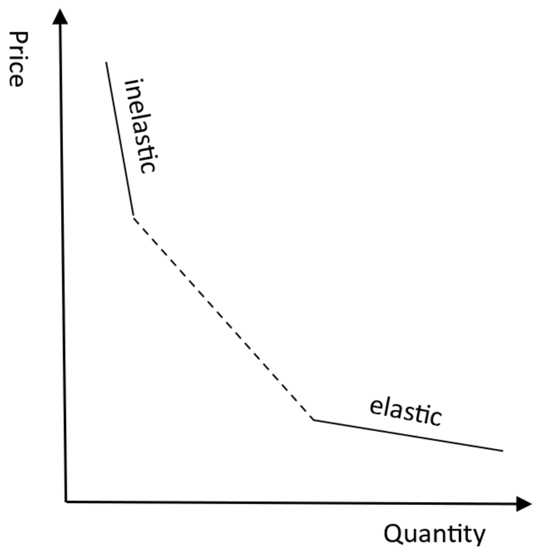
There are two important phenomena or aspects in the economic price of water that can result in different effectiveness of pricing instruments in case water becomes a scarce resource. In a situation where water is present in abundance, a system of water rights can be seen as a market for a 'club good', there is a payment for the water, but it is a non-rival use although stakeholders have to pay a price (e.g. permitting costs), there is sufficient water to meet all demands from all stakeholders. However, in case of drought, this situation can change into a rival use of water, where (the non-metered) use by one stakeholder changes the quantity of water available for the other stakeholders. The tools available to manage this situation could consist of a 'market' tool, such as starting water metering to limit its use, or a 'policy' tool, such as stating use limits (e.g. prohibiting water use for irrigation of lawns or banning groundwater abstraction for agriculture). A combination of both tools is also possible.

In a normal market situation supply and demand are balanced though the price for the good (Figure 3.1). When demand is higher than supply, prices will increase. However, the market of water is often heavily regulated, so water is supplied at a cost which is ultimately sufficient to achieve cost recovery for water service providers (mostly a water utility), but which limits the profits of those suppliers. Furthermore, because the market for water is regulated, sudden changes in prices are difficult or impossible to implement.

Increasing prices will reduce the use of water for 'low end' uses, e.g. watering the lawn, but not affect the use of the water of 'high end' uses, e.g. drinking water. The case studies show that when water pricing policies are implemented in combination with other non-pricing measures, such as leakage reduction, water saving devices and awareness campaigns, increases in price are better accepted. Because of achieved water savings, the impacts of price increases are balanced, so total expenditures for water do not increase significantly.

The problem with an unanticipated shortage of water is that it is difficult to implement water metering and invoicing in a case where there is a shift from a non-rival use to a rival use of water. The only tool that can be applied on short notice is a policy tool. However, when shortages become systemic there will be a need to implement measures, like the introduction of water meters and tariffs to manage the effects of a water shortage.

Figure 3.1 Theoretical water demand curve illustrating the difference in price sensitivity (elasticity) for different quantity (volume) of water demand



Note: The top-left curve part marks a range of price increases that do not deliver significant reductions in water demand, because water demand is already very low and not very sensitive to price increases (i.e. inelastic to price increases). The lower-right curve part marks a range of price increases that deliver a significant reduction in water demand, because water demand is very high and very sensitive to price increases (i.e. elastic to price increases). The dashed line between these curve parts represents intermediate situations.

Source: adapted from Zetland, 2021

The use of Increasing Block Rate (IBR) implies that increasing tariffs are applied for increasing blocks of water use, so higher water use is charged at a different and higher price compared to lower water use. This aims at promoting a water saving culture. Another option is to create a tariff structure in which a 'water scarcity surcharge' is leveraged on the variable costs for water use. If the water use is lower than a chosen threshold, the surcharge is then rebated to the fixed costs within the tariff structure. This guarantees that sufficient funds are collected to cover both fixed and variable costs, while putting a price to the use of the scarce resource.

Financing of water services

There are three basic sources of finance for water services: revenues from (water) tariffs, taxes and transfers. Financing of investments can be arranged through other sources of finance (e.g. loans or subsidies), but repayment of the loans (or costs for re-investments in the case of subsidies) would be dependent on revenues collected through one of the mentioned basic sources (OECD, 2020).

The use of a tariff for water services works best when actual 'consumption' of the water service is measured, e.g. in the case of drinking water. However, for services that are difficult to measure, or have 'common goods' characteristics (e.g. flood risk), tariffs are difficult to implement. In the latter case taxes might be more appropriate. In the case of taxes, the sense of ownership is improved, when taxes for these services are earmarked, i.e. these special taxes can only be used for the purpose for which they are collected. For example, in the Netherlands, taxes for wastewater services, which are collected by municipalities and waterboards, can only be used to maintain and improve the same services of sewage collection and wastewater treatment. This mechanism of levying earmarked taxes for water services is also effective for the funding of flood risk reduction, as illustrated in a comparative study between Germany, the UK, the Netherlands and Australia in (Bisaro, et al., 2020).

In order to have a sustainable system of provision of water services, it is essential that the service provider receives full cost recovery. Furthermore, in order to establish a strong relationship between a service provider and a client, the payment from the client to the service provider should be at (or close to) cost recovery (World Bank, 2003). Tariffs below cost recovery levels often lead to poor service provision and higher costs for these services for low-income households (World Bank, 2003; Zetland, 2021). In the EU Member States, charging water services at full cost recovery rates does not pose a problem for more than 95% of households (OECD, 2020). Furthermore, with the introduction of an Increasing Block Rate tariff system the costs of basic water services can lower for the low-income households. Low-income households could also become exempt of certain taxes for water services.

Regulatory and legal measures

Proper water resources planning allocates water to economic uses, considering its efficient and sustainable use (WFD Art. 16). For example, the Portuguese Regional Water Efficiency Plans shall address water efficiency on golf courses with a diagnosis and proposals for improvement.

Legal frameworks, such as the Revision of the Administrative Decrees on Tourist Accommodation and Local Accommodation (Turismo de Portugal, 2021) or restrictions during periods of water scarcity are another enabling factor for efficiency measures. For example, during the 2022 drought, in the Algarve area (Portugal), and although there should be no real water restrictions for tourists, due to the indications provided by the Portuguese Environmental Authority, towels were in use for at least two days, water features in outdoor areas turned off, watering of outdoor areas greatly reduced or stopped and pool water replacement far less frequent. In addition, outdoor areas such as parking lots were no longer to be cleaned with the help of water (Golf Sustainable, 2022).

All EU Member States shall have proper control and inspection systems in place, as a need to enforce sustainable water use under the Water Framework Directive. However, the European Court of Auditors (ECA, 2021) detected improper systems in several Member States and significant indication that water use was not always appropriate for ensuring water use according to the scheduled permits.

Although drip irrigation has various benefits that may make it desirable (it reduces labour needs, increases yields, allows for fertigation, etc.), Perry and Steduto (2017) find that it can be associated with a ‘rebound effect’ in many cases. Where land is available the cultivated area is expanded, and also the water consumption per unit of land increases as a result of diversification to more water-demanding crops, increase in cropping intensity, etc.; much the opposite of what it claims to achieve. Where fruit trees expand, demand is made more rigid at the very moment climate variability dictates more flexibility, and risk increases. Likewise, canal lining eases distribution and enhances head-end/tail-end equity, but reduced infiltration may further upset the groundwater balance and impact groundwater appropriators. Therefore, irrigation efficiency investments require a clear legal framework to define and handle potential and effective water savings[8].

Governance

Additional to regulatory and legal measures, the governance mechanisms also strongly determine how much water can be saved, and how. It is necessary to understand which regulations, incentives, modes of planning and cooperation are already part of the enabling environment. Regulations establish the framework for responsible water use, with enforcement ensuring compliance. Incentive mechanisms, like pricing policies and subsidies, motivate conservation. Integrated planning and coordination among various sectors enhance the efficiency of conservation initiatives and shall be enhanced further to strengthen cooperation between upstream and downstream users. Transparency and public participation cultivate a

[8] As each case is individual, the balances of upstream and downstream impacts of projects should always be assessed, as required by the Environmental Impact Assessment (EIA) Directive (2011/92/EU as amended by 2014/52/EU) and relevant national legislation.

sense of responsibility among citizens, which is particularly important for the water saving measures in the public water supply.

The governance systems in which water saving potential is shaped and decided upon differ in each Member State, and there are some more behavioural aspects, such as compliance and social norms, that strongly shape the final effectiveness of water saving measures. These can be particularly challenging in Member States where there is a federal or quasi-federal political system. The way institutions are run and could be adapted matters for water saving, to have clear responsibilities and mandates. For instance, for ecosystem protection, the way ecological flow requirements are established and controlled is strongly dependent on the way the overall governance system is set up. The need to consider governance is best addressed by making the considerations mandatory from the beginning and by creating interdisciplinary teams for water saving projects. However, in reality it is a long way from making these institutional changes within the existing structures. A practical issue brought up by the WFD implementation is the re-delineation of RBDs (= where the power of river basin authorities is exerted) and water bodies (= water management units) in each WFD implementation cycle. Additionally, the dynamic restructuring of Ministries, Agencies, Departments, and Directorates can make long-term change processes more challenging.

Raising awareness, education and training

Raising awareness, education and offering training for different stakeholders on water saving options is a substantial enabling measure, because people who feel that it is important to save water, and know why and how, are more likely to do so. This is important for technical, operational, or habit changes, especially when the changes face initial resistance or seem uncomfortable. Actions like information campaigns, training events and positive framing increase social acceptability of water saving, and there are many positive examples that can be replicated at different scales (Text box 3.1).

Text box 3.1: Saving water through public awareness on electricity use

Providing smart meters and technology that offer feedback on electricity use can raise public awareness, but this alone may not lead to savings. Many people lack familiarity with energy concepts or need guidance on effective behaviour changes. Cost-focused energy monitors, which help overcome technical barriers, may be a more effective tool for encouraging electricity savings (Piccolo and Alani, 2016). In addition to lower energy costs, highlighting the environmental impacts of rising electricity use can motivate households to conserve. Many campaigns combine cost and environmental benefits, emphasizing that reducing electricity use can improve the quality of life for all (Kim, 2007).

- Germany's 'Energy Efficiency Pays Off campaign, initiated by the Federal Ministry of Economy and the German Energy Agency, exemplifies a successful long-term effort to conserve electricity. Co-sponsored by utility companies, it offers a platform for cooperation, interactive websites, educational quizzes, and information on EU energy labelling. The campaign also hosts workshops and conferences, provides a free energy-efficiency hotline, and features short, informative ads on saving electricity at home. This broad, multi-stakeholder approach effectively engages diverse audiences (Kim, 2007; Passive House Institute, 2022; BMWK, 2024; JRC 2016b).
- Latvia's 'Let's Live Warmer' campaign successfully encouraged citizens to improve building insulation by addressing gaps in knowledge and cooperation around energy efficiency. The campaign hosted seminars, conferences, and publications to promote awareness, resulting in a rise in funding applications and public discussions on energy efficiency. It continues today and was awarded as an 'ambitious and innovative' measure at the 2012 EE Sustainable Energy Week (JRC 2016b).

Raising awareness can greatly impact water savings in tourism by engaging both industry professionals and tourists. Training tourism employees helps mainstream water-saving practices and enhances the effectiveness of other solutions through staff engagement rather than prescriptive actions (UBA-DE, 2022a). Examples of replicable actions are provided in Text box 3.2.

Text box 3.2: Awareness raising in the tourism sector
Specific awareness campaigns in hotels to their guests are very common already (e.g. washing only towels on the floor, not changing bedlinens). Such sustainability goals and progress are often reflected in ESG[9] reports of hotel groups. The feasibility of transferring campaigns to decrease water demand through behavioural interventions (e.g. #SaveLikeALocal campaign in Cape Town) could be explored by European regions.

- The Portuguese Plan for Sustainable Tourism 2020-2023 promotes the densification of the training content on sustainability, circular economy and energy and water efficiency in the courses of the Schools4 of Turismo de Portugal, as well as digital training for sustainable and circular management of restaurants. It showed that educating key stakeholders such as golf club members, greenskeepers, and golf club managers can provide a greater understanding (Turismo de Portugal, 2021). When people have more information about an issue, they can adopt different management models. This also goes for the use of water at golf clubs and can look to bring about change within the industry (Booth, 2022).
- On the island of Juist (Germany), during weekly guest greetings, the tourism management organization informs their guests about the water supply on the island of Juist and ask them to save water during their stay (Weber, et al., 2017).

Market development and certification

Parallel to and in support of raising awareness, market development and certification can help guide the way for consumers and companies alike to follow certain basic environmental, including water-smart performances, putting their increasing awareness into action. Some examples: In the agricultural sector, Global G.A.P. is a globally recognized standard that enables primary producers to certify their efforts in food safety, sustainability and quality (Global Gap, 2024). The International Water Stewardship Standard (AWS Standard) is a globally applicable framework for major water users to understand their water use and impacts, and to work collaboratively and transparently for sustainable water management within a catchment context (A4WS, 2023). The Standard is intended to drive social, environmental and economic benefits at the scale of a catchment. The ISO 14001 as standard on water and energy saving provides standards as to how much less water can be used, while the EMAS (Eco-Management and Audit Scheme) is a premium management instrument developed by the European Commission for companies and other organisations to evaluate, report, and improve their environmental performance.

Provision of data and information

Timely and accurate data on water abstraction and water use across sectors is crucial for assessing pressures on water resources and ecosystems, supporting informed evaluations and decision-making.

In agriculture, understanding water abstraction and return volumes is essential for assessing farming sustainability. Factors such as conveyance system efficiency, crop type, irrigation technology, location, and water reclamation affect agricultural water needs. Accurate data on these aspects enables better informed policies and resource allocation, ensuring efficient water use.

Data on water abstraction and use is vital for optimizing production and reducing environmental impacts in manufacturing. Due to the diversity of industrial processes across Europe, comparing water use efficiency is challenging, and comprehensive facility-level data on output and water use is limited. The Industrial Emissions Portal Regulation (IEPR) (EC, 2024a) requires mandatory reporting -inter alia - on the water use of large industrial and animal rearing facilities. IEPR has replaced the E-PRTR. This development will enable better data availability in the future for estimating the water-saving potential. Reported data on water use by mining and quarrying activities remains scarce, as available datasets have considerable gaps.

[9] Environmental, Social, Governance. ESG investors seek to ensure the companies they fund are responsible stewards of the environment, good corporate citizens, and are led by accountable managers.

Energy production is another sector intensively reliant on water resources, especially for those technologies involving cooling water and hydropower generation. Understanding the link between energy generation and water abstraction assists in making more informed choices about energy mix and conservation efforts, ultimately promoting sustainable and environmentally responsible energy production (EC and JRC, 2017).

In public water supply, data reporting on water abstraction, use and leakages is instrumental in providing safe and reliable access to clean water for communities. This information is vital for assessing the adequacy of water supply systems, recognizing areas where improvement is needed, and maintaining public health. Timely reporting on water abstractions, when combined with spatial data, helps authorities identify regions with high demand and potential water stress, enabling efficient infrastructure planning and resource allocation.

Tourism is a sector where water demand and water use are embedded either overall into the public water supply or self-supply for which the specific data at European level in many cases is not available. This lack of information poses uncertainties on assessing the impacts of tourism on water resources distinguished from the water use by public water supply. Furthermore, there is usually a lack of distinct data on cruise travels, camping and large-scale events, such as festivals, concerts, sports gatherings, theme parks, etc.

In all sectors, reliable data are needed on operational management practices (e.g. when/how available equipment is used) including spatial and temporal distributions, penetration rates of measures by sector, economic costs and benefits of measures, impacts of water saving on resilience, gap closure of water scarcity considering gains from water saving measures versus climate change impacts.

However, incomplete data coverage is a significant challenge across many countries. Insufficient water statistics and reporting increase the already existing climate and socio-economic uncertainties during the assessment of water availability, pressures and impacts from sectorial activities, limiting the capacity of developing and implementing more effective water policies, not only at the national but also at the EU level. Better decision making can be supported by integrated data and information management, including state-of-the-art remote sensing (e.g. from Copernicus and other satellite programmes), modelling approaches (e.g. watershed models and digital twins), properly maintained ground monitoring programs and sectorial stakeholder engagement. Furthermore, cooperation between upstream-downstream countries is important, especially for transboundary water bodies. With the increase of digitalisation in the water sector, cybersecurity concerns should also be addressed.

4 Water saving potential in irrigated agriculture

4.1 Summary of the chapter

- *Water abstraction for agriculture on average accounts for 29% of total water abstraction and 50% of total water consumption in the EU, with an increasing trend in Southern Europe since 2010.*
- *Water saving can be achieved by reducing losses in water transport, improving operational management and improving irrigation technology. Individual measures could save 10-40% of used water.*
- *If the best conveyance performance of countries in the same European region is used as a proxy for estimating potential water savings in conveyance systems, the EU-27 could save about 10% of its agricultural water abstraction. The same approach applied to the national application efficiency, yields an estimated 8% saving of abstracted water for agriculture annually. Disclaimers are that actual and local conditions are not accounted for in these estimates.*
- *Theoretically, the water saving potential in irrigated agriculture is up to 20% of total water abstraction. In practice, the actually achievable saving can be much lower (e.g. 5%) due to technical and economic constraints.*

Agriculture is a key sector for water saving strategies, as it is responsible for 29% of the total water abstraction and 50% of the total water consumption in the EU-27 between 2000 and 2022. Especially in Southern Europe, water abstraction and water consumption amount to 60% and 74% of the total regional values, respectively. If under the impact of climate change an increasing area of European agriculture will require water supply in the future, water scarcity may aggravate there and the interest in improved water use efficiency will spread to those areas. Water saving in agriculture presents a large potential, with water saving measures covering four main areas (Table 4.1), namely operational management, irrigation water conveyance, irrigation water application and selection of drought-resistant crops and cultivars.

Table 4.1 Overview of the main areas for water saving in agriculture

Irrigation water conveyance	canal lining; construction of closed pipes; digitalisation of the water infrastructure management
Irrigation water application	surface to sprinkler irrigation; sprinkler to drip irrigation; subsurface irrigation;
Selection of drought-resistant crops and cultivars	shift to less water-demanding crops where this is justified; grow cultivars with better drought-resistance, deeper rooting depths, shorter stems, shorter growing seasons
Operational management practices	smart farming, including satellites, drones, ground sensors and digitally connected equipment; sprinkling at night to reduce evaporation losses deficit irrigation; precision farming, supported by climate services and decision support systems

These measures are particularly beneficial when they help reduce water consumption (i.e., help reduce evaporation). That can be the case when closed conducts are installed, when deficit irrigation is introduced, or when unproductive soil evaporation is reduced. When measures are introduced, care must be taken that the saved water is used to build resilience and that rebound effects are avoided (see also chapter 3). Some water-saving measures help reduce abstraction without reducing consumption, for example by reducing leakage losses or by avoiding over-irrigation. In these cases, the potential use of the spilled water downstream must be accounted for.

The implementation rate of these measures across the EU varies widely. There are indications that in some regions or river basins, most notably those that cope with the severest degrees of water stress, the feasible water saving measures have already been taken (Expósito and Berbel, 2017; Fundação Gulbenkian, 2020; Wencki, et al., 2020), reducing room for further savings. For example, in Portugal, 61% of the responders (in a representative survey carried out in 2020) had already shifted to drip irrigation. Added to this the fact that drip irrigation is not suitable for all crop types, suggests that in this respect the maximum implementation rate is close to being achieved. Furthermore, shifting to less water-demanding crops and cultivars requires, in many cases, additional research and time for the development of such cultivars (EIP-AGRI, 2016) as well as for adaptations in the food chain in the case of selecting different crops (EEA, 2021a)

Table 4.2 Overview of promising operational management and technical water saving measures in agriculture

Category	Measure	Aim, related to water saving	Potential saving (m^3 or %)	Remarks
Irrigation water conveyance	Replace earthen canals with lined canals	Reduce leakage during transport	Increase conveyance efficiency from 50-80% to 85-95% -> potential saving up to 95% locally -> potential saving at EU level, calculated from efficiency benchmarks, up to 11%	N.B. It should be assessed if and how the leaked water is currently used. N.B. 93% of this potential in South Europe.
	Replace lined canals with closed pipes	Reduce evaporation during transport	Increase conveyance efficiency from 85-95% to 90-95% -> potential saving up to 12 % locally -> potential saving at EU regional level included in 11% mentioned above	Table 4.5
	Introduce routines for check and repair of the distribution system	Reduce leakage during transport	Not quantified	
	Keep control of over- and under allocations by adequate planning and maintenance	Reduce end-of-system spillings	Not quantified	
Irrigation water application	Replace surface irrigation by sprinkler irrigation	Reduce evaporation and seepage losses	Efficiency increases from 56-60% to 75% -> potential saving up to 45% locally	
	Replace sprinkler irrigation by drip irrigation	Reduce evaporation and seepage losses	Efficiency increases from 75% to 86-90 % -> potential saving up to 22% locally	
	Introduce sub-surface irrigation	Reduce evaporation and seepage losses	Up to 30% locally	
		Combined savings based on benchmarks of national data	Potential saving of 8% in abstraction volume	
Selection of drought-resistant crops and cultivars	Grow less-water-demanding crops or cultivars	Transpire less water	Not quantified	Potential depends on market
Operational management practices	Introduce precision farming	Reduce evaporation and seepage losses	Water savings of 20-40% locally	

Category	Measure	Aim, related to water saving	Potential saving (m^3 or %)	Remarks
	Introduce deficit irrigation	Increase crop yield in kg/m3 water (at the cost of yield in kg/ha)	Water savings up to 30% locally	
	Avoid sprinkling with wind speed > 3 m/s	Reduce evaporation and over-irrigation during use	Sprinkling at night reduces wind and evaporation losses by 50%, compared to noon. Losses reported in literature range from 8-44% at noon to 5-10% at night	
	Improve soil management: zero tillage, mulching.	Reduce soil evaporation, increase soil moisture content	Not quantified	Limited quantitative information on effectiveness

Note: The references to the data presented are provided in the text of this chapter.

Overview of the agricultural sector

The agricultural sector includes the growing of crops, raising and breeding of animals, harvesting of timber and other plants, animals or animal products from a farm or their natural habitats. Included are service activities incidental to agriculture, excluded the subsequent processing of the agricultural products beyond what is needed to prepare them for the primary markets. The focus in this report is on growing perennial and non-perennial crops, because these activities require by far the largest volumes of water (for irrigation).

The EU-27 in 2020 used 38% of its total land area for agricultural purposes, and this area has increased only marginally in recent years (+ 0.3% between 2005 and 2020). The volume of the output of the EU-27's agriculture was almost 3 % lower in 2022, compared to 2013, after a peak of +8% in 2019. The estimated value of agricultural output however, rose sharply in 2022, in nominal terms (+19%). This change in nominal value largely reflected the sharp rise in the nominal price for agricultural goods and services as a whole.

4.2 Water abstraction and consumption of the agricultural sector in Europe

The agricultural sector requires large amounts of water for its various activities, most notably for crop farming. Agriculture is responsible for 29% of total water abstraction and 50% of total water consumption from all sectors in the EU-27 between 2000 and 2022[10].

However, the geographical distribution of water abstraction for agriculture is markedly uneven. Around 85 % of the total water abstraction for agriculture in the EU-27 takes place in Southern Europe, whereas only 30% of the total utilised agricultural area is located within this region (Table 4.3). This is partly related to climate conditions in the region, but also to the types of crops and demands for water irrigation. On average, the irrigation abstraction per hectare of irrigated land is the highest in Southern Europe, out of all European regions (Figure 4.1). In 2016, nearly 19 million ha were equipped for irrigation and 9 to 10 million ha were actually irrigated. In Southern Europe the percentage of irrigated land is much higher, from 13% in Spain and Portugal to 28% in Malta (EEA 2021b). In 2016, the average irrigation abstraction per hectare of irrigated land was around 5400 m^3/ha (or 540 mm) in Southern Europe, 1950 m^3/ha (or 195 mm) in Eastern Europe, 890 m^3/ha (or 89 mm) in Western Europe and 460 m^3/ha (or 46 mm) in Northern Europe. The European average that year was 2560 m^3/ha (256 mm).

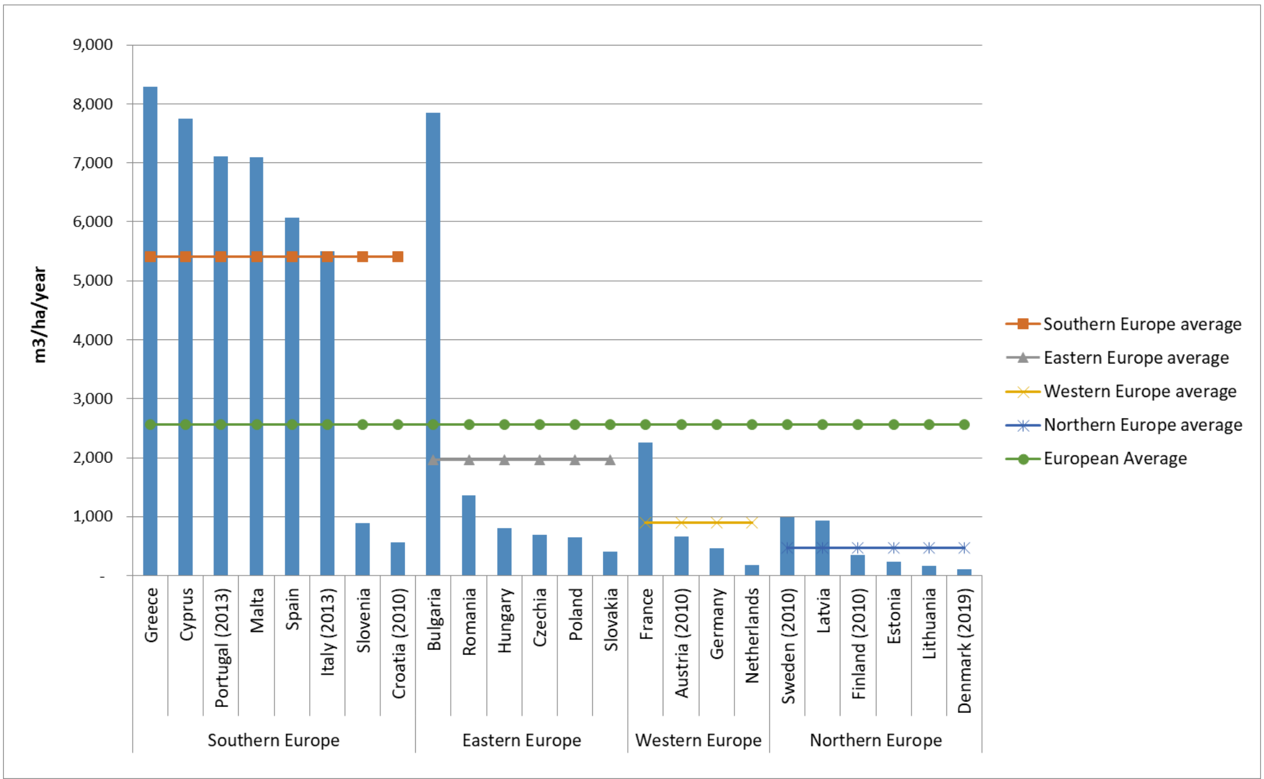
[10] The figure on water consumption by agriculture refers to agricultural activities only; other directly and indirectly associated sectors are not included.

Table 4.3 Utilised agricultural area and water abstraction for agriculture by region in the EU-27 (averaged 2000-2022)

EU-27	Eastern Europe	Northern Europe	Southern Europe	Western Europe
Utilised agricultural area	28%	11%	30%	31%
Water abstraction for agriculture	6.5%	1.5%	85%	7%

Source: EEA, 2024b; Eurostat, 2024a

Figure 4.1 Irrigation abstraction per hectare of irrigated land in Europe by 2016



Note: Comparisons between different regions is not meaningful, due to differences in climatic conditions / water availability, crop types as well as production systems.
According to Austrian authorities, 2010 is not a representative year for the country, as weather conditions were wetter than average.

Source: EEA 2021b

Water abstraction for agriculture decreased by 17% between 2000 and 2022. However, since 2010 an increasing trend can be observed (EEA, 2024b). Scenario-based assessments suggest that climate change may increase water demand in agriculture, particularly in Southern Europe and drive the expansion and diversification of agricultural activities in Northern Europe (Feyen, et al., 2020). Hence, there is a likelihood that efforts made towards water savings are counteracted by the expansion of irrigated areas and the need for more water per hectare. This could create a lock-in as climate change progresses. At the time of writing no data are available to verify such hypotheses. Table 4.4 provides a qualitative, non-exhaustive overview of key drivers of the increasing and decreasing of water demand in irrigated agriculture. The net result of these partly counteracting trends is highly uncertain, variable across the EU and has not been quantified.

Table 4.4 Expected key changes and impacts on demand for irrigation water in agriculture

Relevant drivers in agriculture	Expected trend in driver (increase/decrease)	Expected impact (increase/decrease) on water demand
EU population by 2100	↘	↘
Water-efficient technology and operational management	↗	↘
Income and living standards - high-value and high-water-use crops	↗	↗
Climate change: frequency and intensity of droughts, area of Europe that is affected.	↗	↗
Climate change: length of the growing season	↗	↗
Water-awareness of the public while making food choices	↗	↘
Waste of food	↘	↘
Competitive strength of European agriculture and changes in global import-export balances of water-intensive crops	Variable	Variable

Note: Green indicates a positive effect on water demand (i.e., decreasing demand); orange indicates a negative effect.

Source: Authors' elaboration

4.3 Water saving potential and measures in agriculture

4.3.1 Assessing potential improvement of water intensity in European agriculture

Comparing the total water consumption in agriculture with the net value added (NVA) of the agricultural sector, indicates that the growth of the agricultural production shows early signs of decoupling from water consumption in Northern, Western, and Southern Europe, but not in Eastern Europe. Despite these indications of decoupling, there are uncertainties which prevent from firm conclusions, such as the inter-annual differences in water availability, crop types, and production systems. Table 4.5 presents the average ratio of water consumption and net value added by agriculture (water intensity of agricultural production) at the regional level, alongside with the same ratio for the best performing country in the same region. This comparison serves as a rough indication of the different performances within the same region. However, numbers should be read with caution, as they do not represent necessarily technically and economically feasible improvements. Furthermore, the impact of soil moisture levels is not accounted for, which may favour countries depending more on rainfed agriculture. Therefore, the comparison with the best performing country could lead to very ambitious expectations in terms of water saving potential. However, in a more modest ambition scenario, where each country in each region could achieve at least the same performance as the regional average of water intensity, the potential water saving by the agricultural sector could be around 12 % at the EU level (Table 4.6).

Table 4.5 Water intensity of agricultural production by region in the EU-27

Regional average of water intensity		Water intensity of best performing country within the region	
	m³ / 1000 PPS		m³ / 1000 PPS
Eastern Europe (BG, CZ, HU, PL, RO, SK)	61.0	CZ	12.1
Northern Europe (DK, EE, FI, IE, LT, LV, SE)	63.3	FI	14.3
Southern Europe (CY, ES, EL, HR, IT, MT, PT, SI)	562.1	MT	187.0
Western Europe (AT, BE, DE, FR, LU, NL)	78.6	NL	12.1

Note: Water intensity of agricultural production is calculated as the ratio of the volume of water consumed by agriculture per Member State and the net value added of agricultural production, expressed in the Purchasing Power Standard (PPS), which adjusts values in national currency to a common unit considering purchasing power in every country. Net value added is computed as gross value-added excluding consumption of fixed capital, all expressed in chain-linked volumes (2010). Agricultural production includes dominantly crop farming, animal raising, aquaculture and forestry, but also fishing and hunting. The impact of soil moisture levels for crop farming is not accounted for, which may favour those countries depending more on rainfed agriculture (i.e. showing lower water intensity).
Data refer to the period 2000-2022. The water intensity of agricultural production in Slovenia and Croatia is estimated at 4.4 and 10.1 m^3 per 1000 PPS, respectively, aligning with western instead of southern European countries. For the sake of regional consistency, the water intensity of Slovenia and Croatia is not used for comparison with the regional average intensity of Southern Europe and replaced by the water intensity of the next best performing country (Malta).
Comparisons between different regions may not be meaningful, due to differences in climatic conditions / water availability, crop types as well as production systems.

Source: EEA, 2024b, 2024c; Eurostat, 2025a, 2025b; Authors' elaboration

Table 4.6 Estimated water saving potential by improving the water intensity in agriculture in the EU-27

Region	Average annual water abstraction by agriculture (million m³)	Estimated annual volume of water that can be saved (million m³)	Theoretical water saving (%)
Eastern Europe (BG, CZ, HU, PL, RO, SK)	3 800	650	17
Northern Europe (DK, EE, FI, IE, LT, LV, SE)	820	490	60
Southern Europe (CY, ES, EL, HR, IT, MT, PT, SI)	50 400	4 030	8
Western Europe (AT, BE, DE, FR, LU, NL)	4 280	1 920	45
EU-27	59 300	7 090	12

Note: The values in the table have been estimated based on the annual average volume of water abstraction for the period 2000-2022, assuming that all countries within the same region can achieve at least the average water intensity of that region. Markedly, if saved water is used to expand agricultural production or exploited by other users within the same river basin, then the results of the water saving effort could be partly or totally reversed.

Source: EEA, 2024b, 2024c; Eurostat, 2025a, 2025b; Authors' elaboration

Curbing conveyance losses of irrigation water

Water for agriculture is abstracted either from rivers, lakes, reservoirs, and groundwater (off-farm supply) or directly from surface water and groundwater (on-farm supply). During conveyance to the farming areas, a portion of water is lost as leakages or evaporation from open channels. According to the available data, the conveyance efficiency in the EU-27 varies between 75% (e.g., Italy and Bulgaria) and above 95% (e.g., Malta, Latvia, Denmark)[11].

Canal lining and construction of closed conduits to prevent leakage and evaporation is most relevant for private-collectively or public-owned irrigation systems with extensive transport and distribution networks. However, recent European data on the percentage of agricultural land served by these systems is lacking. It is assumed that groundwater is primarily used by single users, while surface water is used by larger systems, with 79% of irrigation water sourced from surface water (EEA, 2024b).

The best conveyance performance of countries in the same region (Annex 2, Figure A.2.1) can be used as a proxy for estimating potential water savings in conveyance systems in other EU countries. Consistent with this approach, the estimated values show that the EU-27 could save about 6,070 million m^3 of water annually through improvements in the conveyance system. This would reduce the agricultural water abstraction by about 10%. The largest potential gain is expected in Southern Europe, where about 5 540 million m^3 of water could be saved (Table 4.7). These savings could overlap with those shown in Table 4.6, as the improvement of conveyance efficiency can contribute to the improvement of water intensity.

Table 4.7 Estimated water saving potential by improving the conveyance efficiency in agriculture in the EU-27

Regions	Average annual water abstraction by agriculture (million m^3)	Estimated annual volume of water that can be saved (million m^3)	Theoretical water saving (%)
Eastern Europe (BG, CZ, HU, PL, RO, SK)	3 800	300	8
Northern Europe (DK, EE, FI, IE, LT, LV, SE)	820	15	2
Southern Europe (CY, ES, EL, HR, IT, MT, PT, SI)	50 400	5 540	11
Western Europe (AT, BE, DE, FR, LU, NL)	4 280	215	5
EU-27	59 300	6 070	10

Note: The values in the table have been estimated based on the annual average volume of water abstraction for the period 2000-2022, assuming for each region that the average conveyance efficiency is equal to that estimated for the best performing country within that region. Markedly, if saved water is used to expand irrigated areas or exploited by other users within the same river basin, then the results of the water saving effort could be partly or totally reversed.

Source: EEA, 2024b; EEA, 2017; Authors' elaboration

[11] Due to the lack of comprehensive data on conveyance efficiency in Europe, assumptions have been made regarding different water source combinations in agriculture. For on-farm water supply from surface or groundwater, conveyance efficiency is assumed to be nearly 100%. For off-farm surface water (e.g., reservoirs, lakes, rivers), a conservative efficiency value of 75% is used. Off-farm water from public supply networks experiences similar losses. Average conveyance efficiency for public water supply networks has been approximated using Eurostat data on water use and abstraction. Losses are calculated as the difference between water abstraction and use at the supply point. The latest available values per country have been used due to gaps in the datasets.

4.3.2 Improving application efficiency of irrigation water

The type of irrigation that is in use has a substantial impact on water demand for agriculture. Overall, irrigation is applied in three major types: surface, sprinkler and drip. Sprinkler irrigation can be further divided into hose-move, traveller spray boom, centre pivot irrigation systems, micro-sprinklers and mini-sprinklers (Phocaides, 2007). A development of drip irrigation, relatively high-tech, is subsurface irrigation or subirrigation: drip irrigation with the drip lines installed below the surface, thus reducing evaporation losses even further. The efficiency[12] of each type may differ substantially given the local conditions, timing of irrigation, season, crop type, soil type, topography etc. Not all irrigation types are suitable for all crop types (Table 4.8).

Table 4.8 Suitability of irrigation methods for different crop types

Drip irrigation is suitable for:	fresh vegetables, melons, strawberries – open field, fruit and berry plantations, citrus plantations, olive plantations, vineyards.
Sprinkler irrigation is suitable for:	cereals (excl. maize and rice), maize (grain and green), pulses, potatoes, sugar beet, rape and turnip rape, sunflower, textile crops, temporary and permanent grass, other crops on arable land.
Surface irrigation is suitable for:	particularly for rice farming

Source: adapted from Phocaides, 2007

According to available information, the efficiency of drip irrigation is around 90% of total water abstraction, supplied to the farms, followed by sprinkler 75% and surface irrigation 60% (Howell, 2002); (Confederación Hidrográfica del Guadalquivir, 2015); (Berbel Vecino, et al., 2017). (Benitez Sanz, et al., 2018) concludes on somewhat lower figures: 86%, 75% and 56%, respectively. The estimates of (Benitez Sanz, et al., 2018) were also used in the JRC's EU-wide calculations of the effect of water saving measures on the Water Exploitation Index plus (WEI+) (De Roo, et al., 2023). Table 4.9 (Phocaides, 2007) summarises the estimated application efficiency[13] of various on-farm irrigation systems and methods.

Table 4.9 Estimated application efficiency of various on-farm irrigation systems and methods

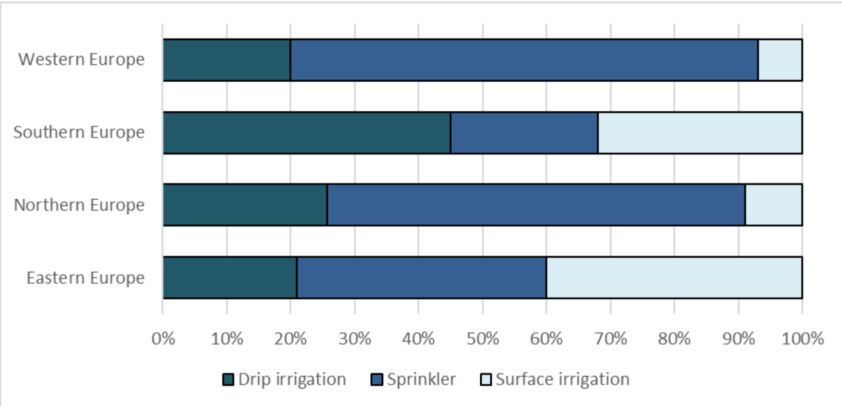
System/method	Application efficiency (%)
Earthen canal network surface methods	40 – 50
Lined canal network surface methods	50 – 60
Pressure-piped network surface methods	65 – 75
Hose irrigation systems	70 – 80
Low-medium pressure sprinkler systems	75
Micro-sprinklers, micro-jets, mini-sprinklers	75 – 85
Drip irrigation	80 – 90

Source: Phocaides, 2007

[12] Irrigation efficiency is defined as the ratio between the volume of water required for irrigation, and the volume of water that is diverted from the source of supply (FAO, 2016).
[13] Application efficiency is defined as the percentage of applied water that is stored in the rootzone, divided by the total volume of applied water

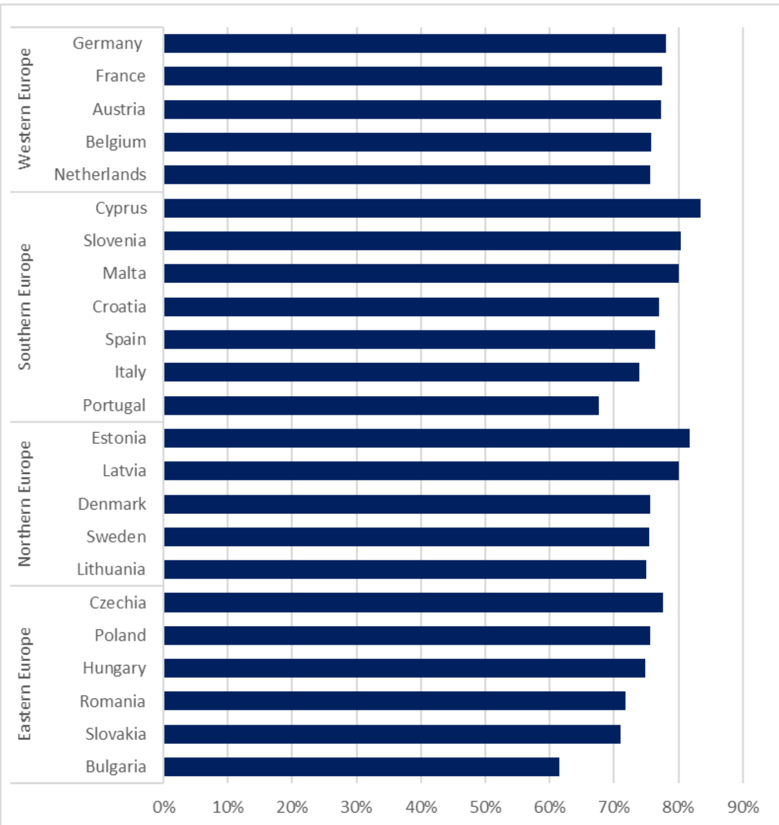
Overall, sprinkler irrigation is a widely used type of irrigation across Europe with large regional variations (Figure 4.2). At the country level, drip irrigation systems are widely applied in Cyprus (in 75% of agricultural holdings), followed by Malta and Slovenia. Sprinkler irrigation systems are widely used in Denmark, followed by the Netherlands and Sweden. As for surface irrigation systems, which have the highest water demand per hectare, these are widely used in Bulgaria, Slovakia and Romania (Annex 2 - Figure A.2.2). Considering the application efficiency of the different irrigation systems in place in each country, the average application efficiency of irrigation water at the national level has been approximated. Large variations can be observed across different countries (Figure 4.3).

Figure 4.2 Application of different irrigation systems in different regions of EU-27 (in % of agricultural holdings)



Source: Eurostat, 2018

Figure 4.3 Average application efficiency of irrigation water in different EU Member States



Source: Eurostat, 2018; EEA, 2017; JRC, 2008; Phocaides, 2007; Brouwer, et al., 1989

The application efficiency affects the volume of water returned from agriculture to surface water and groundwater. Information on water returns from agricultural activities is insufficient, based on internationally reported data. Therefore, the average application efficiency of irrigation water is used as a proxy to estimate the water returns from agricultural activities. According to this approach, the average annual return of agricultural water in the EU-27 is estimated at 22 450 million m^3 between 2000 and 2022. This corresponds to 37% of the total annual water abstraction in the EU-27, for the same period. Based on the best performing country in each region, in terms of the national application efficiency, it is estimated that the EU-27 can save around 4 900million m^3 or 8% of the abstracted water for agriculture annually (Table 4.10). The largest water savings can be obtained in Southern Europe, where 4 540 million m^3 could be theoretically saved by shifting from surface to sprinkler to drip irrigation systems. Also, in Eastern Europe significant water saving is possible, by the same measure, particularly in Bulgaria, Slovakia and Romania. These savings could overlap with those shown in Table 4.6, as the improvement of application efficiency can contribute to the improvement of water intensity.

Table 4.10 Estimated water saving potential by improving the application efficiency in agriculture in the EU-27

Region	Average annual water abstraction by agriculture (million m^3)	Estimated annual volume of water that can be saved (million m^3)	Water saving (%)
Eastern Europe (BG, CZ, HU, PL, RO, SK)	3 800	270	7
Northern Europe (DK, EE, FI, IE, LT, LV, SE)	820	49	6
Southern Europe (CY, ES, EL, HR, IT, MT, PT, SI)	50 400	4 540	9
Western Europe (AT, BE, DE, FR, LU, NL)	4 280	43	1
EU-27	59 300	4 900	8

Note: The values in the table have been estimated based on the annual average volume of water abstraction for the period 2000-2022, assuming for each region that the average application efficiency is equal to that estimated for the best performing country within that region. Markedly, if saved water is used to expand irrigated areas or exploited by other users within the same river basin, then the results of the water saving effort could be partly or totally reversed.

Source: EEA, 2024b; Eurostat, 2018; EEA, 2017; JRC, 2008; Phocaides, 2007; Brouwer, et al., 1989

However, there can be significant distance between the theoretical potential for water saving and water saving, which is technically and economically achievable. According to a representative study carried out in Portugal in 2020, 61% of the survey respondents had already shifted to drip irrigation (Fundação Gulbenkian, 2020).The above fact suggests that the maximum penetration rate of drip irrigation may have been achieved or is close to being achieved, as drip irrigation is not suitable for all crop types. Furthermore, the JRC has calculated the potential effect of selected water saving measures on water scarcity conditions (WEI+ indicator values), suggesting that budget constraints can have a big impact on what is achievable (De Roo, et al., 2023). In specific, it was found that the implementation of the planned agricultural water saving measures with the currently allocated budgets, can increase irrigation efficiency only by 1 to 4% in Spain, Italy, Greece, France and Portugal (i.e. the five Member States with the largest areas of irrigated land. Moreover, there are cases where water efficiency gains can be partly or totally offset by the so-called 'rebound effect' (see Text box 4.1).

Text box 4.1: Water saving measures for irrigation in Austria

The evaluation of the ÖPUL[14] measures in Austria (RDP Austria, 2019) indicates a_reduction of 6% in applied irrigation volume in areas where water saving measures were implemented. Such measures included the increased use of drip irrigation in viniculture and orchards, and improved control of irrigation timing and irrigation volume optimization in field crops. The evaluation also showed that, in some cases, water savings were partly used to increase the irrigation (and output) of crops with high irrigation requirements (rebound effect).

Improving the conveyance and application efficiency of agricultural water may reduce the pressure of diffuse source pollution to surface and groundwater resources and increase the usability of water downstream in ecosystems and economy. Water returns from agriculture contain large amounts of nutrients, which end up leaching into surface and groundwater bodies. Such emissions may cause eutrophication in standing waters, such as lakes and reservoirs, and deteriorate ecosystem conditions and health. According to the 3rd RBMPs reported by EU Member States[15], nutrient pollution was identified as a significant impact for 30% of surface water bodies and 10% of groundwater bodies (EEA, 2024d).

4.3.3 Selection of drought-resistant crops and cultivars

A measure that seemingly can be taken at farm level is to choose crops and cultivars that root deeper, have a shorter growing season, are more drought-resistant and/or require less water for their growth. This could have a significant impact on water consumption but the evidence to quantify the potential water savings in Europe is still largely lacking (EIP-AGRI, 2016). However, an inventory of available literature with a focus on Asia and the Pacific (FutureWater, 2020) points to considerable possible reductions in irrigation volume (up to 23% for cultivars with a shortened growing season).

Farmers depend on market demand and on the supply chain, which is designed to the current spatial distribution of crops, to change their production (EEA, 2021a). Changing cropping patterns must therefore be a coordinated effort through the food chain. A bottleneck seems to be that water does not play a role in consumers' food choices (Fundação Gulbenkian, 2020) and that until recently EU regulations have stimulated the cultivation of profitable but high-water demanding crops (EEA, 2021a). As of yet, the potential and feasible water saving of this measure could not be assessed.

A last way to reduce water consumption in agriculture to be mentioned here is to prevent food waste. The overall waste of food adds up to 20%. Bringing this down by 50% is one of the targets of the Farm-to-Fork strategy (EEA, 2021a).

4.3.4 Improved operational management practices at farm level

Operational and management measures to increase water use efficiency

The water conveyance and the on-farm water use efficiency can often be increased by improved operational management practices, such as adequate maintenance of the transport and distribution network, avoiding sprinkling during windy periods and at noon time, introducing deficit irrigation and smart / precision farming practices, integrating climate services with decision support systems (see Text boxes 4.2, 4.3 and 4.4).

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[14] ÖPUL stands for (in English): Austrian Program for promotion of environmentally friendly, extensive agriculture that protects the natural habitat.

[15] By the time of drafting this report, electronic data from the 3rd RBMPs were available only for 19 out of 27 EU Member States: Austria, Belgium, Croatia, Czechia, Denmark, Estonia, France, Germany, Italy, Latvia, Lithuania, Luxembourg, Netherlands, Poland, Portugal, Romania, Slovakia, Spain, Sweden.

Smart farming practices or precision farming can be summarized as managing crops not at the scale of a plot but at the scale of square meters or even individual plants. It may come, however, with considerable investments in data collection, measuring equipment (meteorology, soil water content, etc.), data processing, processing of satellite imagery and equipment to apply water, nutrients and crop protection at the desired differentiation. Smart farming practices can thus be considered as part of the 'grey area' between operational management measures and technical measures.

Text box 4.2: Indicative examples of water saving estimates from changing operational management practices

- Playán, et al. (2005) report wind and evaporation losses in sprinkling systems in Zaragoza, Spain, of 5-9% at night and 10-15% during daytime. (Naderianfar, et al., 2018) summarize recent papers on the impact of wind and pressure on evaporation and drift losses in sprinkling. They conclude from their own experiments that the losses of sprinkling at noon are about twice as high as those during the night and early morning.
- The stated goal of the EIP-AGRI OG H3 project (EU CAP Network, 2024) is to obtain water savings in horticulture in Andalucia, Spain by at least 25%, by the provision of high-precision data, supporting farmers in their decision making on irrigation.
- The SmartAg project aims at 15% water and fertilizer savings in smart agriculture pilots (Smart Ag Services, 2018).
- In orchards in Tarn et Garonne, France, improved water management through the choice of more adequate irrigation systems and by enhancing their efficiency, thus adjusting the water quantity to the needs, led to water savings of around 30%, i.e. 1000 m^3/ha on average for several years in apple orchards. These data are being verified at CEFEL (EIP AGRI, 2018).
- The Nature Conservancy estimates potential savings in water and nutrients resulting from smart farming practices at 20 to 40% (Nature Conservancy, 2017).

Text box 4.3: An optimised toolbox measures to save water and halt desertification in the Pinios river basin, a major agricultural area in Greece

The Pinios river basin (1 million hectares) is one of the major agricultural areas in Greece, primarily growing cotton, winter wheat, maize, and alfalfa. Nearly half of the 400,000 hectares cultivated is irrigable, with about one-third of irrigation water transported through collective systems that experience high conveyance losses (30-50%). The rest comes from private sources like pumps and boreholes. Irrigated agriculture accounts for nearly 90% of total water abstraction. Unsustainable practices have led to significant groundwater over-exploitation, with levels dropping over 100 meters, resulting in increased costs, seawater intrusion, and water scarcity. This has reduced river flows and caused partial dry-ups downstream during extreme conditions. Water quality issues, including nitrate and pesticide pollution, are worsened by lower water volumes. Most groundwater bodies in the basin have not achieved good quantitative or chemical status, and surface water bodies often fail to meet good chemical or ecological standards.

Research has examined measures to save water in the Pinios river basin. Farm plot experiments found that deficit irrigation could save up to 30% of water for cotton, corn, and alfalfa with minimal impacts on crop productivity and income (up to 7%). A precision agriculture approach using on-farm sensors could save up to 35% of irrigation water for cotton without any productivity loss. Furthermore, upgrading irrigation networks—such as lining earthen trenches, switching from open canals to closed pipes, and moving from surface to sprinkler or drip irrigation—could reduce leakages and evaporation losses by up to 30%. Expanding water reuse in peri-urban cotton fields could also significantly conserve groundwater. A modelling exercise identified that, considering physical constraints and investment costs, optimised combinations of measures could save up to 220 million m^3 per year (24% compared to baseline conditions), restoring a sustainable water balance. The estimated net financial cost of implementing these measures is 22.3 million € per year, or 0.10 € per m^3.

Panagopoulos, et al., 2014; Stefanidis, et al., 2016; Psomas, et al., 2016.

Text box 4.4: An online information system for irrigation advisory in Emilia Romagna, a major agricultural area of Italy

Emilia-Romagna, a major agricultural region in Italy, cultivates about 1 million hectares across over 84,000 farms, with irrigation used on approximately 33% of these farms. Water availability is low compared to other areas of the Po River basin, and changing rainfall patterns have led to significant water deficits. Climate projections indicate further decreases in spring and summer rainfall by 2050, contributing to droughts in 2003, 2012, and 2022, which severely impacted crop yields and increased risks for agriculture.

To enhance water use efficiency, regional authorities have improved governance and developed innovative IT solutions for irrigation scheduling. The first irrigation advisory project began in 1984, leading to the creation of IRRINET in 1999 by the Canale Emiliano Romagnolo (CER). This web-based service inspired the National Association of Land Reclamation Boards (ANBI) to create IRRIFRAME, the most advanced irrigation information system in Italy. In some regions, using IRRINET/IRRIFRAME is mandatory to meet European Regional Development Fund requirements.

IRRINET is free for over 12,000 registered farms, providing daily irrigation scheduling via web, SMS, or mobile apps. It processes meteorological, soil, groundwater, and crop data through a mathematical model to calculate daily water needs. This information is integrated with Google Maps, allowing farmers to identify irrigation requirements for specific plot areas. IRRINET has saved an estimated 90 million m³ of water annually, representing a 20% reduction in agricultural water demand without compromising crop production, while also reducing energy use and CO2 emissions from pumping.

The development of IRRINET cost €200,000, with an annual management cost of €0.02 per hectare, funded by public expenditure and EU projects. Future plans include integrating sensor systems and remote sensing data to improve accuracy and address data scarcity. IRRINET can be adapted to other regions if local calibration data are available, although a lack of daily meteorological data or georeferenced soil maps may pose challenges. Data for IRRINET is sourced from the regional Weather Service, Geological Service, and CER.

IRRIFRAME, 2023; Climate-ADAPT, 2022

Soil management to save and store water

At farm level, a wide range of measures are available to promote sustainable soil management and, simultaneously, store and save water. These measures are rather adjustments of daily operational practices than structural measures; many can be regarded as no-regret nature-based solutions. Relevant examples include improved soil management aimed at rainwater harvesting and reduction of peak flows, increasing soil moisture content and water buffering, conservation tillage, sowing in mulch beds, application of mulch films and no tillage. These can help increase the amount of infiltrating precipitation, while keeping unproductive evaporation losses low. Due to the increased soil water content at the beginning of the growing season, irrigation demand is reduced. Furthermore, they increase the organic carbon content of the soil and they decrease the energy requirements of farming.

However, these effects are difficult to quantify in the EU context, as the body of evidence is limited (see Text box 4.5). An overview is provided, among others, by the EU Landmark project (Landmark, 2018) and in EEA (2021a). Sustainable soil management measures can be closely related to rainwater harvesting, which is discussed in section 9.1, and to Natural Water Retention Measures (NWRM), which are left outside the scope of this report. A catalogue of NWRM is available at the NWRM website (Climate-ADAPT. 2018).

Text box 4.5: Improved soil management

Information about the effectiveness of soil management measures is often not available in quantitative terms, so more research is needed. Nonetheless incentives to apply them include easy implementation, low costs, multiple benefits, contribution to better soil and water condition and compatibility with the overall objective of the European Green Deal to promote more sustainable farming practices (EC, 2019b).

A literature survey on the effectiveness of some selected measures (increasing organic carbon content, increasing infiltration capacity of the surface) on soil water content and storage capacity in the Netherlands (HHNK et al., 2020) revealed the following:

- Increasing organic carbon content of the soil has potential positive impacts on soil biology and structure, which in turn have a positive impact on infiltration capacity and water retention capacity. The degree to which these effects materialize depends largely on local circumstances, with soil type being a major determinator. In sandy soils the measure is more effective in soils with low carbon content, where the soil retention capacity may increase by 15% (in absolute terms however, only a few mm). In clay soils the measure can be effective, but there may be trade-offs in cases where an increased carbon content leads to a decrease of cracks and a subsequent decrease of infiltration capacity. It should also be noted that increasing soil carbon content significantly (by at least 1%) is a long process.
- Increasing the infiltration capacity of the soil is, in many circumstances, an effective way to increase infiltration, reducing (in the first place) overland flow and interflow, and (secondary) increasing the soil water capacity at the beginning of the growing season.
- Williams and Hedlund (2013) found no difference in the soil water retention capacity between conventional and organic farms in southern Sweden.

5 Water saving potential in electricity production

5.1 Summary of the chapter

- *Water abstraction for electricity production accounts for 36% of total water abstraction and 20% of total water consumption in the EU.*
- *Freshwater abstractions in the EU for electricity production could decrease by roughly 25% and consumption by 10% in 2050, due to the replacement of combustion plants by wind turbines and solar power.*
- *Water saving can also be achieved by choosing less water-demanding cooling systems and fuels, technical innovations, and by using waste heat from power plants in industry or district heating systems. Such measures could reduce water abstraction and consumption considerably (45-95%), locally up to almost 100%.*

Electricity production from nuclear, oil, gas, solid fuels significantly rely on water for cooling. Therefore, the more these sources of electricity are replaced by solar and wind power, which use significantly less water over their life cycle, the need for cooling water is expected to decrease in the EU-27. Caution is needed on the expansion of electricity production from biomass, as it currently requires more water than fossil fuels (considering also the water needed for crop production). However, even for the same type of fuel, the volume of cooling water abstracted and consumed differs, depending on the cooling system used and how optimized the electricity generation is.

Table 5.1 provides an overview of promising water saving measures in electricity production. Water savings can be obtained by dedicated choices of cooling system and energy source. Air cooling can reduce water consumption to virtually zero, at the cost of higher CO_2-emissions. Wind and solar energy hardly require water during their operation; but even within the group of fossil fuels there are marked differences and savings of 30% or more are possible when natural gas is used instead of coal or oil. Such choices must be made in an early stage, because costs of adjustments during the life cycles are often prohibitive. Water savings can also be obtained by technical modifications to increase the energy conversion. The related cases studies indicate an extremely wide range of water savings, from 1 to 100%.

Consumption of cooling water can be reduced very effectively, by almost 100%, when there are opportunities for heat integration with other processes, or for the use of waste heat in district heating systems (CHP, Combined Heat and Power). A last option for water saving is to build power stations near the sea where they can use salt water rather than fresh water. This can save up to 100% of freshwater consumption, but the viability of the option depends on the presence of coastline, sea water temperatures, options to get rid of brine and/or blowdown, and permitting procedures.

Water saving is urgently needed in the sector, as climate change is expected to lead to higher water temperatures and more extreme low flow situations, reducing the amount of water that can be technically available for cooling abstraction. Another urgency calling for water saving measures in the sector is the projected increase in the amount of electricity generated and consumed in the EU until 2050.

In this regard, it is important to raise the awareness on the interdependencies between energy and water saving.

Table 5.1 Overview of promising water saving measures in electricity production[16]

Category	Measure	Aim related to water saving	Potential water saving	Remarks
Choice of cooling system	Replace once-through cooling by re-circulatory cooling	Reduce abstraction and thermal pollution (at the cost of higher evaporation)	Saving in abstraction in the order of 95% Increase in consumption by 60%	Once-through cooling is not used in AT, BG, CZ, EE, HU, LT, LU, LV, SK and SL
	Replace re-circulatory cooling by hybrid cooling	Reduce abstraction and consumption	Saving in abstraction in the order of 45% Saving in consumption in the order of 35%	
	Move from any system to air cooling	Reduce abstraction and/or consumption (at the cost of higher CO_2-emissions)	Savings of 100% in abstraction and consumption	Air cooling requires no water for cooling
Choice of energy source	Change fuel type from oil or coal to natural gas (assuming both with re-circulatory cooling)	Reduce abstraction and consumption	Saving in abstraction in the order of 70% Saving in consumption in the order of 30%	
	Change fuel type from oil or coal to biofuels (both with re-circulatory cooling)	Reduce consumption	Increase in abstraction in the order of 10% Saving in consumption in the order of 30%	Biofuels do not consume less water if the water needed for growing is included
	Change any fuel type to hydropower	Reduce consumption (caveat: see remark)	No data could be found	Hydromorphological pressures are often prohibitive; evaporation losses from reservoirs can be high
	Change any fuel type to wind or solar power		Savings of 100% locally At EU-scale until 2050 up to 40% savings in abstraction	During the whole life cycle the water use of wind and solar is not zero. But it is still much lower than other energy sources
Increased conversion efficiency	Various technical measures: improved design, improved catalysis, reuse of water, and process optimization.	Reduce abstraction and/or consumption	Local potential savings show a very wide range, from 1 up to 100%.	No data found at EU level
Alternative use of non-recoverable heat	Technical measures for improved heat integration with other processes, or use of waste heat in district heating systems (CHP, Combined Heat and Power).	Reduce abstraction and/or consumption	Savings up to 100% locally.	Although not quantifiable at EU level, this measure, where applicable, is very effective in reducing cooling water demand.
Choice of water source	Build new power plants near the coast, where they use salt water	Reduce abstraction and consumption of freshwater (at the cost of adaptations in installations, possibly desalination)	Freshwater savings up to 100% locally	Viability depends on presence of coastline, sea water temperatures, options to get rid of brine and/or blowdown, and permitting procedures

Note: The references to the data presented are provided in the text of this chapter.

[16] An overview and deepened explanation of the more technical water saving measures mentioned in Table 5.1 can be found in (EC, 2001) and (EC, 2021a).

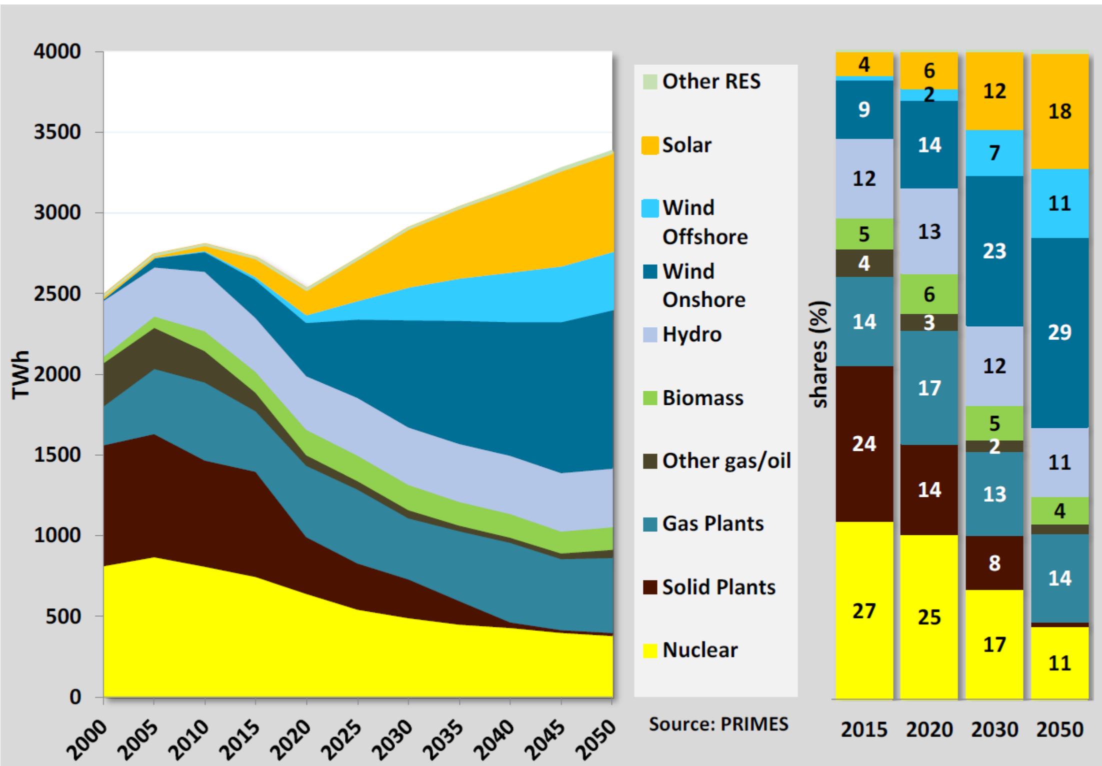
5.2 Overview of the electricity production sector

The electricity production sector includes the generation of bulk electric power through the operation of power plants that produce electric energy (e.g. thermal, nuclear, hydroelectric, and renewables).

Growth in electricity production is primarily driven by growth in the demand of electricity, so it reflects changes to the population size, socio-economic developments and policy targets on energy efficiency. As shown in Figure 5.1 (EC, 2021c), the electricity production in Europe is expected to increase until 2050, despite the plunge observed during the Covid period (2019-2020). Furthermore, Figure 5.1 shows that the shares of electricity production from solar and wind power plants are expected to increase, whereas the shares of electricity production from nuclear, solid fuels[17], oil and gas power plants are expected to decrease by 2050.

This transition from fossil fuels and nuclear power to renewable energy sources is linked to global climate change mitigation pledges and related EU policy initiatives for the decarbonisation of the EU economy (e.g. 'European Green Deal') (EC, 2019b). The 'Fit for 55' policy package is a set of proposals to meet the EU's climate objectives, including the reduction of the EU's net greenhouse gas emissions by 2030 by at least 55%, compared to the 1990 levels (EC, 2024b) (see Text box 5.1).

Figure 5.1 Electricity production by type of energy source



Source: EC, 2021c

The increase of hydropower has slowed down recently because the most suitable locations in Western Europe have been occupied already. In addition, it is becoming more difficult to obtain a permit for new hydropower plants, due to their impacts on the hydromorphology of rivers and lakes, which are strictly regulated by the Water Framework Directive.

[17] Mainly coal, but also lignite, petroleum coke and tire-derived fuel

Text box 5.1: Greece is decarbonising electricity production rapidly

The use of fossil fuels in the electricity sector of Greece is rapidly changing, with coal usage dropping from 25% in 2016 to 9% in 2022. Greece plans to phase out coal by 2028, aligning with the European Council's 2030 Climate and Energy Framework to reduce coal-based energy across the EU. The Greek roadmap for the decarbonisation of electricity production outlines billions of euros in investments to support coal-dependent areas and workers by fostering new clean energy industries, focusing especially on Western Macedonia, which produces 80% of Greece's coal. This region is set to become an alternative energy hub, utilizing local expertise and engaging stakeholders early to build support for affordable clean energy. Key solutions include green hydrogen, pumped storage, and converting power plants to renewable energy with storage, enabling energy to be stored during sun and wind peaks and supplied to the grid as needed.

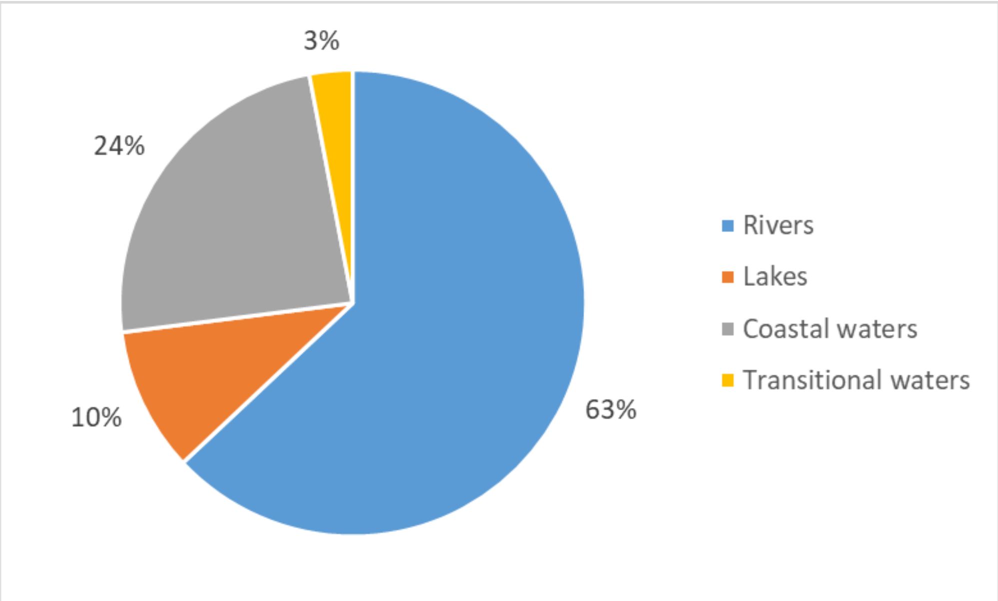
The roadmap was made in collaboration with the World Bank through the 'Directorate-General for Structural Reform Support' provided by the European Commission. This support is offered to EU-countries to help them design and implement reforms to underpin job creation and sustainable growth. Greece was the first EU-Member State that submitted such a detailed roadmap to the European Commission. Thereby, a major milestone was reached in Greece on October 7, 2022, as renewable energy - solar, wind and hydro- accounted for 100% of Greece's power generation for five hours. In August 2022, half of Greece's power mix already consisted of renewables.

World Bank, 2022; Euronews, 2022

5.3 Water abstraction and consumption of the electricity production sector

All power plants operating on combustible fuels, such as nuclear fuels, fossil fuels and biomass (covering 75% of the total electricity production by 2020; see Figure 5.1) require cooling water for their operations. Cooling water is abstracted mainly from surface water sources, such as rivers, lakes, coastal or transitional waters, and only a negligible share (around 0.2%) from groundwater (Figure 5.2).

Figure 5.2 Share of surface water sources in the abstraction of cooling water for electricity production



Note: The share of groundwater sources in the abstraction of cooling water for electricity production is negligible and excluded from the above figure. By 2022, it is estimated around 0.2% (EEA, 2024b).

Source: Ecofys et al., 2014

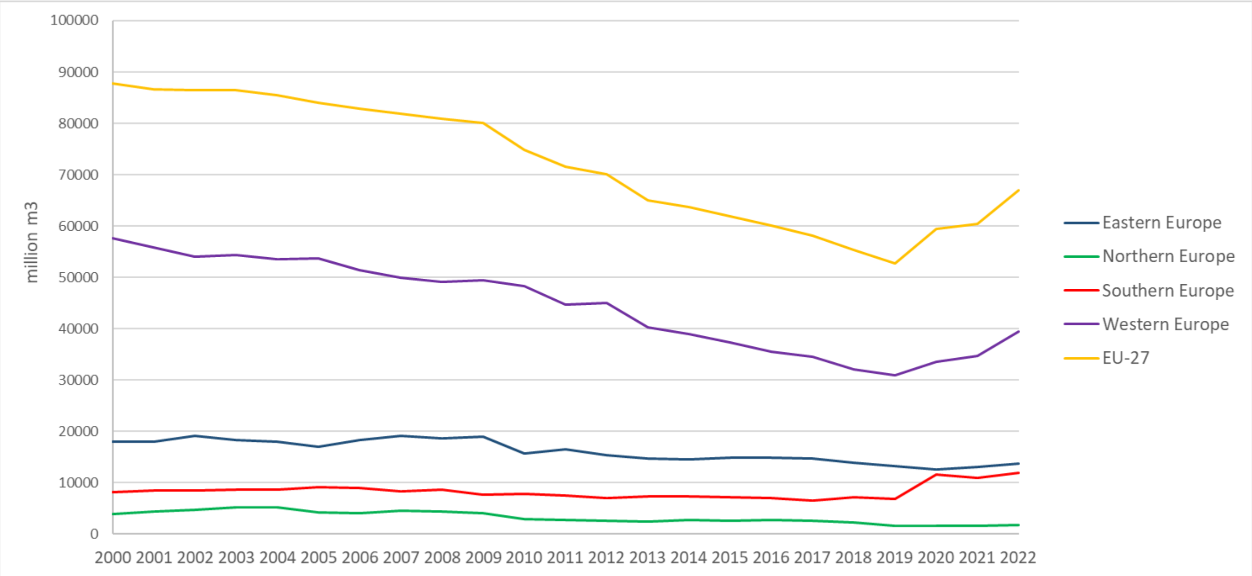
The electricity production sector in the EU-27 has annually abstracted about 72 000 million m^3 of cooling water on average between 2000 and 2022, which represents 36% of the total water abstraction in the EU-27 for the same period (EEA 2024b)). The consumption of cooling water (i.e. the amount of cooling water that is evaporated) is much lower, estimated at 20% of the total water consumption in the EU-27 between 2000 and 2022. (EEA 2024b). Therefore, water saving measures are worthwhile to explore, whereby understanding that the interlinkages between energy and water saving are increasingly important (IEA, 2016).

Hydropower plants are generally considered to have no substantial impacts on water consumption. However, depending on local conditions, a significant volume of water may be indirectly consumed due to evaporation from the reservoir (see section 5.4.2). Wind turbines and solar panels have a much lower water consumption compared to the other forms of electricity generation (EEA 2021b); here, water is mainly required for washing and maintenance and not for cooling purposes (JRC 2016a).

The share of water abstraction for each economic sector differs strongly between the EU countries and regions. As shown in Annex 1, this share is especially large for the electricity sector in Western and Eastern Europe and relatively small in Southern Europe. In Northern Europe the abstraction for cooling purposes is low.

The decreasing share of fossil fuels and nuclear energy in the production of electricity is already reflected in the lower volumes of cooling water required (Mes and van Vossen, 2023). Freshwater abstractions have decreased by 27% between 2000 and 2022 for electricity generation within the EU-27 due to increased use of less water-intensive renewable energy sources (Figure 5.3). The decreasing trend seems to be interrupted after 2018 in Western and Southern Europe. The exact causes are unclear.

Figure 5.3 Water abstraction for electricity production by region in the EU-27 (2000-2022)



Source: EEA (2024b)

A further estimation indicates that freshwater abstractions for the EU-27 could decrease by roughly 25% and freshwater consumption by 10% to 2050 due to the replacement of combustion plants by wind turbines (EEA 2024b).
Table 5.2 provides a qualitative, non-exhaustive overview of the drivers of the increase and decrease of water demand in electricity production that are discussed above.

Table 5.2 Expected key changes and impacts on demand for cooling water in electricity production

Relevant drivers in electricity production	Expected trend in driver (increase/decrease)	Expected impact (increase/decrease) on water demand
EU population by 2100	↘	↘
Water-efficient technology and operational management	↗	↘
Efficiency in electricity consumption	↗	↘
Income and living standards – electricity consumption	↗	↗
Share of wind and solar energy in electricity production	↗	↘
Electrification of private transport	↗	↗
Demand for air-conditioning under climate change	↗	↗
Implementation of Carbon Capture and Storage	↗	↗

Note: Green indicates a positive effect on water demand (i.e., decreasing demand); orange indicates a negative effect.

Source: Authors' elaboration.

Climate change is expected to induce higher water temperatures and stronger extremes in rainfall, leading to more frequent and more extreme low-flow situations. The combined effect of these will have a large impact on the sector as they incur water abstraction limits and eventually reduce electricity output (Ecofys, et al., 2014). For example, in the summer of 2022 France experienced high water temperature and low-flow situations, that caused limitations to electricity production from nuclear stations (Bloomberg, 2022). A consequence of this phenomenon could be that authorities may be inclined to allow higher water temperatures than previously permitted. This occurred in France in 2015, when cooling water temperatures of up to 28°C were allowed, instead of the usual 25 °C (Energy Transition, 2015).

5.4 Water saving measures in electricity production

In most power plants the bulk of the water is used for cooling purposes (JRC 2016a), because in the electricity generation process a substantial amount of heat is generated which cannot be turned into electricity. Cooling water is required to avoid accumulation of heat and thus overheating of the system (Mes et al., 2023); (Ecofys et al., 2014). The amount of freshwater abstracted and consumed for cooling purposes is largely dependent on four parameters: the type of cooling system, the type of fuel that is used, the thermal efficiency and energy conversion of the plant, and the source of the cooling water.

5.4.1 *Water saving by choosing the most water-efficient cooling system*

Most electricity is generated with steam turbines. In these types of plants, the exiting steam needs to be cooled and condensed before the water can again be used. There are four main different types of cooling systems, which require different amounts of water per unit production (IEA, 2016); (JRC 2016a): water-cooling systems, two types of air-cooling systems, and hybrid systems.

Water-cooling systems

The water-cooling system uses once-through cooling, also called open loop cooling. It abstracts large volumes of water, which take up the heat discharge. Because of the large abstraction volumes required, this type of cooling system is generally solely applied along larger rivers, coastal and transitional waters, where sufficient cooling water is available. In Europe, over 90% of power plants use water-cooling systems according to the COWA database (Ecofys,2014), and approximately 70% of them are located along rivers or lakes.

The return flow of water, often 4-7 ^{o}C warmer than the abstracted water, is discharged back into surface waters (Mes and van Vossen, 2023); (Jin, et al., 2019); (EC- DG ENV et al., 2021)). The fraction of the water consumed (evaporated) in the once-through cooling system is low, often between 0 and 5% of the total water abstraction, but the volume of water abstracted is large. The heat emission to water can have a large impact on aquatic life, as it may induce such effects as barriers for migrating fish, oxygen stress (JRC, 2016a) and increased evaporation in the water bodies downstream (Mes and van Vossen, 2023).

Air cooling systems (two types)

In the first type of air-cooling system, water is abstracted from a water body and absorbs the heat, after which it flows into a cooling tower. The airflow in the tower cools the water through evaporation, discharging the heat into the air. Only the water lost to evaporation has to be abstracted from the water body, and no thermal discharges into the water body occur. The cooled water is recirculated. Thus, this system abstracts less water but consumes more water per unit electricity generation than the once-through cooling system; 60-95% of the volume of abstracted water is evaporated in the cooling tower. The system is often applied in places where water is scarce, and it meets environmental objectives of the regulations more easily (Mes and van Vossen, 2023); (Jin, et al., 2019); (JRC 2016a); (Ecofys, et al., 2014).

A second type of air-cooling system uses fans and radiators to remove heat through the process of air circulation. No water is required for evaporation in this type of cooling. The system uses, however, 40% more energy per kWh generated than closed loop cooling, because there is no evaporative heat transfer from cooling water (Mes and van Vossen, 2023); (Jin, et al., 2019); (JRC 2016a); (Ecofys, et al., 2014).

Hybrid cooling system

The fourth type of cooling system is a hybrid water-and-air cooling system. In the hybrid system, the heated cooling water first passes through a dry section of the cooling tower, where heat is removed by air. Hereafter, the water passes through a wet section, where the dry section air is mixed with vapour from the wet section, thereby lowering the relative humidity. This reduces plume formation and reduces both the water abstraction and consumption compared to the open and closed cooling systems (Ecofys, et al., 2014); (Mes and van Vossen, 2023). For hybrid cooling, most of the abstracted water is consumed, however, the water abstracted is the lowest compared to the once-through and re-circulatory cooling (Mes and van Vossen, 2023); (Byers, et al., 2014)).

Table 5.3 presents the volumes of water abstraction and water consumption required per MWh for the four cooling systems. The ranges that are indicated are largely determined by the type of fuel that is used, which is discussed in section 5.4.2. The conclusion that can be drawn from the data is that switching to a more water-efficient cooling system can significantly reduce the amount of water abstracted or consumed (economic consequences set aside).

Table 5.3 Water abstraction and consumption per cooling system

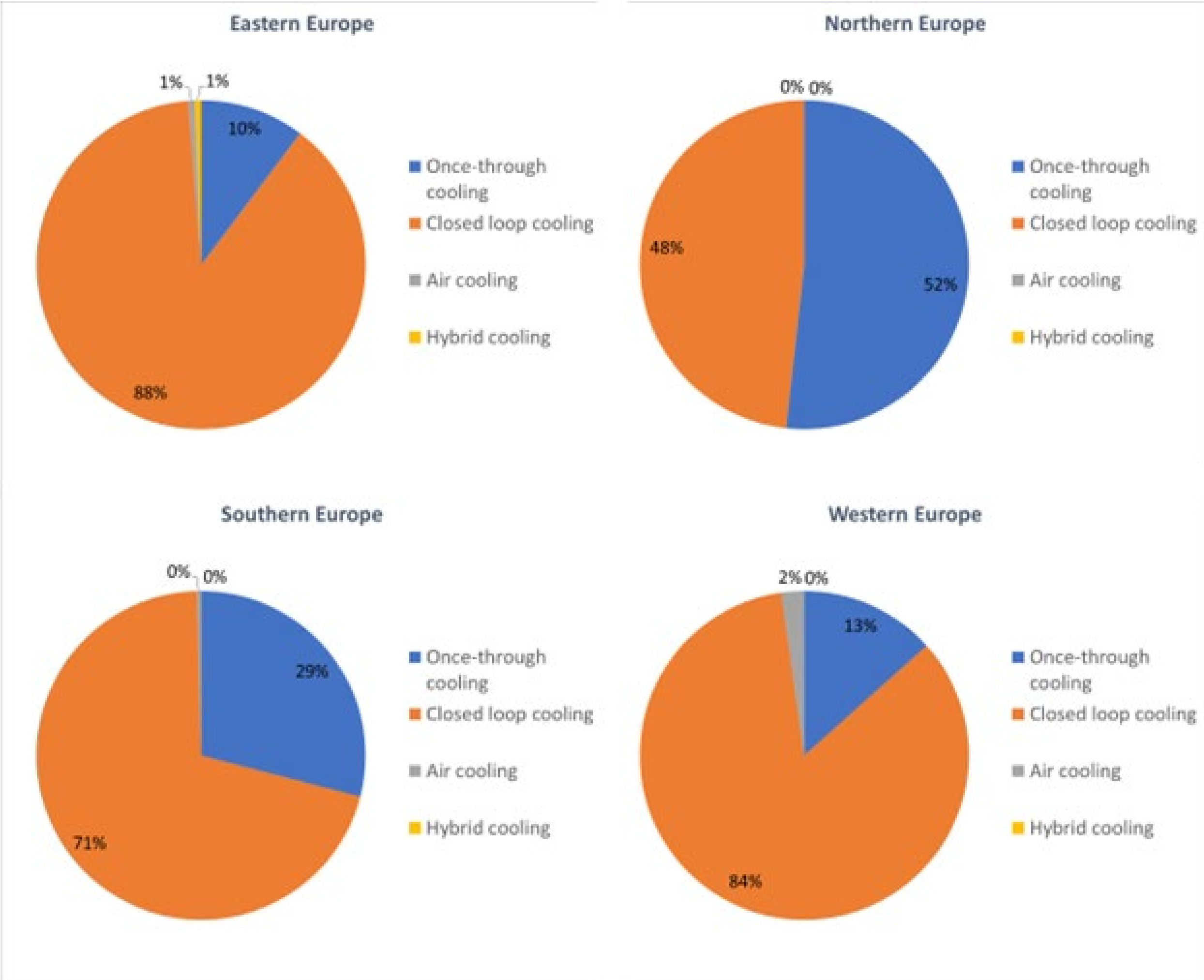
	Once-through cooling	Air cooled with re-circulatory cooling	Air cooled with fans and radiators	Hybrid cooling
Water abstracted (m^3/MWh)	43 – 178	1 – 5	0	0.4 – 2.8
Water consumed (m^3/MWh)	0.4 – 2.1	0.8 – 3.2	0	0.4 – 2.1

Source: Jin, et al., 2019; Byers, et al., 2014; Macknick, et al., 2012

Currently, investments often go to ‘wet’ (once-through and re-circulatory cooling) rather than ‘dry’ (hybrid and air cooled) cooling technologies, as the investment costs are lower, and the technologies are simpler. On the other hand, in areas where water is expensive and/or power is cheap, the operating costs of wet cooling can be much higher than those of dry cooling. This economic justification is often not considered, while also water scarcity is not considered sufficiently when choosing a cooling water system (Dworak, et al., 2007).

Figure 5.4 shows the distribution of the different types of cooling water systems within the EU-27. All regions use re-circulatory cooling the most, although in Northern Europe once-through cooling is also widely used. It is difficult to determine which cooling system is actually used for production, as power plants can have multiple cooling systems installed and can switch between them, based on meteorological circumstances and water availability (Mes and van Vossen, 2023); (Ecofys, et al., 2014). The hybrid and dry cooling types are hardly applied in any region. In all European regions there is still a lot of potential to move towards hybrid and/or dry cooling water systems to save water, considering the water use per MWh produced. The downside of saving water in this way is that it will result in higher CO_2 emissions. The potential to move towards hybrid and/or dry cooling water systems also depends on the switching costs.

Figure 5.4 Share of different types of cooling water systems in different regions of the EU-27



Source: Ecofys et al., 2014

Water, energy and CO_2

A trend in the electricity generation sector is the intensification of the interdependencies between electricity and water, due to the lower water availability that is expected as a result of climate change (see Text box 5.2). Certain measures, such as improving the efficiency of a plant, can lead to savings in both water and electricity use (Dworak, et al., 2007). On the other hand, there are measures to save water, such as moving from wet to dry cooling technologies, that lead to a higher energy consumption and more CO_2 emissions. For example, dry cooling technologies can consume up to almost five times more energy than once-through cooling systems (EC, 2001; EC and JRC, 2017).

A Carbon Capture and Storage (CCS) system can be added to the power generation process. Such a system captures 85-90% of the CO_2 produced at the power plant after which the CO_2 is transported to an injection site for long-term storage. CCS, however, increases the volume of abstracted water for two reasons. First, the chemical and physical processes to capture CO_2 require large volumes of cooling water. Second, the energy required to produce electricity increases by 10-40%, which therefore increases the amount of cooling water required (Mes and van Vossen, 2023). The technology with the highest water consumption (almost 4 m^3/MWh) is therefore coal combined with CCS technology (Jin, et al., 2019).

Text box 5.2: Interdependencies between electricity and water in the Canary Islands

The Canary Islands can be divided into two regions: the Eastern and the Western Islands. The water supply in the Eastern Islands comes mainly from desalination, which is highly reliant on energy, whereas in the Western Islands the water supply is mostly served from groundwater, which requires energy for pumping.

All the islands experience an exponential increase in electricity demand, low efficiency in electricity production, and their dependence on fossil fuels is high. There is also no interconnection between the electricity systems of the individual islands. The high energy costs for desalination and pumping on the Canary Islands, also raises the costs of water supply. The use of renewable energy sources is being explored, to decarbonize the archipelago and, thereby, reduce the dependence on fossil fuels. Water savings can contribute to the reduction of energy demand. Water reuse is also being explored as an option.

Santamarta, et al., 2022

5.4.2 Water saving by choosing the most water-efficient energy source

Combustion and nuclear plants for electricity generation require different amounts of water, even if they have the same type of cooling system installed (Jin, et al., 2019). This relates to differences in conversion efficiency: some fuel types have more electricity output and less waste heat than others per unit of energy. Power plants using the 'less efficient-more waste heat' fuel types require more water for cooling purposes (Delgado, and Herzog, 2012).

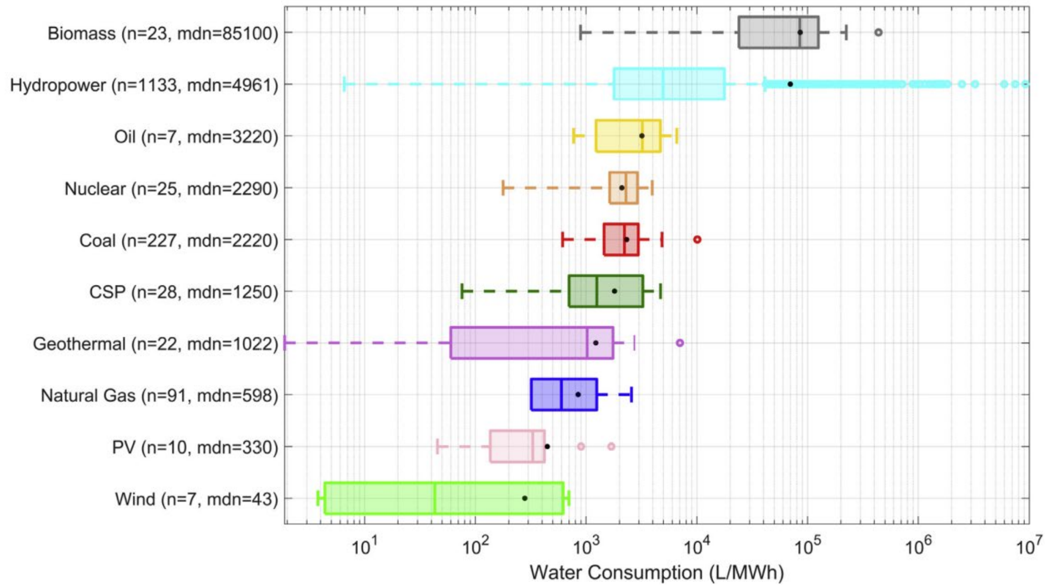
The water saving options for renewable energy sources show a mixed picture. Wind and solar energy consume the lowest amounts of water compared to fossil fuels, nuclear and biogas, because they only require water for the production of the installations and for cleaning. Concentrating Solar Power (CSP), hydropower and biomass on the other hand consume considerable amounts of water; biomass even more than any other energy source, if the water that is required to grow the biomass is taken into account (IEA, 2016); (Jin, et al., 2019).

The amount of water consumed by hydropower plants may at first sight seem negligible, but a significant amount of water may evaporate from the reservoir, depending on the location and the surface area and depth of the reservoir ((EEA 2021b); (Dworak, et al., 2007)). In arid and semi-arid climates, the annual evaporation losses in volume from water reservoirs can vary from 1% for large dams, to 12% or more in small local dams, according to a study by (Martínez-Granados, et al., 2011). In weed-covered reservoirs the losses to evapotranspiration can be up to six times higher than those in open waters (Hurwitz, 2014). Hurwitz (2014) estimated that of the 57,985 large dams in the world, together storing more than 10,000 km^3, 170 km^3 evaporates annually. This amounts to 1.7 %. (Dworak, et al., 2007) determined that for the Serre Ponçon dam in Geneva an annual evaporation occurs equivalent to 1.4% of the total dam capacity and 1.7% of the effective capacity. (Jin, et al., 2019) even state that hydropower is the largest water consumer during the operational phase, whereby the consumption can range from 0 to $1.2x10^5$ m^3/MWh. On the other hand, hydropower stations without reservoirs (run-of-river plants) consume no water (Jin, et al., 2019).

Besides these general options there are specific efficiency measures for hydropower plants. Management measures to increase water efficiency may involve actions to lower the surface water temperature or evaporating area of the reservoir, for example by concentrating the stored water, by minimizing the exposure and evaporative area, or by using the reservoirs that contain water with the highest temperatures first. Other measures, such as installation of covers or chemicals to limit evaporation can also be considered, but will require thorough assessments of their environmental impacts (Martínez-Granados, et al., 2011).

Figure 5.5 shows the water consumption for the total life cycle for each type of fuel. This entails that the figure includes water consumption for growing biomass, and evaporation from reservoirs for hydropower. Biomass consumes the largest amounts of water, followed by hydropower, although hydropower has many uncertainties and therefore outliers. Water consumption is the lowest for wind energy, followed by solar energy (PV, photovoltaic) and natural gas.

Figure 5.5 Water consumption for cooling purposes distinguished per fuel type



Note: ‘n’ expresses the number of studies reviewed, ‘mdn’ stands for median value from these studies

Source: Jin, et al., 2019

The water consumption per fuel type must be considered in combination with the cooling system in place. The combination of fuel type and cooling system eventually determines the required water abstraction and consumption per power plant. Multiple studies have provided examples of quantifying this relation of which an overview is given in Table 5.4. According to these studies, a combination of once-through cooling and a fuel type of nuclear, oil, and biomass requires the highest volumes of water abstraction for cooling. The lowest volumes are required for air cooled technologies and hybrid cooling. Of the once-through cooling systems and closed-cooling systems, the natural gas, coal, and oil closed loop cooling abstract the lowest amount of water. Leaving solar and wind apart, the least water is consumed in a once-through cooling system combined with natural gas, coal, or geothermal energy. The highest amount is by far consumed in re-circulatory cooling systems combined with nuclear energy or oil. Figure 5.5 indicates that biomass also has high water consumption, but Table 5.4 indicates a lower consumption. This could be due to differences in the type of biomass power plants that were considered in the studies.

Table 5.4 Water abstraction and consumption per fuel type and type of cooling system

Type of fuel	Type of cooling system	Water abstraction (m^3/MWh)	Water consumption (m^3/MWh)	Source(s)
Biomass	Once-through cooling	133	1.4	Macknick et al., 2012
	Re-circulatory cooling	3.3	0.9 – 2.3	Macknick et al., 2012; Jin et al., 2019; JRC, 2016b
	Air cooled	No data found	0.1 - 0.2	Jin et al., 2019; JRC, 2016b
	Hybrid cooling	No data found	No data found	
Oil	Once-through cooling	134	1.1	Jin et al., 2019 ; Byers et al., 2014
	Re-circulatory cooling	2.1	1.8 – 2.7	Byers et al., 2024 ; Jin et al., 2019
	Air cooled	No data found	No data found	
	Hybrid cooling	0.7	0.6	Byers et al., 2014
Coal	Once-through cooling	118 - 138	0.4 – 1.0	Macknick et al., 2012; Jin et al., 2019; Byers et al., 2014; JRC, 2016b
	Re-circulatory cooling	2.1 - 3.8	1.8 – 2.7	Macknick et al., 2012; Jin et al., 2019; Byers et al., 2014; JRC, 2016b
	Air cooled	No data found	0.3	Jin et al., 2019
	Hybrid cooling	1.3	1.2 - 1.5	Jin et al., 2019; Byers et al., 2014
Natural gas	Once-through cooling	43 - 48	0.4 – 0.6	Macknick et al., 2012; Jin et al., 2019 ; Byers et al., 2014
	Re-circulatory cooling	0.9 – 1.0	0.7 – 2.5	Macknick et al., 2012; Byers et al., 2014 ; JRC, 2016b
	Air cooled	0.01	0.01 - 0.6	Macknick et al., 2012; Jin et al., 2019; Byers et al., 2014; JRC, 2016b
	Hybrid cooling	0.6	0.4 – 0.5	Jin et al., 2019
Nuclear	Once-through cooling	164 - 168	1.0 – 1.3	Macknick et al., 2012; Jin et al., 2019; Byers et al., 2014; JRC, 2016b
	Re-circulatory cooling	3.9 - 4.2	2.5 – 2.7	Macknick et al., 2012; Jin et al., 2019; Byers et al., 2014; JRC, 206b
	Air cooled	No data found	0.2	Jin et al., 2019
	Hybrid cooling	2.5	1.7	Byers et al., 2014
CSP	Once-through cooling	No data found	No data found	
	Re-circulatory cooling	No data found	3.4	Macknick et al., 2012
	Air cooled	No data found	0.3	Macknick et al., 2012; Jin et al., 2019
	Hybrid cooling	No data found	1.1 – 1.3	Macknick et al., 2012; Jin et al., 2019
Geothermal	Once-through cooling	No data found	No data found	
	Re-circulatory cooling	No data found	0.1	Macknick et al., 2012
	Air cooled	No data found	1.0 – 1.1	Macknick et al., 2012; Jin et al., 2019
	Hybrid cooling	No data found	1.7	Macknick et al., 2012; Jin et al., 2019
Solar PV	N.A.	0	0	Macknick et al., 2012; Jin et al., 2019; Byers et al., 2014; JRC, 2016b
Wind	N.A.	0	0	Macknick et al., 2012; Jin et al., 2019; Byers et al., 2014; JRC, 2016b

Note: Numbers represent median values reported in available sources. For better readability, they are rounded up and colourised in two classes:
Water abstraction: green: less than 10 m^3/MWh; yellow: more than 10 m^3/MWh;
Water consumption: green: less than 1 m^3/MWh; yellow: more than 1 m^3/MWh.
For re-circulatory cooling, it is assumed that a cooling tower is in place instead of a cooling pond. Data presented in the table is partly derived from studies in other regions than Europe, such as the US.
CSP=Concentrating Solar Power; PV = Photovoltaic

Source: Jin et al., 2019; JRC, 2016b; Byers et al., 2014; Macknick et al., 2012

In 2023, 44% of all electricity produced and 24% of the energy finally used in the EU-27 was from renewable energy sources. Between 2022 and 2024 there was a significant increase in solar power generation by 19%, and wind power by 9% (EEA, 2024).

5.4.3 Water saving by technical improvements in energy conversion

The thermal efficiency and energy conversion of the plant is a third factor that determines the waste heat discharge. When the amount of non-recoverable heat can be reduced, less water is needed for cooling. New technologies and more efficient energy transmissions can decrease the energy conversion factors of plants (UN, 2014). This requires a technical optimization of the electricity production process and/or the creation of a symbiosis system within the production and consumption chain of the electricity, aimed at using the non-recoverable heat elsewhere, for example in district heating or other industrial processes (Ecofys, et al., 2014).

In that context, there are several options for general technological improvements in power plants and their cooling water systems (for a European overview see also (EC, 2021a)):

- Technology that enables processes taking place at lower temperatures; this will reduce the required volume of cooling water (Ecofys, et al., 2014).
- Technology to produce electricity in a more energy-efficient way ('improving conversion efficiency'). This is most frequently mentioned as a key driver for the reduction of cooling water consumption (Jin, et al., 2019); (Suppes and Storvick, 2007). There is significant variability in the relative water savings due to the diverse water consumption of each cooling system and fuel type (Table 5.4). Considering minimum and maximum values, water savings for re-circulatory cooling range from 1.1% (in CSP) to 65% (in geothermal energy); for once-through cooling, it varies between 1.2% (biomass) and 4.3% (natural gas); and for dry cooling, it can range from 0.9% (geothermal) to 100% (natural gas).
- Increasing the water productivity due to multiple or re-circular use of cooling water (Mes and van Vossen, 2023); (UN, 2014). This will reduce abstraction volumes, but not water consumption of the power plant.
- Control optimization of the wet cooling towers (Industriellen Vereinigung, 2016).
- Reducing water leakage.

The non-recoverable heat can be used in different ways:

- Improved heat integration, where a process stream exchanges heat with another process stream through a heat exchanger. Less heat needs to be released, resulting in a lower cooling water requirement (Ecofys, et al., 2014).
- Waste heat is exported towards district heating systems providing heating to cities or agricultural areas. This is known as Combined Heat and Power.

5.4.4 Water saving through relocation and use of saline or brackish water

Relocation of power plants to tidal and coastal locations where they use brackish or saline water is an option for saving freshwater for cooling. In Europe, this trend can already be observed, triggered by limitations to abstraction licenses for freshwater inland (Byers, et al., 2014); (Harto, et al., 2014); (Jin, et al., 2019). Obviously, this is an option in countries that border the sea. Besides this geographical limitation, the discharge of the warmed-up water can be a limiting factor. There are three main differences between the requirements for a traditional freshwater cooling tower and a re-circulatory saline cooling tower. First, the vapour pressure of saline water is lower, resulting in decreased cooling tower performance and increased water consumption for cooling. Second, there is a need for corrosion resistant materials in the cooling towers, which are more expensive. Third, the maximum number of concentration cycles is lower for saline water than for freshwater cooling towers, which reduces the efficiency of the cooling tower and the cooling capacity of the cooling system (Harto, et al., 2014).

The temperature of the seawater is an important factor in the decision whether or not to use saline water for cooling. In Northern and Western Europe, the seawater temperatures are generally sufficiently low to allow for efficient cooling; but even there, limitations may occur (see Text box 5.3). In Southern Europe the sea water temperatures can increase considerably during summer, resulting in significant constraints to the use of cooling water (IEA, 2016).

Text box 5.3: High temperatures in Sweden

Sweden already uses seawater to cool several power plants, including the Swedish Ringhals nuclear power plant. However, in July 2018 the operation of this power plant was suspended, as continuous hot weather resulted in seawater temperatures reaching close to 25 ^{o}C. Each reactor has a maximum permissible temperature at which the seawater can be used for cooling, which was reached that summer. It is an unusual situation for Northern Europe where the seawater temperatures normally do not increase by this much.

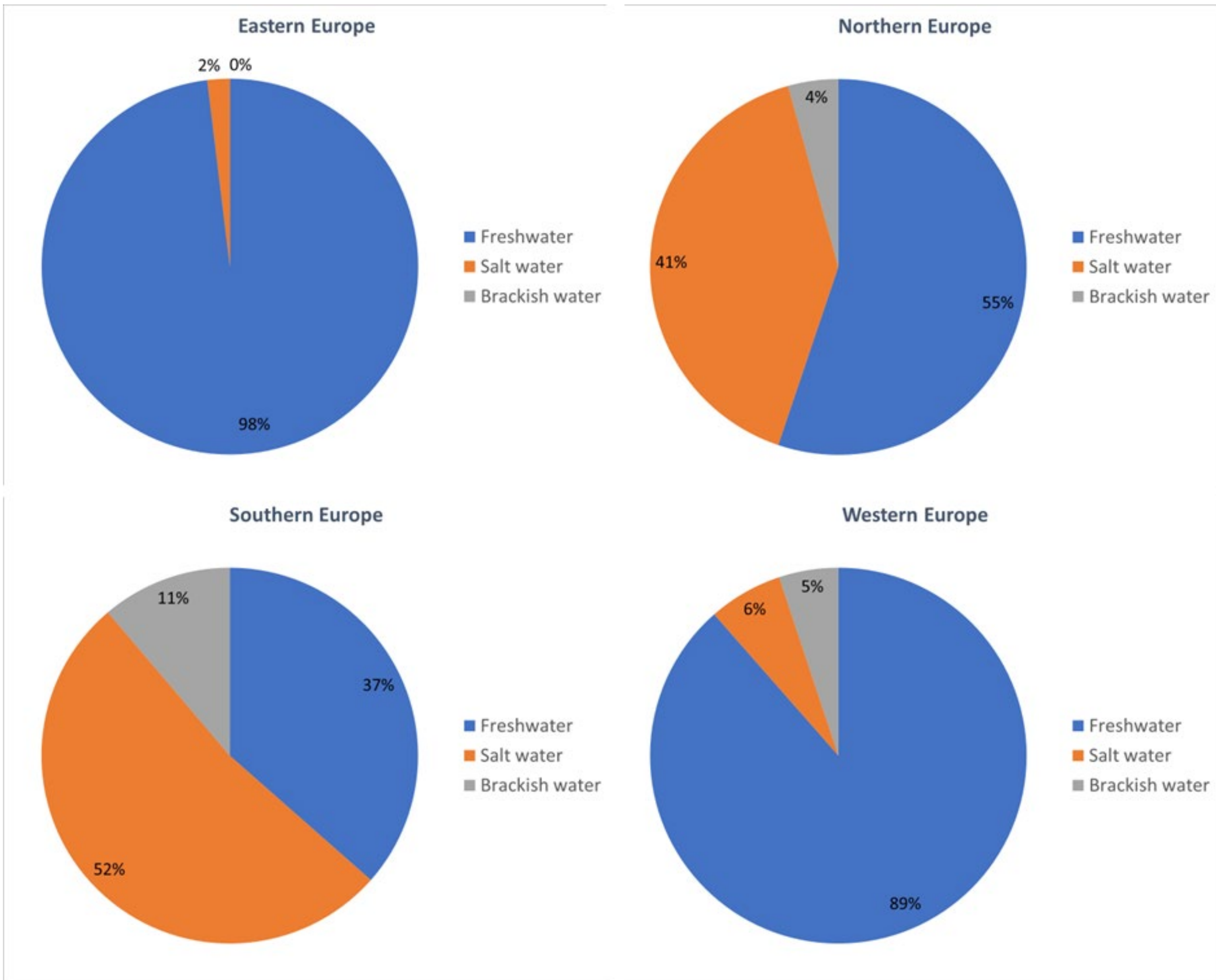
Vattenfall, 2018

Seawater can be used in two ways: 1) directly using through-flow, or 2) indirectly through desalination where freshwater cooling systems can still be used. No exact numbers could be found on the number of plants in the EU using desalinated water-cooling systems and through-flow cooling systems using seawater. We assume that once-through cooling using seawater is more-often used, because salinization technologies require a considerable amount of energy and therefore increase the amount of cooling water required.

The trend towards saline sources could slow down in the future or even reverse, because of increasing sea water temperatures caused by climate change impacts, if stricter regulations were to be implemented in the EU on the use of once-through cooling systems, or by an increased use of air or hybrid cooling techniques. A slightly reversed trend is already observed in the USA, where recently stricter regulations for once-through cooling have been implemented (Harto, et al., 2014).

Figure 5.6 shows the share of the use of different water types, such as freshwater, brackish water, and salt water, in cooling water systems in different regions of the EU-27. The use of salt or brackish water by cooling systems of power plants is included for both options: through a saline cooling tower or through desalinization. Especially in Southern Europe salt water and to a smaller extent brackish water are already used due to the limited freshwater availability in rivers (IEA, 2016). Slovenia and Croatia within this region do not use these sources yet or data is unavailable. In Northern Europe the share of saltwater use is already significant, which can especially be attributed to Denmark, Sweden, and Finland, which have a significant area near the coast with sufficiently cool seawater. In Eastern Europe the share of salt water is very small, but this is also due to the fact that several countries in this region are landlocked. There is, however, room for growth for the countries in this region that have a coastline. In Western Europe, the coastline is quite extensive, but salt water or brackish water is still little used. This could be an attractive option for the countries in Western Europe that are located near the coast (IEA, 2016).

Figure 5.6 Share of water types used by cooling water systems in different regions of the EU-27



Source: Ecofys et al., 2014

6 Water saving potential in the manufacturing industry

6.1 Summary of the chapter

- *The manufacturing industry (including cooling water for the industry) accounts for 14% of the abstraction and 19% of the water consumption in the EU-27.*
- *This report assesses three major subsectors of the manufacturing industry: food and beverages, steel, and the pulp and paper industries.*
- *Significant water savings can be achieved in these subsectors through improved water reuse and recycling.*
- *Key drivers for water efficiency in these sectors are regulations, local factors such as limited water availability, and prices for energy and water services.*
- *Detailed data and information on existing water-saving measures and remaining potential are limited.*
- *Nonetheless, the sector organisation reports point to a substantial remaining potential, if the associated investments are made. Theoretically, water saving could reach up to 30-50% of abstractions.*

The manufacturing industry is highly diverse, producing a wide range of goods through varied production processes. This report focuses on three water-intensive sectors: food and beverages, steel, and pulp and paper. The analysis suggests that 30-50% of water savings are possible in these sectors with adequate investment.

For these industrial sectors and for the industrial activities covered by the Industrial Emissions Directive (EC, 2010), Best Available Techniques (BAT) are available to improve water efficiency of the industrial installations. These BATs are described in Commission Implementing Decisions ('BAT Conclusions') (EC, 2019a, 2012a, 2014), which are the reference for setting the permit conditions of individual installations, but which do not assess the water saving potential of the techniques.

Food and beverages industry

The water saving potential of the food and beverages industry is substantial. An integrated and systematic approach to increase water efficiency at plant scale could reduce water use by up to 30-50% (Price and Heldmann, 2018;Ölmez, 2013). Such an approach includes auditing and monitoring, training and raising awareness, investing in water saving technologies, and optimizing water reuse and recycling. (Lee and Okos, 2011) combine multiple water saving, reusing, and recycling measures in different plants and report a possible reduction of water input for the processing of edible beans and corn masa, of 55% and 95% respectively.

Steel industry

In the steel industry, effective water saving can be achieved by optimized process organisation, improved cooling, energy saving and/or water re-use. In the steel industry, effective water savings of 20-50%, and in some instances up to 90%, can be achieved through optimized process organization, improved cooling, energy saving, and/or water reuse, either individually or in combination.

Pulp and paper industry

For integrated mechanical pulp and paper mills, achievable water savings are in the order of 25-40%, but this also depends on local conditions. Factors such as climate, water availability, source and quality of fresh water and the type, water quality and sensitivity of the receiving watercourse may influence technical solutions. Most European paper mills have implemented stepwise water-saving measures. A study of 30 paper mills in Italy showed that with a very low investment a potential saving rate of 12% of the water use could be reached; savings of 22% are possible with an improved water use and some important investments. With significant investments for the rebuild of numerous parts of the mill, it is possible to reach a savings rate of 40% (JRC 2015). (Ricardo, 2018) presents a high-level assessment of the impact of BAT implementation on water use in the pulp and paper industry (Table 6.1). Additional information on applicable techniques, albeit without information on potential water savings, can be found in (EC, 2019a, 2012a, 2014).

Table 6.1 Overview of promising water saving measures in selected manufacturing segments

Subsector	Measures	Aim and field of application	Potential saving in abstraction and/or consumption (m³ or %)	Remarks
Food and beverages	Treat cleaning water for reuse/recycling	Reduce water abstraction and return flows	25% saving in Belgian brewery 75% of water reused by Danone (yoghurt), reducing abstraction by 500 000 m^3/yr Up to 90% overall savings achievable 35-60% reduction of total abstraction	Ölmez, 2013 Socotec, 2020; Suárez and Riera, 2015
	Raise awareness and improve operational management practices	Reduce unproductive water use to reduce water abstraction and return flows	Up to 30% abstraction savings possible	
	Technical measures for more efficient equipment cleaning		9% saving in Belgian brewery	
	Reduce losses from steam	Reduce water consumption	Consumption saving 95% by reduction of steam losses in German brewery	
	Apply measures mentioned above in an integrated and systemic way	Reduce water abstraction and return flows	Potential savings in water abstraction of 30-50% locally 20% obtained in Dairy Crest factory Possible saving 55% in processing of edible beans, 95% in processing of corn masa 50% savings obtained by Anheuser-Busch	
Steel	General improvement at plant scale	Reduction of water abstraction in integrated steelworks	Abstraction savings possible of 1 – 147 m3/t, or up to 97%	JRC 2013
	Energy saving technologies	Reduction of water abstraction in integrated steelworks	Abstraction saving of 0.68 m^3/t	Gao et al., 2019
	Improve furnace system	Reduction of water abstraction	Abstraction savings of 10 to 16%	JRC 2013
	Spray nozzle optimization, use of nanofluids	Reduction of water abstraction for secondary cooling in continuous casting	Abstraction savings 70%	Klimeš et al., 2019
	Dry cooling	Reduction of water abstraction for secondary cooling in continuous casting	Abstraction savings 48%	Klimeš et al., 2020

Subsector	Measures	Aim and field of application	Potential saving in abstraction and/or consumption (m³ or %)	Remarks
	Reverse osmosis and ultrafiltration / nanofiltration	Reduction of water abstraction for cooling	Abstraction saving 20% / 90%	A.SPIRE, 2024ª, 2024b
	Capacitive deionization	Reduction of water Abstraction for cooling	Abstraction saving 1-5%	SpotView, 2016
Pulp and paper	Integrated improvements in the production line	Reduction of wastewater flow	Abstraction saving 30-50%	Requiring ''considerable investment''; case Swedish paper mill
	Integrated improvements in the production line	Reduction of water abstraction	Abstraction saving of 12-40% achievable, dependent on the level of investments	Italian paper mills cited in (JRC, 2015)
	A combination of technical water-saving measures, reuse	Reduction of water abstraction	Abstraction saving of 8-10%	Ricardo, 2018

Note: The references to the data presented are provided in the text of this chapter.

6.2 Overview of the manufacturing industry

The production of a wide and varied range of goods, e.g. metals, chemicals, wood products, paper, processed foods, beverages, automobiles and textiles, is the main activity of the manufacturing industry[18]. For practical reasons in this chapter a selection has been made of the various activities of the manufacturing sector, confining the scope to the food and beverages, steel production and pulp and paper industries.

The consumption of the goods produced in these manufacturing subsectors is strongly related to standards of living and the economic situation of the user populations and, in the long term, there is a strong correlation between the increase in the consumption of these products and the growth in the Gross Domestic product (GDP). The main uncertainties relate to the exact relation between consumption growth and economic drivers, and also to the position of the EU in the international market. For instance, while the EU's steel consumption was 6% higher in 2021 than it was in 2012, the EU's crude steel production decreased by 4% in the same period. The EU became a net steel importer in 2015 and has remained so until at least 2021 (Eurofer, 2022).

6.3 Water abstraction and water use by the manufacturing sector in Europe

The products of the manufacturing industry, as well as the processes and equipment employed in their production, are wide-ranging. Ultimately, this has implications on the water use level of individual manufacturing operations. In food and beverage production facilities, significant water uses include those for personal hygiene, equipment sterilisation and product, facility and equipment washing. The relevance of water use as an ingredient is then expectedly relative to the product type, ranging higher in e.g. distillation and brewing facilities (where the finished product has a high-water content) and lower in e.g. meat processing facilities (where water is used mainly for spraying and rinsing). In steel production, water

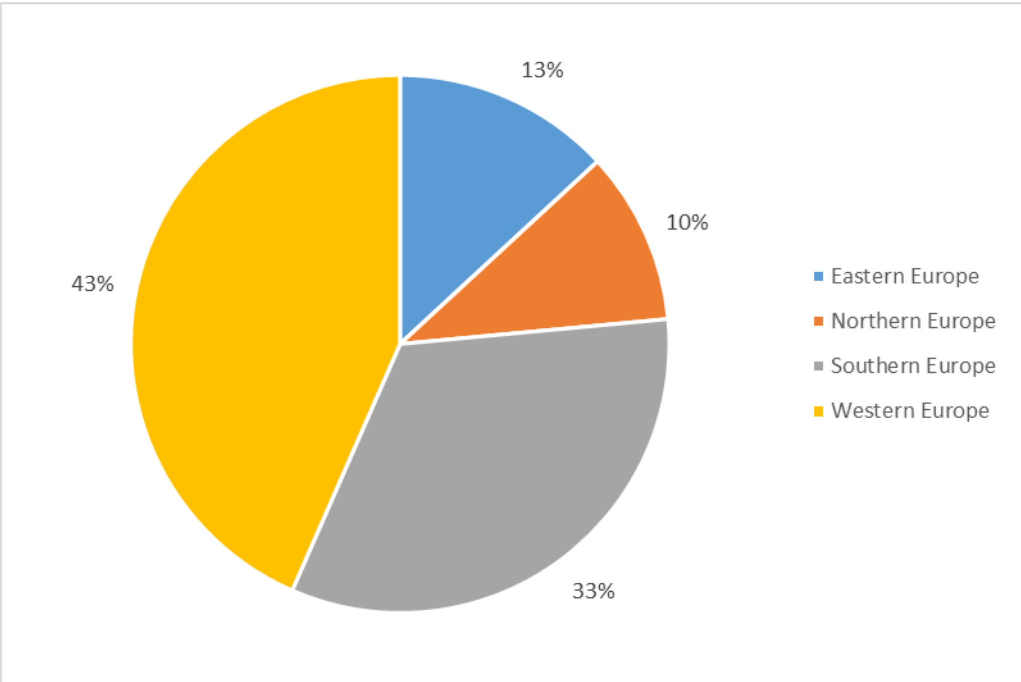
[18] According to the NACE classification (UN DESA, 2012; Eurostat, 2008), manufacturing includes 'the physical or chemical transformation of materials, substances, or components into new products. The materials, substances, or components transformed are raw materials that are products of agriculture, forestry, fishing, mining or quarrying, as well as products of other manufacturing activities. Substantial alteration, renovation or reconstruction of goods is generally considered to be manufacturing'.

is used mainly for cooling and rinsing of materials and equipment, whereas de-inking and cooling are commonly the most water intensive steps of the pulp and paper production process.

At the outlet, discharge volumes and their pollution load will also vary depending on the facility type. Wastewater from the food and beverages industries, such as meat processing and olive oil production, commonly carries high concentrations of organic contaminants, fatty acids, and phenolic compounds (Valta, et al., 2015). Additionally, wastewater from metal, chemicals, paper, and machinery manufacturing facilities is generally associated with thermal pollution and contamination with dissolved minerals, acids, and other process water additives. Data availability on the water use in various manufacturing activities at national level is relatively good for the period 2011-2022, as 16 out of the 32 EIONET member countries report regularly to Eurostat.

The average annual water abstraction for the manufacturing sector, including cooling water in the industry is around 28 160 million m^3 in the EU-27 for the period 2000-2022. The regional distribution indicates that almost half of Europe's total abstraction volume for industrial activities is abstracted in Western Europe (43%) and about a third in Southern Europe (33%) (Figure 6.1).

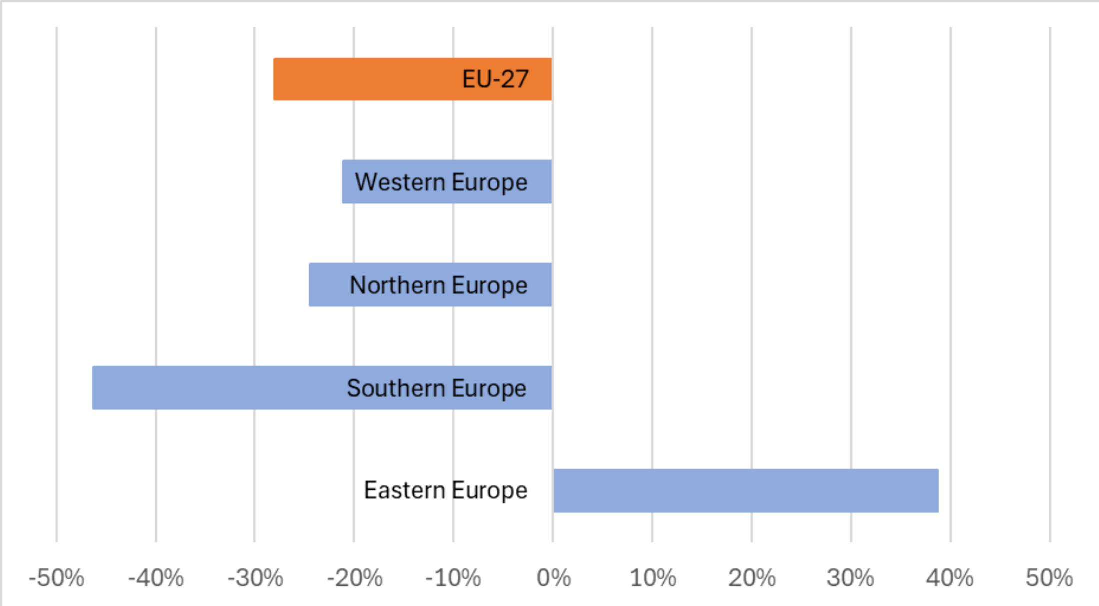
Figure 6.1 Share of water abstraction for the manufacturing industry by region in the EU-27 (2000-2022)



Source: EEA, 2024b

Overall, water abstraction for the manufacturing industry has declined by 28% between 2000-2022 in the EU-27. This comes as a result of improvements in water use efficiency by the sector. However, a look at the regional level shows the trend is actually mixed, with an important increase of water abstraction levels in Eastern Europe partly offsetting efficiency gains in the other three regions (Figure 6.2). The substantial increasing trend of water abstraction for industry in Eastern Europe is mostly related to the economic transition of the region's countries, resulting from their integration into the EU. While it should be noted that Eastern Europe holds the second smallest share of total annual water abstraction for industry from all regions (13%), efforts should be made to reverse this trend. Furthermore, it is necessary to assess the remaining water saving potential in Southern Europe, the total annual water abstraction for industry has decreased by 46% over the last two decades.

Figure 6.2 Changes in water abstraction for the manufacturing industry by region in the EU-27 (2000-2022)



Note: Positive values identify an increase and negative values a decrease.

Source: EEA, 2024b

Table 6.2 provides a qualitative, non-exhaustive overview of the key drivers of the increasing and decreasing of water demand in the manufacturing industry. The net result of these partly counteracting trends is highly uncertain and variable across the manufacturing sub-sectors and across the EU.

Table 6.2 Expected key changes and impacts on demand for the manufacturing industry

Relevant drivers in manufacturing	Expected trend in driver (increase/decrease)	Expected impact (increase/decrease) on water demand
EU population by 2100	↘	↘
Income and living standards – manufacturing production	↗	↗
Water-efficient technology and operational management	↗	↘
Air and surface water temperature under climate change	↗	↗
Competitive strength of Europe's manufacturing industry; changes in global import-export balances of water-intensive products	Uncertain	Uncertain

Note: Green indicates a positive effect on water demand (i.e., decreasing demand); orange indicates a negative effect.

Source: Authors' elaboration.

6.4 Water saving potential and measures in the manufacturing industry

6.4.1 Assessing potential improvement of water intensity in the manufacturing industry

The ratio of water consumption and net value added by the manufacturing sector (water intensity of manufacturing production) can be used to compare the amount of water consumed in the manufacturing sector of different countries to produce the same amount of net value added. For instance, Denmark consumes 0.8 m^3 of water to generate 1000 PPS of net value added from manufacturing production, whereas Finland, from the same region, consumes 32 m^3 of water to generate the same amount of net value added.

Table 6.3 presents the best performing country at the regional level and the regional average of water intensity for all countries in the same region, as a rough indication of the regional differences in performance. However, it should be considered that while the countries are grouped in the same geographical region, the characteristics of their manufacturing production systems can differ largely. Furthermore, the indicated numbers should be read with caution as they do not necessarily represent the technically and economically feasible improvements of water intensity. Therefore, the comparison with the best performing country could lead to very ambitious expectations in terms of water saving potential. However, in a more modest ambition scenario, where each country in each region could achieve at least the same performance as the regional average of water intensity, the potential water saving by the manufacturing sector could be around 32 % at the EU level (Table 6.4).

It is noted that current common practices for water saving in the manufacturing sector in Europe seem to focus mainly on the implementation of new water saving technology and / or control processes to treat and recirculate process water and/or wastewater. This appears to run across the board for the industries for which information has been found and reviewed. Reducing the water intensity of the manufacturing production should be further pursued, in line with existing EU policy, e.g. Action Plan on Sustainable Consumption and Production, Sustainable Industrial Policy, CEAP, ZPAP, Eco-design guidelines and more.

Table 6.3 Water intensity of manufacturing production by region in the EU-27

Regional average of water intensity		Water intensity of best performing country within the region	
	m^3 / 1000 PPS		m^3 / 1000 PPS
Eastern Europe (BG, CZ, HU, PL, RO, SK)	10.2	HU	3.1
Northern Europe (DK, EE, FI, IE, LT, LV, SE)	11.8	DK	0.8
Southern Europe (CY, ES, EL, HR, IT, MT, PT, SI)	11.7	MT	0.9
Western Europe (AT, BE, DE, FR, LU, NL)	9.7	LU	0.3

Note: Water intensity of manufacturing production is calculated as the ratio of the volume of water consumed by the manufacturing sector per Member State and the net value added of manufacturing production, expressed in the Purchasing Power Standard (PPS), which adjusts values in national currency to a common unit considering purchasing power in every country. Net value added is computed as gross value-added excluding consumption of fixed capital, all expressed in chain-linked volumes (2010).
Data refer to the period 2000-2022.
Comparisons between different regions may not be meaningful, due to differences in production systems.

Source: EEA, 2024b, 2024c; Eurostat, 2025a, 2025c; Authors' elaboration

Table 6.4 Estimated water saving potential by improving the water intensity of the manufacturing industry in the EU-27

Region	Average annual water abstraction by manufacturing industry (million m^3)	Estimated annual volume of water that can be saved (million m^3)	Theoretical water saving (%)
Eastern Europe (BG, CZ, HU, PL, RO, SK)	3 700	1 590	43
Northern Europe (DK, EE, FI, IE, LT, LV, SE)	2 930	1 400	48
Southern Europe (CY, ES, EL, HR, IT, MT, PT, SI)	9 300	3 260	35
Western Europe (AT, BE, DE, FR, LU, NL)	12 230	2 690	22
EU-27	28 160	8 940	32

Note: The values in the table have been estimated based on the annual average volume of water abstraction for the period 2000-2022, assuming that all countries within the same region can achieve at least the average water intensity of that region. Markedly, if saved water is used to expand manufacturing production or exploited by other users within the same river basin, then the results of the water saving effort could be partly or totally reversed.

Source: EEA, 2024b, 2024c; Eurostat, 2025a, 2025c; Authors' elaboration

6.4.2 Water saving in the food and beverages industry

As one of the most water intensive industries, the food industry accounts for about 1-1.8% of the total European water use, and about 8-15% of the total industrial water use. Major water consuming sub-sectors are the fruit and vegetable processing (2.4-11 m^3/t), meat and poultry processing (2-20 m^3/t) dairy processing (0.6-60 m^3/t), and fish and seafood processing (7-50 m^3/t) (Ölmez, 2013). Moreover, water use for the production of beverages can be as high as 45 litres of water per litre of final product (Socotec, 2020).

Across the industry, most water (70%) is used for washing, cleaning, and disinfecting the intermediate and final products, but also any external surfaces, equipment, machinery or containers within process facilities. About 20% of water is consumed for heating (e.g. blanching, cooking, steaming, pasteurizing) or cooling (of products and equipment). Roughly 20-30% of all water is used as an ingredient. Other purposes include water as mechanical energy vector (e.g. to transport crops, for jet cutting, for gravity-based separations), as a boiler feed for process steams, or as a solvent to extract or transfer solutes from or to solids (e.g. sucrose extraction, pickling, candying). The water quality requirements vary for different processes. Any water that comes into contact with food products, for cleaning or as an ingredient, must at least have potable quality. The same applies to any water that comes into contact with surfaces or materials that directly touch food products. Certain processes, such as jet cutting, process steaming, or ion-exchanges for solvents, require further water treatment such as filtration, demineralization, or pH changes (Ölmez, 2013); (Maxime, et al., 2006); (JRC, 2019). Sources of water that are used in the food, drink and milk sector are tap water, groundwater, surface water, rainwater, and water originating from the raw material and reused water (JRC, 2019).

Options for reducing water use in the food and beverages industry

Enabled by continued technological advancement and driven by environmental, regulatory, and economic requirements, the food and beverages industry has been reducing its water use since the 1950s, from an average of 10-12 m^3/t of final product to less than 2 m^3/t by the 2000s (Flörke and Alcamo, 2004).

Moreover, the industry continues to improve processes and practices, which provide substantial ground for further water saving potential (see Text box 6.1).

Text box 6.1: Indicative examples of achieved water savings in the food and beverages industry

- The beer brewing sector is continuously adopting new technologies and practices to save water (FoodDrinkEurope, 2022). In Belgium, overall, 16 breweries adopted new water management practices in a joint effort that resulted in a reduced water use of 289 000 m3. For instance, the Flemish brewery Brouwerij Vanhonsebrouck reduced water use by 9% through optimized cleaning and washing machinery, while Duvel Moortgat Brewery reduced water use by 25% with a new water reuse instalment (Fevia, 2021). Anheuser-Busch, a major American beer producer, reported to have reduced water use by 50% within 10 years, integrating various measures at plant scale and aiming for further reductions in the future (Danigelis, 2018).
- At the Danone production site Rotselaar, where the main output is yoghurt, Danone reuses 75% of its consumed water by means of new technologies, saving 500 000 m3 annually (Danone Belgium, 2020). Another dairy producer, Dairy Crest Davidstow in the UK, reduced its fresh water use by 20% through various measures, such as fixing leaks, optimizing cleaning systems, and recovering water vapour (FoodDrinkEurope, 2022).
- Inalca SpA implemented several technical measures at its beef processing facility in Rieti, Italy, which processes 40,000 tonnes of meat annually and is significantly dependent on water for steam generation and cooling. The aim of the measures was to reduce water and energy consumption among other operating costs. Implemented measures included the installation of a reverse osmosis system to remove contaminants at the inlet, which coupled with other process enhancements, resulted in a reduction of over 55 tonnes per year in chemical use and its associated risks and expenses. Further, automation solutions incorporated in the plant's boiler and cooling systems allowed for a reduced frequency of boiler water blowdown and for water reuse in the cooling towers, altogether generating annual water savings of 14,000 m3. Additional potential could be exploited, as about one-third of the cooling towers could still be fitted with the technology (Business Wire, 2017).

According to (Ölmez, 2013) water reuse and recycling in four major water using sectors (fruit and vegetable, meat and poultry, dairy, and fish and seafood) could reduce their freshwater use by up to 90%. This figure is based on the largely untapped potential to reuse or recycle vast quantities of process water, in particular cleaning water. For example, Lee and Okos (2011) demonstrated that the reuse of soak water in the production of masa corn may result in a reduction of water intake and wastewater discharge by 55% and 88%, respectively, without a considerable effect on the quality of the end-product.

However, as food safety standards require potable water quality for most of the process water, water reuse may depend on several stages of costly water treatment to achieve the required quality and disinfection. Physical processes, such as sedimentation, centrifugation and filtration, separate all larger particles from the water, before a biological treatment removes organic matter. Finally, advanced treatment methods separate or eliminate any remaining contamination for the disinfection of the water. The replacement of high-quality fresh water with treated process water depends on economic considerations of comparative cost.

Chlorination has been the most common disinfection technology in the industry. However, high levels of chlorine are toxic for the human health, while discharges of chlorinated water may pollute natural water bodies. For this reason, more recent technologies, including UV irradiation, ozonation, and membrane filtration with reverse osmosis, are increasingly being favoured (Kirby, et al., 2003). Ozonation enables high recycling ratios of process water, without the risk of chemical contamination (Prabha, 2015); Socotec 2020). Coca Cola, for example, has reduced its water use by 13% over the term of five years with an ozonation based water treatment solution (Grainger Editorial Staff undated). Technologies for membrane filtration and reverse osmosis have also been optimized to increase water efficiency (Basile and Ghasemzadeh, 2024). While previous systems had a discharge rate of 25-50% of water input, recent technologies offer a discharge rate of less than 10% (Socotec, 2020); (Suárez and Riera, 2015). Considering

that cleaning water accounts for 70% of the industry's water use, a possible reduction of discharge from nearly 100% (without treatment) to 10% suggests a substantial water saving potential.
Improved management practices are the most cost-effective to increase water use efficiency. Up to 30% of reduced water use is made possible by adopting a wide range of small-scale measures, including the raising of awareness, improved cleaning routines, basic maintenance to prevent water leaking, manual triggers on hoses, improved set up of cleaning stations (Food Engineering, 2016). The Australian Government found a water saving potential in the Australian food and beverages industry of up to 25-60%, based on measures that do not require large investments such as water use monitoring, behavioural changes, and water reuse without treatment for purposes that do not require high water quality (Nikmaram and Rosentrater, 2019).

Other small to medium scale measures have been compiled by (Ölmez, 2013):

- Easy to clean conveyor belts like V-shaped rollers.
- Automatically controlled spray rinsing and overspray foggers instead of typical overflow systems;
- Multi-stage counter-current flow systems which consume up to 50% less water as compared with the conventional single-step washing system.
- Flow restrictors to maintain the optimum water flow rate.
- Segregating effluents with different wastewater characteristics to reduce the overall pollutant load and allow for the optimization of the reuse of water and treatment needs.
- Removing organic material from the process water at the point where it is first introduced to water, before the progress of bacterial growth and before it is mixed with other contaminants.
- Dry pre-cleaning prior to washing.
- High-pressure low volume washing systems.
- Pneumatic or mechanical conveying systems instead of hydraulic systems.
- Steam blanching instead of water blanching[19].
- Vacuum thawing, air blasting or still air instead of open tubs of water for thawing.
- Air blast cooling instead of water cooling.
- Dry peeling instead of wet peeling.

The optimization of clean-in-place (CIP) systems provides another widespread opportunity to reduce water use in the food and beverages industry. CIP is 'the cleaning of complete items of plant or pipeline circuits without dismantling or opening of the equipment and with little or no manual involvement on the part of the operator. The process involves the jetting or spraying of surfaces or circulation of cleaning solutions through the plant under conditions of increased turbulence and flow velocity' (Walton, 2008). CIP systems account for 50% of all non-product water used in the food and beverages processing environment (Price and Heldmann, 2018). Several measures can increase the water efficiency of CIP systems, including the capturing and storing of rinse water, use of pulsed rinses (Ölmez, 2013), membrane technology for water reuse (Pagan et al., 2004), optimizing pipe sizes, strategic locations of the CIP in the facilities, optimized CIP circuits, among other measures (Price and Heldmann, 2018). (Pagan et al., 2004) report a 50% water use reduction through the use of optimized CIP systems using membrane technology.

6.4.3 Steel industry overview

The EU produces 177 million tons of steel per year, roughly 11% of the global steel supply. It comes second only after China in terms of production volume. Important activities of the European economy depend strongly on the steel industry, such as the manufacturing and processing of cars, electronics, mechanical and electrical engineering, and construction. About 500 production sites are located across 23 EU

[19] Blanching is a heat treatment that is commonly applied to food before it is dried, frozen, fried, or canned. During blanching, food is heated in steam or hot water for a short period and then cooled by dipping into iced water or water spray to end the cooking process. Blanching is used to soften food by partially or completely cooking it, or to eliminate a sharp flavour (for example, of bacon, cabbage or onions) (Jafari, 2023)

countries. The main challenges of the European steel industry relate to the costs of energy – which make up 40% of the total operational expenses – and access to raw materials (EC, 2024c).

Water use in steel production

Steel production involves different process facilities, which are often found integrated in steelworks. Suvio, et al. (2012) report average water use (including re-used and recycled water) for different process facilities in the steel production chain. In 2011, an average integrated steelworks had a water abstraction of around 24-28 m^3 for each ton of steel produced, while discharging 25 m^3/t (World Steel Association, 2015; Colla, et al., 2017). Although these figures might be lower in the European context, they clearly point towards substantial water requirements, possibly reaching a large volume of water each year. Accordingly, the CDP Water Impact Index ranks all activities related to the steel industry (e.g. smelting, refining, forming, processing) as having a critical water impact (CDP, 2024). In general, cooling and rinsing of materials and equipment are the most water intensive steps of the steel production process. The water consumed (i.e. lost to evaporation) is in the order of 1 m^3/t or 4% of the abstracted volume.

Water use varies substantially across integrated steelworks, ranging from less than 1 m^3/t to over 148 m^3/t, correlating to water discharge figures from less than 1 m^3/t to about 145 m^3/t (Colla, et al., 2017; Suvio, et al., 2012). These vast differences are only partially explained by the presence or absence of particular process facilities within individual steelworks. From the perspective of water use efficiency, it is critical to assess different water systems of the water using operations. However, a detailed analysis is beyond the scope of this report.

Water systems can be closed loops, semi-closed or open circuits (Suvio, et al., 2012; JRC 2013). Most water in the steel industry is used via open circuits, in particular once-through cooling systems. Once-through cooling systems account for 82% of all water use within a sample of 28 steelworks representing 8% of the global supply (Suvio, et al., 2012). These systems are only viable where water is abundant, relying mostly on sea water, brackish water, or large rivers (Colla, et al., 2017; Suvio, et al., 2012); also cf. cooling water use in the electricity production sector (Chapter 5). While completely closed loops are relatively rare, semi-closed circuits are more common. Such systems are used in cooling towers where cooling water temperature is decreased for re-use, while a smaller discharge prevents the accumulation of salt deposits (Colla, et al., 2017). The recycling and re-use of waste and process water also employs semi-closed circuits, in which undesirable substances are extracted and treated with fresh water before their final discharge (JRC 2013).

Moreover, a large amount of water is used indirectly by supporting functions, such as equipment cooling and power generation, outside of process facilities. When such supporting functions are included, they account for 33% of the average water use (including re-used water) (Colla, et al., 2017).
Major drivers for water efficiency in steelmaking are local factors such as limited water availability, regulations, and prices for energy and water services (World Steel Association, 2015; JRC 2013). Such drivers have reduced water use by the European steel industry since the 1980s, by incentivizing investments into improved processes and technologies (JRC 2013). The following section presents the different approaches used to reduce water use in the steel industry, as reported in the literature.

Optimizing process facilities

One approach to improve water use efficiency reviews water use of different process facilities to develop opportunities for greater efficiency (Klimes Lubomir et al., 2019). The European Commission's Joint Research Centre (JRC), for example, published a reference document for best available techniques (BAT) in steel production, which proposes general principles to improve water use efficiency of sinter plants, palletization plants, blast furnace, electric arc furnace and casting, and basic oxygen steelmaking and casting (JRC 2013). These techniques include maximizing the recycling of cooling water, minimizing discharge by increasing water re-use, applying multiple filters for wastewater treatment, closed water circuits, and dry-cleaning methods. The JRC has not quantified the water saving potential of BATs. However, the BATs provide a ground to understand the differences in water use among integrated steelworks, roughly indicating water saving potentials. As water use ranges from less than 1 m^3/t to over 148 m^3/t (Suvio, et al., 2012), the water saving potential of the BATs could in principle be anything from 1-147 m^3/t. In an example plant mentioned in (JRC 2013) the recirculation rate was increased to 97.2% and only 2.8% needed to be replenished with fresh water. The discharge as wastewater was only 1.2% and the rest were evaporation losses of about 1.6%. As a result, the water intake was about 3.2 m^3/t crude steel.

Improving cooling technology

The improvement of cooling technology in the industry sector can directly reduce water use in the cooling process. (Klimeš et al., 2020) note that 'any technological improvement in the cooling technology leading to a reduced consumption of water, even in the order of 0.1%, has a potential to globally spare a vast amount of water in the natural environment and minimise the water footprint' (Klimes Lubomir et al., 2019). Moreover, the water saving potential of spray cooling in the secondary cooling process is particularly relevant for saving high quality water (e.g. drinking water), as this technology relies on high quality freshwater to prevent the clogging of the spray nozzles.

(Klimes Lubomir et al., 2019) discuss two approaches to reduce water use in spray cooling processes. Firstly, the optimization of spray nozzles and their arrangement can reduce water use by 10-20%. Secondly, adding nanofluids to the cooling water increases the heat transfer capacity of the water and can reduce water use by up to 33%. Both approaches combined can reduce water use in spray cooling by up to 70%. However, the high costs of the applied nanofluids makes their application economically unattractive despite their water saving effects. It is further unclear, to what extent nanofluids increase water treatment costs. In a later paper, (Klimeš, et al., 2020) propose the use of dry cooling technologies, which could save 48% of once-through cooling water in the process of continuous steel casting.

Energy conservation measures

Water use in the steel industry is positively correlated with energy consumption. As the largest industrial energy consumer (Conejo, et al., 2020), the steel industry can reduce water use through energy conservation measures. Among the two main alternative production routes for steel – blast oxygen furnace and electric arc furnace – the more energy-efficient electric arc furnace route uses 10-16% less water (Klimes Lubomir et al., 2019); (JRC 2013). While the blast oxygen furnace constitutes the traditional steelmaking process from iron ore and coke, the electric arc furnace uses electricity to re-cycle scrap metals.

(Gao, et al., 2019) developed a hybrid model to optimize the water-energy nexus in Chinese steelworks. They assessed 16 energy-saving and energy-recycling technologies. Eight energy-recycling measures can achieve a direct reduction of water use of 0.13 m^3/t steel. Moreover, the assessed energy-saving and energy-recycling technologies further contributed to an indirect water saving of 0.17 m^3/t and 0.47 m^3/t, respectively. The authors found that a simultaneous implementation of all assessed technologies can achieve a total reduction of direct and indirect water use of 0.68 m^3/t.

The penetration rate of these technologies in the European steel industry is unknown. On average, Chinese steelworks use about twice as much water as their counterparts in western countries (Gao, et al., 2011). However, it could be expected that older European steelworks may lack some of the discussed technologies, especially when they have faced only limited pressures to reduce water use in the past.

Water re-use and re-cycling for cooling water supply

The majority of water efficiency measures focus on water re-use and recycling to reduce freshwater abstraction. (Colla, et al., 2017) discuss reverse osmosis and ultrafiltration to desalinate cooling water in semi-closed circuits, which reduces water use by up to 20%. They further assess the technologies as 'transferable and easily implementable'.

Similarly, at ArcelorMittal's plant in Gijon, Spain, reverse osmosis allowed for a 10-13% reduction of freshwater use and 80% reduction of wastewater production. ArcelorMittal reports to recycle water up to 75 times (A.SPIRE, 2024a). A potential limitation of these technologies is the need to manage the concentrates in a sustainable way. VDEh-Betriebsforschungsinstitut has used capacitive deionization (CDI) for the electromagnetic absorption of salts from the cooling water, which improved water re-use and reduced water losses through discharge by 1-5% (SpotView, 2016). A prototype technology by the Swedish steel producer Sandvik allows to reuse more than 90% of the process water used for steel pickling, by using reverse osmosis and nanofiltration and recovering 65% of phosphoric acids from the spent pickling acids (A.SPIRE, 2024b).

6.4.4 Pulp and paper industry overview

Paper is produced from either recycled paper or from wood pulp. In the EU, recycled paper represents around 50% of the total (JRC, 2013). The annual production of wood pulp in Europe is about 42 million tonnes/year (JRC 2015). Assuming an average water use of 30 m^3/tonne (see Table 6.5), the total abstraction volume for pulp production in Europe is estimated at 1250 million m^3/yr, which is around 4% of the total abstraction for the manufacturing industry.

Table 6.5 Water use in paper and board production

Product type	Specific water use (m^3/t)
Coated and uncoated folding boxboard	5 – 30
Corrugated medium and packaging paper	1.5 – 35
Newsprint	9 – 20
Tissue	9.5 – 50
Writing and printing paper	9.5 – 55

Note: About 1.5 m^3 of water per tonne of paper is vaporised in the dryer section of the paper machine and does not appear as wastewater.

Source: JRC, 2015

Water use in pulp and paper production

Water is used in the pulp and paper industry in the subsequent production phases of debarking, chipping, pulping[20] and paper production. Processing of recycled paper to pulp can replace the pulping process.

Within the phases of pulp and paper production water is used for processes such as chemical or mechanical treatment, showering, washing, steaming, cooling and transport. The volumes of water used for production vary with the type of pulp and paper that is produced: mechanical pulp[21] or chemical pulp[22]; type and quality of paper, from packaging to tissue, to writing and printing paper. A detailed overview of

[20] Pulping is the process of converting raw fibre (e.g. wood) or recycled fibre to a pulp that is usable in papermaking.

[21] Papermaking pulp made entirely by mechanical means from various materials such as wood, wood chips or sawdust. Mechanical pulp contains a considerable amount of non-cellulosic compounds.

[22] Chemical pulp which is manufactured using sodium sulphide, various sulphites or bisulphites as the main cooking chemical to digest wood chips.

the existing production arrangements is provided in (JRC 2015). The wastewater flow of the various types of chemical pulp mills varies, between 14 and 156 m^3/aDt (Air Dry tonne of pulp).

There is a marked difference in water management between integrated and non-integrated pulp mills. In an integrated mill pulp and paper production are combined, and the pumpable pulp comes from the pulp process to the papermaking process. The pulp consistency depends on the dewatering device between the pulp and paper mill. Waste water from pulping and from papermaking is often treated in one single treatment plant. However, separate treatment plants are also used at integrated mills. In non-integrated pulp mills, the market pulp is dewatered and dried. The volume of water used is closely linked to the wastewater load discharged from the mill.

In mechanical pulping processes, the water systems are usually closed in order to maintain high process temperatures. Fresh water is only used for sealing and cooling, as the surplus clarified waters from the paper machine are usually used to compensate for the water leaving the circuit with the pulp (5 – 10 m^3/tonne of pulp) and with the fibre losses and sludge. For a mechanical mill, sources of emissions to water are wood handling, cleaning and bleaching.

Mechanical pulp mills are, with few exceptions, integrated with paper production. This means that water for the pulp mill usually comes from the paper machine and the effluents from the pulp mill are directed to the sewer, where wastewater from both the pulp mill and paper machine is mixed and subsequently treated together.

Water saving measures

The basic water reduction solutions in pulp and paper mills are the following:

- Improvement of paper production planning.
- Increasing internal water recirculation.
- Efficient separation of cooling waters from process water and their re-cooling in cooling towers for reuse; 10-15% fresh make-up water is required when reusing this stream.
- In a pulp mill by changing wet debarking to dry debarking, by changing over to more efficient washing equipment, by recycling filtrates, by using the condensates from evaporation and by closing the screen room with respect to water.
- In integrated mills, the water circulation in the paper machine is kept separate from pulping sections and excess white water[23] from the paper machine is fed in counter-current mode to the pulping department.
- The shower water system is usually the biggest consumer of fresh water in the paper machine system. Shower water use is usually in the range of 2 – 7 m^3/t, assuming a total water use of about 10 – 15 m^3/t of paper. To reduce the freshwater use to reasonable levels, most of the freshwater must be replaced by clarified white-water[24].
- The recycling loop for part of the vacuum pump sealing water with cooling and solids removal
- Management of all raw material flows through the paper mill in considering them a unit of fibres, chemicals and water that interfere with each other. All inputs of chemicals for instance are controlled and investigated with respect to how they influence water quality and wet-end chemistry
- Design and maintenance of piping and storage chests in such a way that excess water volumes can be stored, and the water quality is not deteriorated
- Training and motivation of the staff, which is crucial to achieve and maintain low water use.

[23] General term for all process waters of a paper mill that have been separated from the stock or pulp suspension, either on the paper machine or accessory equipment, such as thickeners, washers, save-alls, and from pulp grinders. It carries a certain amount of fibre and may contain varying amounts of fillers and dyestuffs.

[24] 'White water' is the term used for the process water in the pulp and paper sector, because it contains fines, fibres and other suspended solids that render it a milky or cloudy appearance (Valmet, 2024).

A modern bleaching plant normally uses a wastewater flow in the order of magnitude of 15 – 20 m^3/t. One mill in Sweden reports achieving a water effluent of 10 m^3/t. Considerable investment is required. The driving force for implementation are the environmental requirements from competent authorities (JRC 2015).

Depending on the starting point, the characteristics of the mill and the product quality, the freshwater use of a standard quality uncoated paper or board machine could reach 3-12 m^3/t and a standard quality coated printing paper machine 5-15 m^3/t (JRC 2015).

Achievable specific volumes for water use for integrated mechanical pulp and paper mills, using the production of graphic paper as example, is 9-15 m^3/t (JRC, 2015). The reasonable extent of water circuit closure also depends on local conditions. Factors such as climate, water availability, source and quality of freshwater and the type, quality and sensitivity of the receiving watercourse may influence technical solutions.

Most European paper mills have implemented stepwise water-saving measures. In the context of the EU-funded project 'PaperBREF', cited in (JRC,2015), the implementation costs of a more systematic water management plan in 30 paper mills in Italy were investigated. The results of the study carried out in the paper mills showed that with a very low investment a potential saving rate of 12% of the water used could be reached; savings of 22% are possible with an improved water use and some important investments. With significant investments for the rebuild of numerous parts of the mill, it is possible to reach a savings rate of 40% (JRC 2015).

Furthermore, replacing virgin paper with recycled paper results in significant cuts in water use, as recycled paper needs considerably less water to be produced. It is estimated that recycled paper for copying machines requires 49% less water than virgin paper. Recycled paper also has additional benefits as it needs less energy (-33%) and results in lower CO_2 equivalent emissions (-37%), wastewater discharges (-49%) and solid wastes (-39%) (Kinsella, S., 2012).

7 Water saving potential in the public water supply sector

7.1 Summary of the chapter

- *Water abstraction for public water supply accounts for 19% of total water abstraction in the EU-27 between 2000 and 2022, increasing by approximately 10% since 2000.*
- *Nearly 33% of water abstraction for public water supply is lost between the point of abstraction and the point of supply, with the highest losses (>40%) being observed in Bulgaria, Croatia and Italy, and the lowest losses (<15%) in Austria, Denmark and Netherlands.*
- *Non-revenue water, including real losses, apparent losses and unbilled authorized consumption, reaches up to 25% of the water that enters the urban distribution networks or 2,700 m^3 per km of pipe per year.*
- *Leakages and other losses in the internal distribution systems of buildings ('indoor water leakages) could be more than 10% of supplied water. Level(S), the European framework for the evaluation of building sustainability performance, includes a target to reduce water consumption in buildings by 30%.*
- *If the lowest daily household water use per person was attainable in all countries within the same region, then the daily household water use per person could potentially decrease by 10-40% in each region from its current levels. Recent trends indicate a 3% reduction in daily household water use per person in Europe between 2017 and 2021.*
- *A reduction of water abstraction for public water supply by 20-50% overall is theoretically feasible.*

According to (Dworak, et al., 2007) individual measures could reduce domestic water use by 20-50%, which is a quite significant reduction to justify the installation of water saving devices through state-funded or utility-funder rebate programmes with a short payback period for users. Water utilities could benefit from the saved energy costs for transferring, treating and distributing the saved water, which, in various cases, would remain unmetered or unbilled. Furthermore, (Benito, et al., 2009) estimated that households could save up to 32% by using more water-efficient household appliances and up to 20% by using more water-efficient toilets and showers alone.

A more recent EU-wide modelling study by the JRC (De Roo, et al., 2023), based on best available estimates of planned investments, estimated that the planned public investments in urban leakage reduction between 2016-2027 could save marginal amounts of water at the national level (<1%), with the highest savings expected in Croatia, Cyprus, France, Hungary, Italy and Malta. This leads to a similar conclusion as drawn in chapter 4 for agriculture: the currently planned investments are not sufficient to achieve the potential water saving. Furthermore, the same study estimated that desalination could cover more than 20% of the water use for public water supply at a cost up to 0.5 Euro per m^3 in Croatia, Greece, Italy, Malta and Spain. At a cost up to 1 Euro per m^3, more than 20% of the water use for public water supply could be covered additionally in Portugal and Slovenia. In all above cases, water scarcity conditions, measured by the Water Exploitation Index+ (WEI+), could improve, but not in a substantial way, meaning that countries in severe water stress would remain at the same regime, not taking into account the additional impacts from climate change.

Based on the literature review an overview of promising water saving measures in public water supply is presented in Table 7.1.

Table 7.1 Overview of promising water saving measures in public water supply

Category	Measure	Aim related to water saving	Potential saving (%)
Leakages and other losses in external water works (excluding evaporation losses from reservoirs)	Sound design, maintenance and quick repair	Reduce abstraction	up to 10%
	Shift from open channels to closed pipes		25-35%
'Non-revenue' water: Real losses due to leakages in distributions mains, transmissions and service connections up to the metering point, as well as overflows from storage tanks	Sound design, maintenance and quick repair / Replacement of aging pipes	Reduce abstraction	
'Non-revenue' water: Apparent losses due to metering inaccuracies and data handling errors	Device replacement / Smart metering installation / Modern Information System	Reduce abstraction and consumption, as a side-effect of billing	up to 25%
'Non-revenue' water: Unbilled authorised consumption, due to unbilled unmetered or metered water use	Metering / Good management practices	Reduce abstraction and consumption	
'Revenue' water: Billed metered and unmetered consumption Reduction in daily household water use per person	Metering / Water-smart devices / Awareness raising / Good management practices / Incentive pricing	Reduce abstraction and consumption	10-30%
Leakages and other losses in internal distribution systems of buildings	Sound design, maintenance and quick repair / Replacement of aging pipes / Water auditing – Level(S)	Reduce abstraction	10-30%

Note: The references to the data presented are provided in the text of this chapter.

7.2 Overview of the public water supply sector

Public water supply is the organised collection, transfer, treatment and distribution of water by relevant utilities[25]. Water can be collected from rivers, lakes, reservoirs, groundwater (e.g. through springs, wells and boreholes) or directly from rainwater. Public water supply may also include desalination of brackish groundwater or sea water (UN DESA, 2012), where applicable. Public water supply takes place primarily through the mains of an urban distribution network, but it may also involve trucks, ferries or other means. The supply of bottled water and the self-supply of water intended for human consumption (e.g. by individuals, individual households or rural communities) is not included in the scope of public water supply.

Water is treated to remove any pathogens or hazardous substances and to improve its general properties (e.g. smell, taste, corrosivity). The highest level of treatment is applied to water intended for direct human consumption or other domestic purposes taking place in private or public premises, such as in households, offices, businesses, commercial sites and tourism facilities (e.g. for drinking, cooking, food preparation,

[25] Water utilities are economic entities (enterprises) conducting activities associated with 'Water collection, treatment and supply' (ISIC, Rev. 4, div. 36 / NACE, Rev 2, E36.0). The same economic entities usually conduct activities associated with 'Sewerage' (ISIC, Rev. 4, div. 37 / NACE, Rev 2, E37.0) (UN DESA, 2012; Eurostat, 2008).

washing, cleaning, sanitation, gardening, amenities). The same level of treatment is also required for water being used in food businesses, such as restaurants and food industries (e.g. for manufacturing, processing, preservation or marketing of products or substances, etc.). In some cases, tourism facilities, which are connected to organised public water supply networks, may also depend on self-supply of water to meet their needs either partly or alternatively to the main supply (e.g. groundwater abstraction or desalination at times of water shortage). The relevant water quality requirements for water intended for direct human consumption or other domestic purposes are stipulated in the Drinking Water Directive (DWD) and associated national legislations, whose primary aim is the protection of human health through the supply of clean and wholesome water. It is noted that the DWD covers not only public water supply, but also self-supply and bottled water. National authorities may exempt from the provisions of the recast DWD only very small water supplies or supplies posing no risk to human health[26].

Furthermore, water utilities may provide water of suitable quality to manufacturing and industrial facilities, which are connected to public water supply networks. However, such manufacturing and industrial facilities may also depend partly or alternatively on self-supply of water by private means. Water intended for manufacturing or other industrial processes does not generally require as high a level of treatment as drinking water, but it may require special treatment to remove particles harmful to the industrial equipment, following national regulations and international guidelines.

By definition, public water supply does not include the organised collection, supply and application of water intended (primarily) for agricultural purposes (e.g. irrigation of crops, raising of animals) (Eurostat, 2023a; UN DESA, 2012). However, there are water utilities that among other users provide water to agricultural holdings within their area of operation. Agricultural water quality requirements are lower than those for drinking water supply and they should follow the standards of the WFD, GWD, EQSD, Water Reuse Regulation as well as national agronomic regulations.

Moreover, in an urban environment public water supply may serve the irrigation of parks and other green spaces, public fountains and taps, street cleaning, urban firefighting and other minor urban uses.

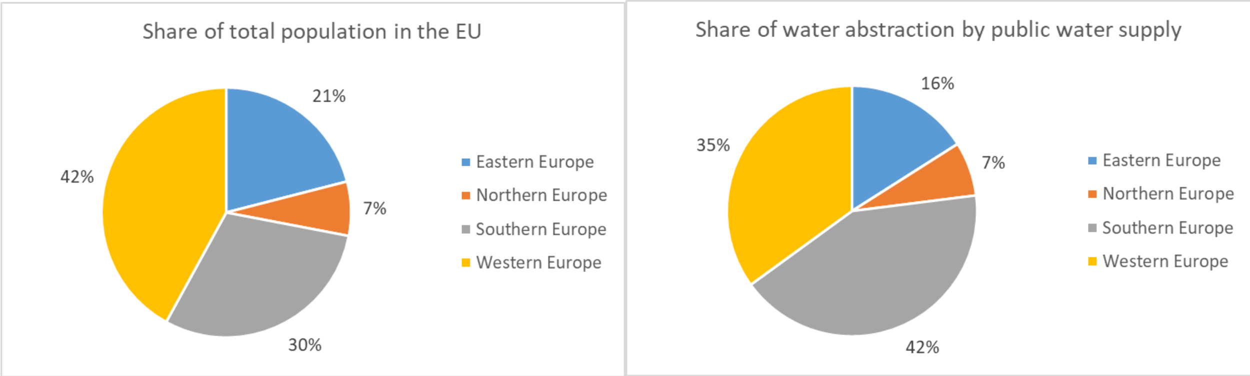
7.3 Water abstraction and water use in the public water supply sector

Water abstraction

The public water supply sector in the EU-27 has abstracted around 39,000 million m^3 of fresh surface water and groundwater on average between 2000 and 2022 (EEA, 2024b). Southern Europe accounts for 42% of this abstraction volume (Figure 7.1), which is significantly higher than the population living permanently in this region (30%). Indicative factors which may explain this disproportionality, include adverse climate conditions, higher water use per person, impacts of tourism on water use, higher leakages in water infrastructure, insufficient incentives for water saving provided by water pricing.

[26] Member States may be exempt from the recast DWD water intended for human consumption from an individual supply providing less than 10 m^3 a day as an average or serving fewer than 50 persons, unless the water is supplied as part of a commercial or public activity, or water intended exclusively for those purposes, for which the competent authorities are satisfied that the quality of the water has no influence on the health of the consumers concerned, either directly or indirectly (EC, 2020).

Figure 7.1 Percentage of total population and water abstraction by public water supply at regional level in the EU-27 (2000-2022)



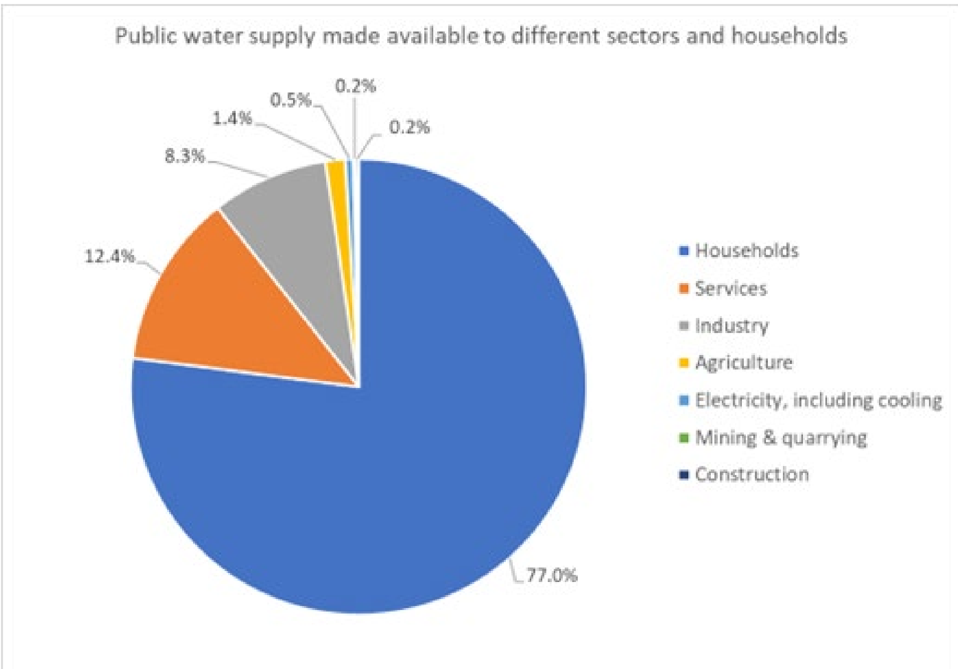
Source: EEA, 2024c

Between 2000 and 2022, water abstraction by public water supply increased by 10% in the EU-27. There is a significant increase in many southern countries, such as Greece (112%), Italy (62%), Portugal (32%) and Slovenia (66%). However, water abstraction by public water supply is decreasing particularly in eastern countries (EEA, 2024b) .

Water use

Between 2000 and 2022, around 24,500 million m^3 of water were made available for use by households and other non-household activities by the public water supply sector in the EU-27. Around 77% of this volume is allocated to households, while the rest 23% is allocated to other non-household activities (Figure 7.2) served by the public water supply network (offices, businesses, commercial sites, tourism facilities, parks and other green spaces, manufacturing and industrial facilities, agricultural holdings, public fountains and taps, street cleaning, firefighting) (Eurostat, 2024f).

Figure 7.2 Water made available for use by households and other non-household activities by the public water supply sector in the EU-27



Source: Eurostat, 2024f

In 2020, 94% of the EU-27 population was connected to public water supply networks, increasing from 92% in 2010. Despite the high EU-27 average, the connection rates were below 90% in several countries, such as Estonia, Lithuania, Romania, and Sweden (Eurostat, 2024g). Connection rates in some countries can be lower than the EU-27 average, due to lower population densities in rural parts of a country, making network connection less affordable than decentralised systems, as well as due to investment gaps, limiting the potential of network connection where this is technically and economically reasonable.

An average household member in Europe[27] uses around 124 litres of water daily (EurEau, 2022). This amount is comfortably above the threshold of 50 litres per person per day, which is considered the minimum amount of water required daily to meet basic human needs (Gleick, 1996). Taking into account that the average household in Europe consists of 2.3 members currently, the average water use of a European household is estimated at 105 m^3 per year (EurEau, 2022).

Furthermore, the average European household uses around 60% of the total household water for bathroom activities (40% for showering and 20% for toilet flushing on average), 20% for laundry and/or other washing activities (e.g. clothes washing machine, dish washer), 5-10% for kitchen activities (e.g. drinking, cooking, washing in the sink) and 10-15% for other household uses (Table 7.2).

Table 7.2 Indicative break-down of total household water use in various European countries

Household activity type	% of total household water use			
	France	**Germany**	**Netherlands**	**Spain**
Showering	40	36	47	34
Toilet flushing	20	27	21	21
Laundry machine	12	12	12	10
Other washing machine	10	6		5
Drinking, cooking, washing in sink	7	4	9	4
House cleaning, house gardening, other	11	15	10	26
Total	100	100	100	100

Sources: France in (LAVIE, 2024), Germany in (UBA-DE, 2024), Netherlands in (Waternet, 2022), Spain in (Castillo Martinez, et al., 2003)

Population change, urbanisation, economic growth, living standards, social values, attitudes, infrastructure maintenance, technological advances and climate change are among the key drivers influencing water abstraction and use in public water supply. Table 7.3 indicates key changes expected and associated impacts on the demand for public water supply. However, the public water supply will also depend on the choices and actions of relevant stakeholders, including governments, water utilities, industries, households, and consumers. Positive impacts are generally expected from applied measures, excluding the case of rebound effects or maladaptation.

A quantitative assessment of future trends in public water supply across the EU-27 was not identified in the literature. Such an exercise is complex because it needs to combine patterns, processes and interactions from the micro-scale (at individual person, household, or urban parcel level) to the macro-scale (at municipal, regional and national scale). For example, local interactions among individuals can accumulate over space and time, generating meso-scale and macro-scale impacts which in turn may feedback to influence or constrain the choices of the individual (Liu, et al., 2007; Irwin, et al., 2009; House-Peters and Chang, 2011; Sattler, et al., 2023).

[27] EurEau's estimate is based on the EU-27 Member States, Norway, Switzerland and the United Kingdom.

Table 7.3 Expected key changes and impacts on demand for public water supply

Relevant drivers in public water supply	Expected trend in driver (increase/decrease)	Expected impact (increase/decrease) on water demand
EU population by 2100	↘	↘
Urbanisation of the population	↗	↗
Rates of network connection	↗	↗
Income and living standards – share of single households	↗	↗
Income and living standards – affordability of water-efficient household devices	↗	↘
Climate change – frequency and intensity of droughts, water scarcity, heatwaves	↗	↗
Current gap of investments and infrastructure maintenance		↗
Digitalisation and technological advances	↗	↘
Shift towards environmentally friendly social values and attitudes	↗	↘

Note: Green indicates a positive effect on water demand (i.e., decreasing demand); orange indicates a negative effect.

Source: Authors' elaboration

7.4 Water saving potential and measures in the public water supply sector

Water saving is important to decrease the volume of water abstracted from the environment and to ensure that abstracted water is not wasted and returned to the environment without actual benefit for the potential users. In parallel, water utilities have high economic interest to reduce the cost of water which is abstracted, treated and conveyed in the urban distribution network (or even supplied to the end-user), but in the end is not properly accounted for and billed. Large water utilities, especially those listed in stock exchange markets, may also have additional motivation to improve their performance on ESG[28] criteria and enhance their access to sustainable financing.

[28] Environmental, Social, Governance. ESG investors seek to ensure the companies they fund are responsible stewards of the environment, good corporate citizens, and are led by accountable managers.

7.4.1 Aggregate leakages and other losses between the point of abstraction and the point of supply

A proxy method to estimate the aggregate leakages and other losses between the point of abstraction and the point of supply is to estimate the gap between the volume of water abstraction by public water supply and the volume of water made available for use to all other socio-economic sectors by public water supply. The volume missing is the potential leakages and other losses. Based on this assumption, the average rate of leakages and other losses relevant to public water supply in the EU-27 was 33% for the period 2015-2019, showing an increase from 30% for the period 2000-2005[29] (Eurostat, 2024h; (Eurostat, 2024f).

The highest rates of leakages and other losses (>40%) are observed in Bulgaria, Croatia and Italy, whereas the lowest rates (<15%) are observed in Austria, Denmark and the Netherlands. Czechia, Greece, Lithuania, Portugal and Spain show significant decreases in their rates of leakages and other losses between 2000-2005 and 2015-2019, although they are still over 20%.

7.4.2 Leakages and other losses in external water works

External water works include reservoirs, boreholes, open channels and closed pipes. As reservoirs are designed to be water-tight, leakages to groundwater are usually negligible compared to total water storage. However, evaporation from their surface area can be considerable. Water transfers through open channels also have losses due to evaporation from the exposed surface area. However, an estimate of the potential losses through evapotranspiration is not feasible, because the evaporation rate is site-specific, depending on climate conditions and reservoir/channel geometry. Water transfers through closed pipes have the lowest rate of losses, which usually takes the form of leakages through the joints of the pipe segments or occurs after pipe damage (e.g. landslide, earthquake). There are currently no comprehensive data available on these types of leakages and other losses. In many cases, the total estimated losses account both for the external water works and the distribution network.

Measures addressing leakages and other losses in external water works

As leakages and other losses increase with the length of external water works for public water supply (e.g. water transfer channels and pipes), balancing the water demand to ensure that it stays within the capacity of local water availability, is important to avoid the need for lengthy and costly water transfer infrastructure. However, where this is not the case and such water transfer infrastructure is already in place, leakages and other losses are usually addressed with typical technical and management measures, such as sound design, maintenance and quick repair. Furthermore, where technically and economically feasible, the shift from open channels to closed pipes could eliminate water lost through evaporation.

7.4.3 Leakages and other losses in urban distribution networks

The OECD study on ‘Financing water supply, sanitation and flood protection in the EU’ provides national estimates of leakages and other losses in urban distribution networks, which range from between 14% and 57% (OECD, 2020). Furthermore, a review of local case studies across Europe (ERM, 2012) indicated that the leakages and other losses in urban distribution networks may range from between 10% and 72%. Similar ranges of leakage/losses rates are also reported in other publications (Ávila, et al., 2021; De Roo, et al., 2023) (see Text box 7.1).

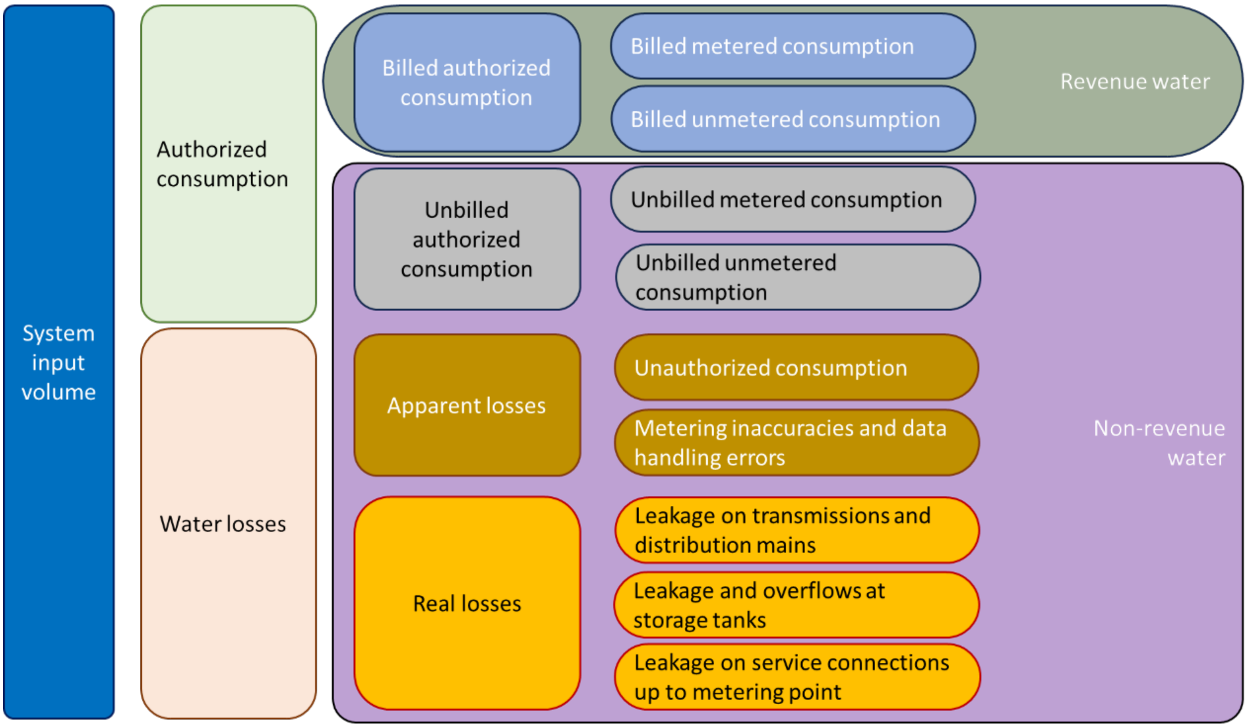
[29] Ten countries were excluded from the estimate due to data gaps (Estonia, Finland, France, Ireland, Latvia, Luxembourg, Romania, Slovakia) or high use of desalinated and reclaimed water (Cyprus, Malta).

Text box 7.1: Computation of water infrastructure leakage losses

According to (EurEau, 2022), there is currently no feasible and agreed European methodology for leakage computation. EurEau is currently working with the European Commission on how to implement the provisions of the new DWD in practice (see: ILI - Infrastructure Leakage Index; e.g. (Lenzi, et al., 2014)) on reporting leakages in the water infrastructure of large water supply zones. However, both the volume and the percentage of leakages, although commonly quoted and widely used, are considered unreliable. It is noted that the assessment of losses gains meaning in the local context, when the management of the network, the origin of the losses and age of the network are known. Mean values provided at the national level are usually extrapolations of local level data (EurEau, 2022). As a result, direct comparisons between different countries should be considered with caution.

Figure 7.3 provides an overview of the key components of consumption and losses in public water supply from a utility-oriented water balance perspective.

Figure 7.3 The key components of consumption and losses in public water supply



Source: World Bank, 2006

Currently, significant shares of public water supply can be physically lost from the urban distribution networks before they are actually used ('real losses'), due to leakages in distribution mains, transmissions and service connections up to the metering point, as well as overflows from storage tanks. Such leakages can be addressed with technical and management measures, such as sound design, maintenance and quick repair. However, they cannot be eliminated for various technical and economic reasons. Sustainable Economic Level of Leakage (SELL) is the optimum level of leakage, when balancing both the cost of leakage management and the cost of lost water (PWC, 2019).

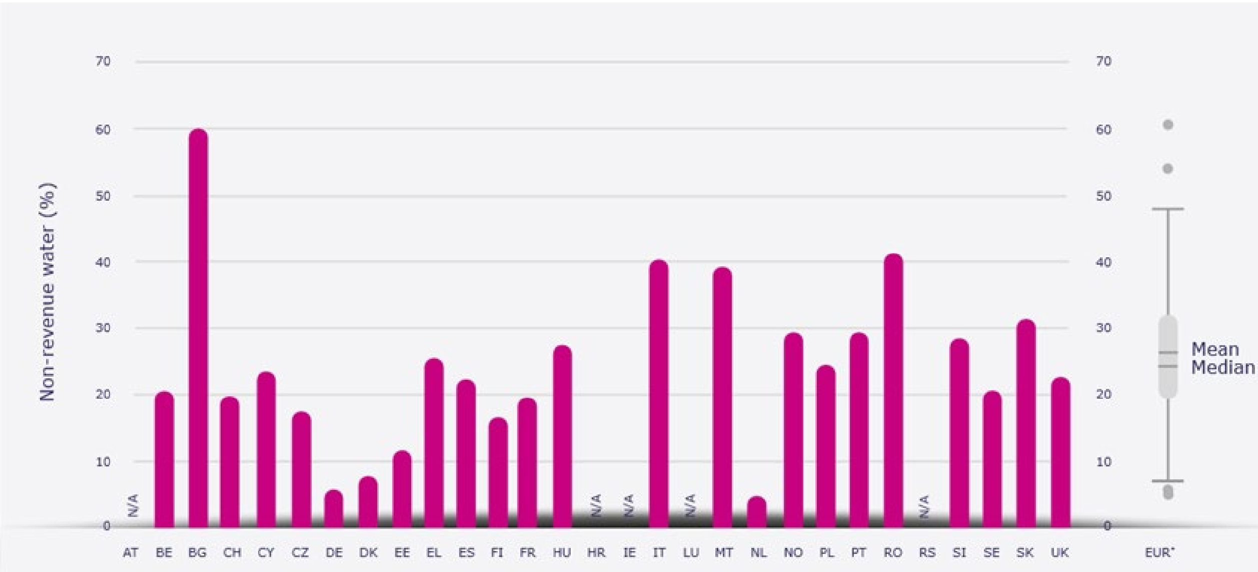
Furthermore, unauthorised users might divert the water and use without being metered and billed. Such water users are 'free riders' of the water service, which can make them less motivated to save water, while the economic damage is passed to the bills of the actual clients. The extent of the problem can vary significantly across regions and cannot be quantified, in terms of the number of illegal connections and unauthorised supply of water. Moreover, metering inaccuracies and data handling errors can result in the increase of water being used without being billed by water utilities. The severity of this issue is also variable across different regions, and the extent of the problem cannot be quantified. Illegal connections, metering inaccuracies and data handling errors are regarded as 'apparent losses'.

There are also authorised users whose water use is not metered (e.g. charged on a non-volumetric basis) or their metered water use remains unbilled (e.g. network maintenance, irrigation of green spaces, street cleaning, firefighting) which is called 'unbilled authorised consumption'. There are no comprehensive data to quantify this category of water use either. In general, the lack of water metering in the first case can lower the motivation of water users to save water, so it should be limited only in non-water scarce areas and where the installation of metering devices costs disproportionately more than the potential water loss. In the second case, water saving can be limited to irrigation improvements and avoidance of waste during street cleaning.

'Non-revenue' water, which includes real water losses, apparent water losses and unbilled authorised consumption, is a major concern for water authorities and water utilities. Non-revenue water needs to be limited as much as possible, based on technical and financial criteria. 'Revenue' water, which represents the input volume for public water supply excluding non-revenue water, consists of billed metered and unmetered consumption (World Bank, 2006). Both components of revenue water may need to be targeted by water authorities with water saving measures, with a priority on the unmetered component. The purpose would be to reduce the high pressure exerted on fresh surface water and groundwater resources, although the revenues of water utilities may be impacted negatively.

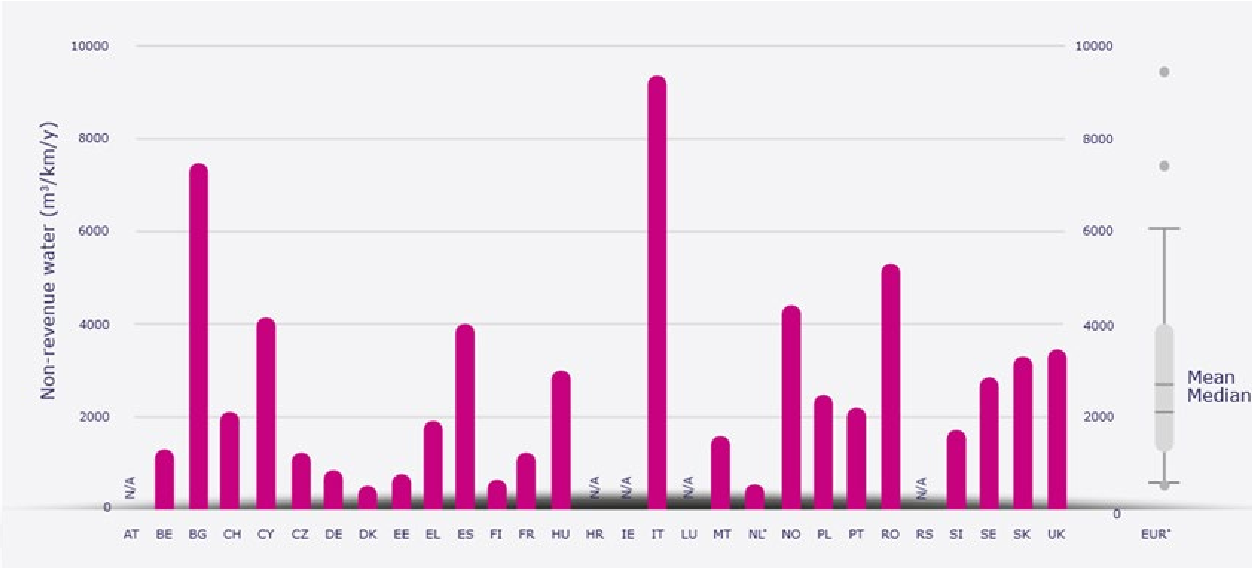
In 2021, 25% of the input water to the urban distribution networks or about 2,700 m^3 per km of pipe per year was regarded as non-revenue water for water utilities. Compared to 2017, there was no significant change. Figure 7.4 and Figure 7.5 show the non-revenue water in urban distribution networks across European countries, as a percentage and as volume of losses per km of pipe. The percentage of the non-revenue water is the highest (>30%) in Bulgaria, Romania, Slovakia, Italy and Malta. The volumetric loss per km of pipe is the highest (>4000 m^3/km/year) in Bulgaria, Romania, Norway, Italy and Cyprus (EurEau, 2022).

Figure 7.4 Non-revenue water in urban distribution networks across European countries, as a percentage (%) of losses



Source: EurEau, 2022

Figure 7.5 Non-revenue water in urban distribution networks across European countries, as volume of losses per km of pipe



Source: EurEau, 2022

Measures addressing physical losses

Physical losses refer to the water lost from the urban distribution system due to leakages, pipe bursts, or other infrastructure-related issues. A strategy addressing physical losses is an essential step towards improving technical water efficiency of the urban distribution network and reducing non-beneficial water abstraction from the environment (see Text box 7.2). Typical measures, which are usually proposed internationally, include the following (World Bank, 2003; Dworak, et al., 2007; Water UK, 2022; EC, 2015a):

- **Pipeline and asset management: progressive network rehabilitation in an economical manner to reduce the need for future corrective maintenance.** Aging pipework is more susceptible to leakages and bursts. Despite the high investment, water utilities must strategically select pipes for renewal using network data, step testing, metering, or burst frequency. A projected 1% annual network rehabilitation for 25 years (2025-2050) in the UK is anticipated to cut leakages by nearly 30% (Water UK, 2022).

- **Pressure management: regulating network pressure through pump pressure control and judicious use of pressure-reducing valves.** The Water Loss Specialist Group of the International Water Association (IWA WLSG) has estimated that the occurrence of leakages and bursts is highly correlated to network pressure fluctuations. In specific, 1% reduction in average pressure reduces leakage flow rates between 0,5% to 1,5% (depending on pipe material and type of leak) and burst frequencies are reduced up to 3% (depending upon initial burst frequency). The control and optimisation of pump pressure in Romania has shown to reduce leakages up to 10% and energy use by 20% (EC, 2015a). Furthermore, advanced pressure management in Cape Town, South Africa, has shown to reduce leakages up to 38% and burst frequency up to 58 % for a reduction in pressure by 27% during peak demand time and 33% during off-peak demand time (EC, 2015a).

- **Active leakage control: pro-active monitoring and localisation of unreported leakages or bursts, and location and pinpointing of reported leakages or bursts.** Urban distribution networks employ sectorisation for enhanced pressure and leakage management, tailored to network configuration and objectives. Pro-active monitoring tracks unreported issues, while technicians use methods like shutting off valves and acoustic techniques for detection and repair. Integrating pressure management, these measures in Malta reduced leakages by over 88% from the mid-1990s to 2013[30] (EC, 2015a).

- **Speed and quality of repairs: repairing leakages in a timely and efficient manner.** From the moment that a leakage or burst takes place, utilities/authorities need a certain amount of time to fix the issue. This period includes the time to build up awareness, the time to detect the location and the time to repair the issue. This time determines how much water is lost in such events (Water UK, 2022). Improving speed and quality of repairs may need better organisation, thorough the shakeup of working practices, stock keeping of repair materials, close supervision of repair works, and service level agreements with technicians that incentivise speed and quality of repairs and impose financial penalties for relevant failures.

Text box 7.2: The Irish Leakage Reduction Programme

Ireland estimates that about 38% of the treated water is currently lost through leaks before it reaches the users' taps. Leaks happen in the vast pipe system below ground and can be difficult to locate. Many of the pipes are old and need to be repaired or replaced. As part of the national Leakage Reduction Programme, national authorities are working with Local Authorities across the country to repair bursts and fix underground leaks. Despite the challenges, Ireland is making progress. In 2018 the rate of leakage nationally was 46%, by the end of 2021 it was reduced to 38%. This rate of progress will enable the country to achieve its national goal of 25 % leakage rate by the end of 2030.

Uisce Éireann, 2021

Measures addressing commercial losses

Commercial losses refer to the commercial aspect of the water lost from the urban distribution system due to leakages, pipe bursts, or other infrastructure-related issues. Therefore, they focus on financial losses for water utilities and extra charges in water bills to account for water collected and treated but lost during the distribution process. A strategy addressing commercial losses is equally important to that addressing physical losses, because it supports the viability of relevant water services and the capacity of financing future investments. Reducing commercial losses is nearly always cost-effective and offers fast payback. Typical measures, which are usually proposed internationally, include the following (PWC, 2019; World Bank, 2006):

- **Improving customer meter accuracy and reading of metering devices - Smart metering – Improved billing process**. Properly installing, maintaining, and promptly replacing faulty or outdated water meters reduces apparent losses from inaccuracies and unbilled consumption. Human errors in meter reading and data handling at billing offices can be mitigated by introducing and maintaining smart metering with integrated geo-referenced systems, enhancing billing efficiency and reducing apparent losses.

- **Detection of illegal connections and water pilferage**. Illegal connections are a fraudulent behaviour, which is unfair for the general population, because the authorised users have to bear the extra costs in their water bills. Smart metering, awareness raising, regular sample checks based on risk analysis and analysis of network pressures, and targeted checks after complaints may reduce apparent losses from unauthorised water consumption.

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[30] The Infrastructure Leakage Index (ILI) reduced from nearly 20 in the mid-1990s to 2.1 in 2013 (i.e. leakages and other losses reduced from over 600 to 70 litres per connection per day).

7.4.4 Leakages and other losses in internal distribution systems of buildings (‘indoor water leakages’)

Leakages and other losses in internal distribution systems of buildings (‘indoor water leakages’) are generally much lower compared to the leakages and other losses occurring in the urban distribution networks. Furthermore, they are usually metered and billed to clients. As a result, their management tends to be overlooked by water utilities and local authorities (Shin, et al., 2022). However, they are still a concern from an environmental perspective and a primary economic issue for affected households.

In 1999, a US study reported that 9% of the surveyed houses (111 out of 1188) were detected with indoor water leakages, with the average leakage ranging between 110 and 342 litres per day (Pietrosanto, et al., 2021). The US Water Research Foundation (WRF) provided an updated assessment in 2016. The report found a decline in household (residential) water use by 22%, compared to the 1999 levels, although population increased in the meantime. The average volume of indoor water leakages had decreased to 67 litres per day, but they represented 13% of total household water use.

Level(S)[31] is a European framework for assessing and reporting the sustainability performance of buildings in the EU, serving as a simple entry point for applying circular economy principles. It offers a tested system for measuring and supporting improvements from design to end-of-life for residential or office buildings. Core sustainability indicators cover carbon, materials, water, health, comfort, and climate change impacts throughout a building's life cycle, with a target to reduce water consumption by 30%.

Measures addressing leakages and other losses in internal distribution systems of buildings

Typical measures include sound design, maintenance and quick repair of leakages or bursts, replacement of aging pipes and water auditing. In general, the responsibility for repairing indoor water leakages or bursts lies upon the property and building owners, whether one or many. However, in the case of major and long-running issues, it is environmentally and economically rational that water utilities/authorities intervene to shut down reckless water loss or even support property and building owners to repair service connections running through their private property or plumbing running within their buildings. In the latter case, a clear action protocol needs to be established and relevant costs to be rebated in the upcoming water bills.

7.4.5 Reduction of water use by household activities

The daily household water use per person shows large deviations between different countries, when comparing with the European average of 124 litres per person per day (Figure 7.6). Italy, Norway, Slovenia, France and Austria[32] have the highest daily household water use per person (>150 litres), whereas Malta has the lowest (77 litres per capita per day). In fact, the daily household water use per person in Italy is 3 times higher compared to Malta. Thus, water saving measures have a good potential to reduce daily household water use per person, especially for those countries with the highest values. There is a good sign that this is feasible, taking into account that daily household water use per person is decreasing in Europe (-3% between 2017-2021) (EurEau, 2022).

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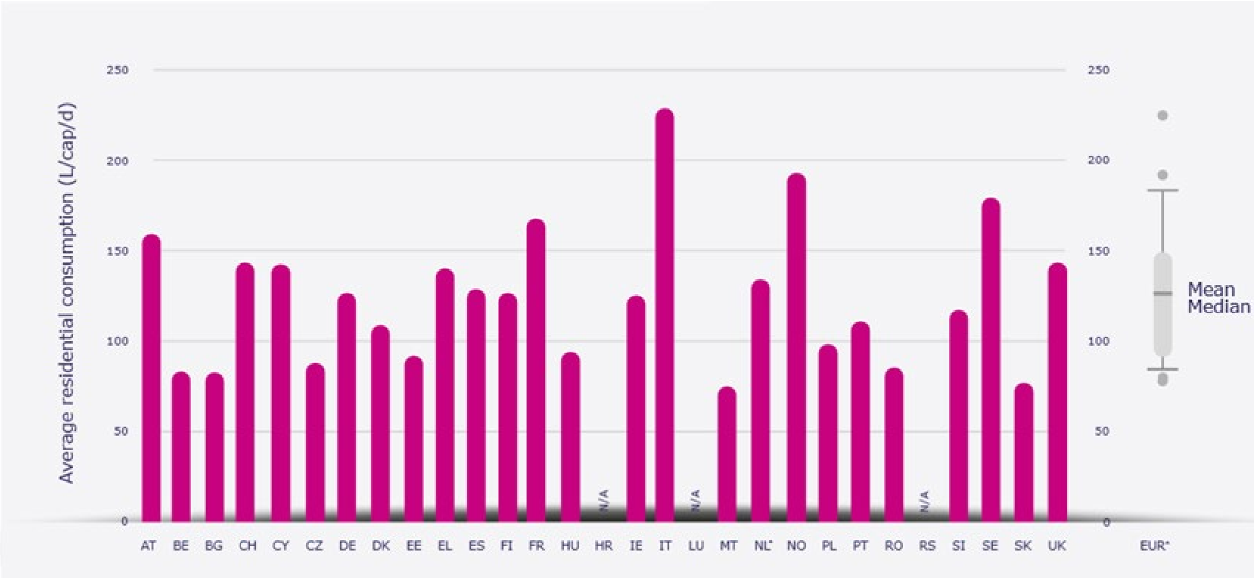
[31] Level(s): European framework for sustainable buildings: https://environment.ec.europa.eu/topics/circular-economy/levels_en

[32] The Austrian authorities have clarified that the average daily household water use per person in the country is 130 litres per person. The reported number in the Eureau report includes also water volumes for other uses served by the public water supply system (e.g. manufacturing).

Figure 7.6 Average use of household water per person per day (in litres per capita per day)



Source: EurEau, 2022

A comparison between the median value of the daily household water use per person in each region with the lowest daily household water use per person in a country within the same region (Table 7.4) shows that, if the lowest daily household water use per person was attainable in all countries within the same region, then the potential reduction from current levels could range between 10-40%. Annex 4 presents different types of measures for water saving in household activities.

Table 7.4 Daily household water use per person (2000-2019) and potential water saving in the EU-27

Median value of daily household water use per person in a region or in the EU-27		Lowest daily household water use per person in a country within a region or in the EU-27		Potential water saving
Region	**litres/person/day**	**Country**	**litres/person/day**	**(%)**
Eastern Europe (BG, CZ, HU, PL, RO, SK)	88	SK	79	10
Northern Europe (DK, EE, FI, IE, LT, LV, SE)	125	EE	93	26
Southern Europe (CY, ES, EL, HR, IT, MT, PT, SI)	128	MT	77	40
Western Europe (AT, BE, DE, FR, LU, NL)	133	BE	85	36
EU-27	126	MT	77	39

Note: Comparisons between different regions may not be meaningful, due to differences in climatic conditions and water infrastructure.

Source: adapted from EurEau, 2022; Authors' elaboration

7.4.6 Reduction of water use by other non-household activities served by the public water supply

As noted previously in section 7.3, non-household activities account for nearly 23% of the total water served by the public water supply network in the EU-27. Such activities include offices, businesses, commercial sites, tourism facilities, parks and other green spaces, manufacturing and industrial facilities, agricultural holdings, public fountains and taps, street cleaning and firefighting.

Annex 5 presents different types of measures for water saving in non-household activities served by the public water supply. For many activities in this group, the water saving potential can be similar to that presented for household activities or other activities elaborated in different chapters of this report (e.g. tourism facilities, parks and other green spaces, manufacturing and industrial facilities, agricultural holdings).

8 Water saving potential in tourism

8.1 Summary of the chapter

- *The tourism industry is in terms of its water use a subsector of the public water supply. With an estimated overall direct water use of 1 800 million m³/year it covers around 5% of the water abstraction of the public water supply.*
- *Although its water use is relatively low, tourism places additional stress on already water-scarce areas, such as islands, coastal areas, or high-level mountains, especially considering the expected growth of the tourism sector in Europe up to 7.5 % until 2034.*
- *In the most severe emission scenario, climate change is expected to have the most pronounced impact on tourism demand between Southern and Northern Europe, with a projected 9% decrease for the Greek Ionian Islands and a 16% increase for West Wales (UK) as notable examples in coastal regions.*
- *In the analysis, a distinction has been made in water use and consumption in accommodation, leisure infrastructure and transport. The estimated potential water saving is 10-30%, keeping in mind that the assessment of the sector is surrounded by many uncertainties.*

The tourism industry plays a pivotal role in shaping economies and connecting cultures. While it offers countless opportunities for exploration and relaxation, it also presents locally significant challenges, one of which is the responsible use of water resources. It is crucial to reduce water consumption within the industry and yet, measuring its real water use remains a difficult task.

The tourism industry relies on water for various purposes, including hotels, resorts, restaurants, and recreational activities. Tourists often enjoy water-intensive experiences like swimming pools, spa treatments, and golf courses. As global travel to Europe is expected to grow between 1.3 and 8% per year, the demand for water in these establishments will grow, exerting pressure on local water supplies and ecosystems. Additionally, in Europe tourism in the southern coastal areas is projected to decline in the summer, especially with temperature increases of 3°C and 4°C, whereas Northern European coastal regions are anticipated to experience a surge in tourism demand, yields a new JRC study, which compares the effects of climate scenarios ranging from a 1.5°C warming to a 4°C warming on the development of European regions as tourist destinations. In the most severe emission scenario, climate change is expected to have the most pronounced impact on tourism demand, with a projected 9% decrease for the Greek Ionian Islands and a 16% increase for West Wales (UK) as notable examples in coastal regions (JRC, 2023).

Overall direct water use by the European tourism sector can be estimated, based on the own elaboration of the authors, at 1,800 million m³/year [33], though with significant unaccounted-for data gaps. Accommodation of tourists is the most water-using tourism segment (1,700 million m³/year). However, part of this water is reused or taken from alternative water sources, such as desalinisation. The share of consumed water is low, mainly caused by evapotranspiration losses from irrigated green areas and golf courses, swimming pools and snowmaking for ski slopes.

The priorities of water saving in tourism should be holistically assessing per water use / water user, how to minimize the respective water use, and special attention should be paid to systematic reduction changes in the accommodation sector, including cooling systems. Strategies, guidance, investment plans and case studies on water saving have been found for all tourism segments. Plenty of water-saving measures have been implemented in the past in different tourism segments, including water audits, repair of leaks, replacement of water-consuming devices, water-saving design of installations, and improved water-use practices, such as deficit irrigation; thus, similar measures also applied in households, industry and agriculture.

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[33] Accommodation accounting for 800 million m³/year, golf courses for 750 million m³/ year, Snowmaking for 250 million m³/ year, airports for 20 million m³/ year, cruise ports 8-14 million m³/year.

Given the many uncertainties, a rough overall figure for the water-saving potential in the tourism sector of 10-30% shall be handled with caution. In addition, the effects of water-saving measures will be different according to their type and location: Some measures reduce water abstractions from freshwater sources (e.g., groundwater, rivers and lakes), whilst others only replace them (e.g., rainwater harvesting, desalinisation, water reuse / recycling). The effects of the latter on the water balance of a mountain valley are very different to those of an island. A third group of water-saving measures reduces also the consumption of water (e.g., due to evapotranspiration of irrigated greeneries, or wind and evaporation losses of artificially made snow).

As much as it would be recommendable to maximize all possible actions to increase water saving, as much as possible, several barriers should be noted:

- Lack of political and entrepreneurial accountability and limited legislation time (decision-makers likely focus on the promises they made, rather than pushing for systematic, long- term change).
- Forecast of tourism sector growth, which may be higher than potential savings in the same period of time.
- Cascade effects of climate change and magnitude of droughts, heatwave, wildfires etc.

An overview of promising water saving measures in tourism is presented in Table 8.1.

Table 8.1 Overview of remaining water saving potential per tourism segment

Segment	Measures	Aim/rationale	Potential saving (m^3 or %)	Remarks
Accommodation	Replacement of water-consuming devices, fittings and flow controls	Reduce water abstractions	Up to 14-50%	Up to 400 million m^3/yr
Swimming pools	Cover; improved filtering systems	Reduce water consumption	Up to 45% of losses	
Golf courses	Rainwater harvesting Water reuse / recycling	Reduce water abstractions	Up to 90% Up to 100%	Together up to 750 million m^3/yr
	Various as below (audit, metering, leakage control, deficit irrigation)	Reduce water consumption	Up to 10-30%	Together up to 75-260 million m^3/yr
	Water audit	Reduce water consumption	Up to 35%	
	Water metering and leakage control	Reduce water use or consumption	Up to 10-20%	
	Deficit irrigation	Reduce water consumption	Up to 80-90%	
Snowmaking	Improved technologies, snow guns and operations	Reduce water consumption	Up to 30-40 million m^3/yr	
Airports	Rainwater harvesting Water reuse / recycling	Reduce water abstractions	Up to 58% Up to 30 %	Together up to 7-12 million m^3/yr
	Semi-dry aeroplane washing technology	Reduce water consumption	From 12,000 to 150 L/plane	
Cruise ports				No water is returned

Note: The references to the data presented are provided in the text of this chapter.

8.2 Overview of the tourism sector

In the EU-27, the food and accommodation services sector (which approximates the tourism sector) includes 1.9 million businesses, primarily small and medium-sized enterprises (SMEs), employing around 10 million people. In 2021, the sector directly contributed 2% to the EU GDP and accounted for 6% of the total labour force (Eurostat, 2024e).

Overall significant tourism growth is expected for the coming years (European Travel Commission, 2023), which could reach up to 7.5% until 2034 (FMI, 2024a).

8.3 Water use of the tourism sector

The assessment of the water use of the sector addresses three major tourism segments: Accommodation, related leisure infrastructure and transport related infrastructures, aiming to cover the most relevant tourism activities related to water: beach, snow, sport and leisure, reflecting information and knowledge as available.

Tourists travelling in Europe require water for several uses, ranging from basic sanitation and leisure activities and more indirect and hidden uses such as irrigation for green premises of accommodation and transportation facilities. So far there is not enough research in comparing available water resources and the demand associated with tourism (Pérez, et al., 2020).

Tourism in Europe is focused on warmer climates in the South of Europe, with tourists making the highest number of foreign trips and spending the highest number of accommodation nights in Spain, Italy and France (Eurostat, 2024j; Eurostat, 2024k). The majority of tourists visit these (and other countries) in June to September, causing a peak of water demand and use in the time of the year when water stress already compromises drinking water, agriculture and other sectors, and exacerbates the problem of water availability. In these areas, droughts are already more severe and frequent. Winter tourism is also important and can have negative effects on the Alpine environment.

According to several studies carried out, an average tourist within Europe uses directly (accommodation and activities) between 300 and 2,000 L/person/day of water (Dworak, et al., 2007)[34], revealing that tourists use significantly more water than citizens at home (124 L/person/day) (EurEau, 2022). When accounting also for travel, energy use at hotels and food, the overall sum of direct and indirect tourism water use is calculated at an average of 6,575 L/person/day (Gössling, et al., 2012); (Gössling, 2015)[35] (see Text box 8.1).

Text box 8.1: Tourist water use in Valencia

The total volume of water use derived from tourism activity in the city of Valencia (Spain) in 2019 was 74.23 million m3, which means a water footprint of 315 L/person/day, including also cruise passengers and day visitors. Only 16% corresponds to water directly used by tourists, mainly in tourist accommodation, while 84% is indirect use associated with the production of goods and services, or food processing. This mainly includes the meals that visitors have in the city's restaurants, their purchases in shops and the maintenance of attractions and entertainment venues. The use of transport (public and private such as car rental) makes up only 0.10% of tourism’s water footprint.

VisitValencia, 2021

[34] Not all references included in this study refer solely to tourism in Europe, but in this report the value of 775 litres per day is taken as baseline, as an average of the findings from the existing studies.
[35] Whilst the average is calculated at 6,575 L/person/day, the conservative range varies between 4600-12,000 L/person/day.

Table 8.2 provides a qualitative and non-exhaustive overview of key drivers resulting in an increase or decrease of water demand in tourism. The net result of these partly counteracting trends is highly uncertain and variable across the EU, and while the tourism sector is expected to grow, the resulting impact on water demand has not been quantified.

Table 8.2 Expected key changes and impacts on demand for tourism

Relevant drivers in tourism	Expected trend in driver (increase/decrease)	Expected impact (increase/decrease) on water demand
EU population by 2100	↘	↘
Water-efficient devices and management	↗	↘
Income and living standards – global travel	↗	↗
Air temperature, evaporation, need for cooling under climate change	↗	↗
Air temperature in ski areas and demand for snowmaking under climate change	↗	↗
Shifts in most popular tourist destinations under climate change (heatwaves, forest fires)	Variable	Variable

Note: Green indicates a positive effect on water demand (i.e., decreasing demand); orange indicates a negative effect.

Source: Authors' elaboration

8.4 Water saving measures at tourism segments

Overall, tourist activities requiring water usually revolve around the following segments:

- Accommodation, including hotels and others, as well as the services they provide.
- Leisure infrastructure, such as for swimming, skiing or playing golf.
- Transport-related infrastructure, like airports and cruise ports where tourists depart and arrive.

8.4.1 Accommodation

In 2023, tourists spent 2.9 billion nights in tourist accommodation establishments in the EU-27 (Eurostat, 2024k), with 63% of them spent in hotels and motels. The top five destinations, in terms of nights spent, are Spain, Italy, France, Greece and Austria, which all together account for 40% of total nights spent in the EU-27 (Eurostat, 2024k). Furthermore, the tourism intensity [36] is the highest at the Mediterranean coastlines and islands, such as Croatia, Cyprus and Malta (Eurostat, 2024k).

The amount of water used by a tourist staying in a hotel in Europe can vary depending on a variety of factors, such as the type of hotel, the location, the time of year, and the behaviour of the tourist. On average, a tourist staying in a hotel in Europe uses between 120-300 L/day (Styles, et al., 2015) – thus accommodation overall accounts for a water use by accommodation services of 300-800 million m^3/year.

[36] The ratio of nights spent at tourist accommodation establishments relative to the total permanent resident population of the area

This estimate includes the water used for showering, bathing, washing hands, flushing toilets, washing clothes and other activities that require water. Within an accommodation, the highest share of water use (35% of the total) is associated with the rooms, whilst the (industrial washing machine) laundry water use is estimated to be 22 L/guest/day with a strong occupation rate (Alhudaithi, et al., 2022). Water use is generally higher in luxury hotels than in cheaper accommodation options (see Text box 8.2).

Text box 8.2: Water use in luxury hotels

Luxury Hotels (3 stars or more) generally use more water (Gössling, et al., 2012), with 400-600 L/guest/day and the more stars a hotel has, the more water is used (Cruz-Pérez, et al., 2022). Luxury hotels generally offer more water-intensive amenities and services such as larger swimming pools, spa facilities, and landscaped gardens, which can increase water use. Additionally, they may offer higher levels of service, such as frequent linen changes and towel replacements, which can also lead to higher water use. On the other hand, some luxury hotels may invest more heavily in water-efficient technologies and practices, which can reduce their water use despite offering more amenities and services. Therefore, while luxury hotels are generally expected to use more water than average hotels, the exact amount can vary widely depending on several factors, and it is important to consider each hotel's water management practices to get an accurate estimate (Cruz-Pérez, et al., 2022).

A questionnaire responded to in 2014-2017 by 73 Euro-Mediterranean resorts reflected that 30% of them had no water-saving measures implemented. Water use monitoring was generally restrained to overall control for the whole facility (65%), and strategies target most often the water-saving shower (34%). Separation of grey and black water streams was not implemented among most of the hotels consulted (CORDIS, 2022). Water-inefficient hotels can typically reduce water use by over 50% (Styles, et al. 2013). Given similar water use patterns, hotels and households could be addressed by common potential measures of water efficiency (BIO Intelligence Service, 2012). A large portion of potential savings can be achieved, similar as in households (section 7.4.5) through relatively simple and inexpensive installation of efficient water fittings which have a relatively high frequency of replacement. Such measures include the replacement of water-consuming devices such as washing machines, showerheads or dishwashers with water-saving alternatives, for example, the 'Blue Angel' eco-label or WELL (Water Efficiency Label) (Gabarda-Mallorquí, et al., 2022), the reduction of water flow rate by adding air (change of compression) or water saving armatures, flow controls or installing dual-flush toilets or flushing volume dispensers (Styles, et al. 2013) (see Text box 8.3).

Text box 8.3: Potential water savings in the tourism sector of the Loire-Bretagne River basin, France

A study of potential water savings in the tourism sector for the Loire-Bretagne River basin in France identified camping sites and hotels as the main water use sub-sectors for this basin, with an overall demand of 224 L/tourist/night, equivalent to a 32% reduction in total water demand. While camping sites are characterized by high seasonal variation with peak water demand during the summer season, hotels show lower variability in occupancy rates within the year because part of their customer base are professional salesmen and workers. The total water use is estimated at 5 million m^3/year and 6.7 million m^3/year for camping sites and hotels respectively. Saving potential is estimated at between 10% and 20% of the current consumption. This low saving rate is explained by the fact that many hotel and camping owners have already invested in water-saving appliances and techniques to reduce their water bills and enhance water use efficiency. For hotels, potential water savings between 14% and 37% have been estimated for water use attached to room occupancy. This is consistent with water-saving estimates of 6% for a hotel in the United Kingdom due to water-saving devices in showers and toilets only – resulting in a 400 Euro saving per year from water bill reduction (Dworak, et al., 2007). Part of the French National Recovery and Resilience Plan is the Fund for sustainable tourism. The fund consists of an investment envelop of EUR 50 million for sustainability measures in rural tourism establishments (accommodation and restoration), including better use of water (Interreg Mediterranean, 2022).

8.4.2 Leisure infrastructure

Apart from accommodation, tourists usually also make use of their travel destination by engaging in activities that are special to the area or appeal to the purpose of their stay. This section includes information on artificial irrigation, snowmaking, pools and beach infrastructure that all use water.

Gardens and parks

Parks and other vegetated recreational areas in and outside the hotel premises and used by tourists – including hippodromes - are often irrigated. The main factors for water use are the size of gardens, irrigation systems, plant species and the climate (Alhudaithi, et al., 2022). There are no relevant available data on the water use of gardens and parks in Europe.

Golf courses

Golf is both a sport and a leisure activity, encompassing aspects related to tourism, hospitality and real estate. In Europe, there are nearly 7,000 golf courses, led by England, Germany, and France, with 900 of them located in Mediterranean countries (Statista, 2022). The Golf Tourism Market Snapshot foresees further growth of the golf tourism market by 5% between 2024 and 2034 (FMI, 2024b).

The water consumption of a golf course can vary from zero in rainy seasons to significant amounts during a dry and hot season. In Southern Europe, the average water consumption on a standard 18-hole golf course (with an irrigated surface of 54 ha (Salgot, et al., 2012)) is estimated around 200,000 – 300,000 m^3/year, even reaching up to 700,000 m^3/year[37] in the Mediterranean coasts of Spain (IAGUA, 2017). In Western Europe, the average water consumption is around 50,000 m^3/year (Booth, 2022; Deutscher Golf Verband, 2016). Bearing in mind the number of golf courses, the overall water consumption can be estimated at 450 million m^3/year in the Mediterranean and 300 million m^3/year in the rest of Europe[38].

The design of golf courses can fundamentally influence their water consumption. Usually, advanced players or professionals enjoy courses with narrow fairways, high and rough and numerous hazards. In contrast, golf courses for tourists have generally wide fairways and the rough is reduced, to avoid players wasting time searching for balls (Salgot, et al., 2012). Such a design usually has larger water consumption. Some courses have removed the areas of grass that are not needed and replaced them with cacti and desert-loving plants. These need little irrigation, and they are also a good contrast to the green fairways and greens (TWL Irrigation, 2020). In addition, in the past, courses used Bermuda grasses as these were fast-growing and tough. However, research has been going on into alternatives that not only need less water but can also handle more salt. Poor quality water often has a higher salt content, which can be bad for the grasses. By increasing their tolerance, water from more sources can be used (TWL Irrigation, 2020). The golf course Golf della Montecchia in Italy is one example of such a transformation. With so many courses locked down during the COVID restrictions, greenkeepers and course managers have been looking at ways to take what they have learned from essential maintenance into ongoing practices. Royal Birkdale Golf Club in England made a 35% saving on water by choosing not to irrigate certain areas of rough around the course. Atlantic Beach Country Club in South Africa implemented a range of measures to deal with a prolonged period of drought. These included waterless soap and upgrading air conditioning units to more water-efficient models. Royal Johannesburg & Kensington Golf Club changed its taps, so they went from running at 6 litres per minute to 1.3 litres per minute (Sustainable.Golf, 2022).

In golf course irrigation systems, it is common to find facilities with obsolete designs (EGA, 2019). It makes sense to start with an audit of how the course is doing and where improvements can be made

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[37] The calculation is based on a water use of up to 13,500 m^3/ha/year multiplied by an area of 54 hectares.

[38] The calculations are made using the following figures: 500,000 m^3/year/course multiplied by 900 courses estimated to be located in the Mediterranean; and 50,000 m^3/year multiplied by 6000 courses estimated to be located outside the Mediterranean, respectively.

(Sustainable.Golf, 2022). The use of new technologies (e.g. meteorological stations, drones, measurements of soil moisture, computer systems, etc.) can lead to saving of 15 or 20% of the irrigation of water, improving irrigation uniformity and avoiding overwatering (TWL Irrigation, 2020). Deficit irrigation to golf courses encounters certain difficulties but can represent 70-90% of the optimum theoretical demand, except for critical areas like tees, putting greens and areas with heavy duties (Salgot, et al., 2012). Survival irrigation (between 20 and 40% of the ideal quantity) can be applied when there is an extreme shortage of water to avoid the death of the grass (Salgot, et al., 2012). Avoiding mechanical operations on vegetation during heat waves adds to its resistance (UBA-DE, 2022). Some examples to visualize such savings are Golf de Moliets, in Les Landes (France), which has signed an agreement with the French Golf Federation and the Ministry of the Environment to decrease water consumption by 30% thanks to the investment into a computerised water management system with an efficient pumping station (Greens and Grapes, 2024). At Hirsala Golf in Finland, their audit resulted in a 50% reduction in water use via the readjustment of sprinklers on the tees (Sustainable.Golf, 2022). In St. Leon-Rot (Germany), the sprinkler has been optimised to ensure that semi-rough and rough are not irrigated, and hand-watering for individual dry areas is widely extended in Germany (Golf.de, 2022).

Ski areas: snowmaking

Annually more than 60 million people use ski areas in Europe (Statista, 2024). Snow or ski tourism plays a major socio-economic role in the snowy and mountainous areas of Europe such as the Alps, the Pyrenees, Nordic Europe, Eastern Europe, Türkiye, etc. (Morin, et al., 2021). In Europe, there are at least 1,200 major ski resorts (Vanat, 2021) , with an overall length of ski slopes of several ten thousand kilometres. In the Alps alone, there are about 18,000 slopes (European Parliament, 2016).

The ski sector is under pressure because of climate change. For example, under a +2°C warming scenario, by the end of the 21st century, snow may decline between 30 and 70% in the Alps (Damm, et al., 2017) (Marty, et al., 2017).

In response to climate change, but also to address new developments in skiing and snowboarding, snow management, i.e., snowmaking and grooming, is an integral part of modern ski resort management. Its goal is to have well-controllable snow conditions at the right time, which are smooth, even and robust enough to withstand the impact of today’s usual number of skiers (Hanzer, et al., 2020). From this perspective, snowmaking can be considered an important climate adaptation strategy in the short and medium term, applicable for resorts at higher altitudes and financially viable all-year destinations at lower elevations. At the same time, snowmaking is criticized, as it exacerbates climate change impacts and can therefore not be considered a suitable and long-term adaptation measure (Dworak, et al., 2021a). It even can have negative effects on the tourist’s perception, as they can feel uncomfortable with the high density of snowmaking facilities along the slopes (Bausch et al., 2019). In addition, snow management exerts disturbances to the local hydrological cycle, through the uptake of water used for snowmaking - either directly after uptake or following temporary storage - and changes in water runoff due to added snow mass through snowmaking and/or delayed melting of the snowpack due to snow grooming. This pressure on local water resources can be substantial.

Notwithstanding these drawbacks, snowmaking has already become common practice. In 2022, 90% of the slopes in Italy, 70% in Austria, 48% in Switzerland and 39% of the slopes in France use artificial snow in practice, at least for part of the operations, and infrastructures to secure artificial snow are more widely in place (LeMonde, 2022). According to the Alpine Convention, nearly three-quarters of Alpine ski slopes are already covered with artificial snow (European Parliament, 2016). German resorts have recently heavily invested in snowmaking systems to mitigate meteorological risks (Vanat, 2021).

Snowmaking needs to be increased by 50-100% in some European regions to guarantee a 100-day season in the 2050s under the high-emission scenario (Steiger, et al., 2019), and increased snow production costs will make operations unviable in some low-lying resorts as early as the 2030s (Dannevig, et al., 2021).

Regarding the use of water for snowmaking, the International Commission for the Protection of the Alps (CIPRA), estimates that approximately 1,000 m^3 of water are needed to cover a 1-hectare slope area with manmade snow, and UBA estimates that 400–500 litres are needed for 1 m^3 of snow (Dworak, et al., 2021a). Rixen et al. (2011) investigated the annual freshwater use of two Swiss municipalities with large ski resorts and found that the share used for snowmaking was 21 and 36%. Vanham et al. (2008) even calculated a water demand of 2.3 million m^3 for snowmaking in Kitzbühel, Austria, corresponding to more than 50% of the communal water use during the winter season (Grünewald and Wolfsperger, 2019)[39]. In France, 25 million m^3 of water are transformed each season, with 43% of the resorts each using at least 100,000 m^3, supplied from at least one high-altitude reservoir (Sustainable.Golf, 2022). As the 317 French ski areas correspond to 10% of the European ski areas (Statista, 2024), the overall water use for snowmaking can be estimated at 250 million m^3/year in Europe.

Snowmaking includes, in practice, losses due to evaporation and sublimation, and as a result of wind drift (Hanzer, et al., 2020). How much water is lost is still unclear, the estimates reveal a broad range between 0 and 50% (Grünewald and Wolfsperger, 2019). Also, the type of snow guns used is a factor (Olefs, et al., 2010). Wind and evaporation of 15% have been estimated recently (Morin, et al., 2022), and based on this figure, the number of water losses for snowmaking overall can be estimated at 30-40 million m^3 water/year.

Many ski resorts have invested to upgrade their snowmaking operations, including snow guns which can regulate water output and automatically shut down when the weather gets too warm — a major upgrade from older technology that required workers to monitor the temperature and manually turn off the system (AP, 2022). An increasing number of ski resorts, public agencies, and snow industry players are currently detecting the demand for systematic field tests.

Swimming pools and water parks

Swimming pool use can be both public and private, ranging from municipal installations to sports clubs, fitness centres, health clubs, universities and educational facilities. Swimming pools can also be found in many private homes or single-family buildings (Liebersbach, et al., 2021).

Europe has around 4.4 million swimming pools, which corresponds to around 29% of the total number of global swimming pools. France has the most swimming pools in Europe (1.5 million, 34% of the European total), followed by Spain (27%), Germany (20%), Italy (6%) and the UK (5%) (CORDIS, 2016).

How much water is used by a pool depends on the size of the pool (surface area and depth), the local climate (precipitation, evaporation, air and water temperatures, wind, humidity, shadowiness, etc.), the design conditions of the pool (presence and use of a pool cover, pool water temperature, presence of water aesthetic features like a fountain or waterfall, pH and chemical content of pool water, leakage), individual maintenance (frequency of backwashing, frequency and the method of pool and pool deck cleaning) and human behaviour like splashing-out and swimming habits (Liebersbach, et al., 2021).

As a rough estimate, an average-sized outdoor pool in Europe (around 10 x 5m) can hold about 50-75 m^3 of water. The initial filling will use this amount of water, and some water will be refilled due to the losses by backwashing, splashing or evaporation. An indoor heated 25 m (300 m^2) pool located in a hotel can lose 21,000 L of water per week by evaporation (Styles, et al. 2013); and water consumption is calculated between 40 and 260 L/person/day for large outdoor pool areas, including showering.[40]

[39] The Austrian authorities noted that the water demand for snowmaking in Austria will be around 65 million m³ or 3600 - 4600 m³/ha by 2025.

[40] Figures from different sources: 40 L/person/day is referenced in (Neunteufel, et al., 2012). 52 and 60 L/person/day are referred to in (Styles, et al. 2013); 155 L/day are presented in (Vidal, et al., 2010). 150–260 L/person are collected by (Liebersbach, et al., 2021).

Regarding the water saving measures, pool covers can reduce evaporation (which accounts for 15% of the losses in typical community pools); in addition, monitoring and adjusting water chemistry can minimize the need for water replacement, as well as installing water-efficient filtration and circulation systems. Backwashing accounts for 30% of the water losses in typical community pools (Liebersbach, et al., 2021). These actions are independent of the frequency of use of hotel pools.

Beach infrastructure

Bathing facilities are multifunctional establishments consisting of a leisure area on the beach often equipped with sun loungers and parasols, a restaurant and/or a café, and sanitary services with toilets, and cold and hot showers. Bathing facilities are widespread in coastal areas of Southern Europe, specifically in Greece, Spain, and Italy. In Italy, recent analyses revealed the presence of a total of 11,000 bathing facilities over about 3,300 km of beach, indicating, on average, about 3.3 bathing facilities per km of beach. However, to date, no studies have focused on water consumption in bathing facilities (Mazzoni, et al., 2022).

8.4.3 Transport-related infrastructure

Water is required for various transport-related work, bringing tourists to their destinations.

Airports

In 2019, just over 1 billion air passengers in total were recorded in the EU. In 2021, still affected by COVID-19, the total number of passengers travelling by air in the EU was 373 million (Eurostat, 2023b). According to data from the European Travel Commission, international tourist arrivals in Europe reached 743 million in 2019, which was a 4% increase compared to the previous year. Most of these tourists arrived by air, as it is the fastest and most convenient mode of transportation for long-distance travel; this often applies also to domestic tourism, especially in countries with islands (European Travel Commission, 2020).

Airports, aeroplanes and flight operations support tourism and are important water consumers, including aspects such as the production of aeroplanes, the production of fuel, taking care of the aeroplane, consumption of the ground infrastructure (airport, machines, repair, offices etc.) and the flight operations themselves.

In airport complexes, most of the water is used to meet non-potable demands, such as water cooling systems, fire control, cleaning and washing of vehicles, runways, and aircraft (Moreira Neto, et al., 2012; Carvalho, et al., 2013), terminals and offices, as well as de-icing of aircraft and terminal uses such as toilets and urinals (Özlem Vurmaz and Boyacioglu, 2018). The total water consumption per passenger has been estimated at 44.7 L/passenger in Munich Airport, Germany (Munich Airport, 2021). The 2020 average of the 27 airports managed by Aéroports de Paris in 11 countries is 35.1 L/passenger, with 4% being recycled (ADP, 2021). For this study, a conservative average use per passenger of 25 litres has been assumed, resulting in an overall at-airport water use of approximately 20 million m^3/year.

Different water-saving measures have been taken by airports and airlines. Efficiency improvements and innovations have led to water savings in different airports: Frankfurt Airport (Germany) installed low-flow taps and in Belgium's largest airports, waterless urinals have resulted in 32 000 m^3 of annual water savings (Smart Water Magazin, 2021). At the Airbus facilities in Spain, waterless urinals were installed and air-cooled pumps replaced water-cooled versions (Skycop, 2019). In 2012, KLM was among the first airlines to switch to the EcoShine (Ecoshine, 2024), which is a semi-dry washing technique for cleaning the exterior of an aircraft, needing 80 times less water than the previous cleaning system (150 instead of 12 000 litres to clean a Boeing 777). This adds up to an annual saving of 8 000 m^3. After adopting this method in 2016, Emirates has saved 11 million m^3 of water per year (Skycop, 2019). Frankfurt Airport reduced the water use by shifting from chlor-based disinfection of aircraft water supply vehicles to electrochemical disinfection practices, as well as circular water use in vehicle cleaning installations (Fraport, 2020).

Cruise ports

Global cruise travel expects to reach 31.5 million passengers in 2023 (CLIN, 2023), with almost 7 million passengers in European destinations. There are no official numbers for cruise port water intensity when loading for cruise ships and related activities. Cruise operator TUI estimates freshwater withdrawals of 162 L/passenger/night, whilst a case study of the Port of Palma, Mallorca calculates that the average freshwater amount of load is 285 L/passenger/night (Garcia, et al., 2020). Based on these figures, overall port water supply to cruise ships in Europe accounts for 8-14 million m^3/yr.

8.4.4 Trade-offs and conflicting water use

Due to the intensifying competition over water, one aspect is that while water can enable tourist attractions and therefore serve the local economy, the water used for golf courses for instance, may be better used for essential provision. This type of conflict can be well illustrated with the case of towns of Vieille Toulouse and Blagnac, where in 2022 climate activists filled the holes of golf courses with cement after exceptions were made to the irrigation ban for watering the greens at golf courses in towns particularly affected by the drought. At the same time, private gardens were no longer allowed to be watered, nor were cars allowed to be washed. While the French Golf Federation argued that over 15,000 people work on French golf courses and that the greens will break down without water, various politicians opposed the exemption for golf courses. The mayor of the city of Grenoble said, 'We continue to protect the rich and powerful.' Only one region, Ille-et-Villaine in western France, completely banned watering of golf courses (Golf sustainable, 2022). In some cases, the very attractions of the tourism area are also endangered, when there is not enough water, i.e. on the East Frisian Islands, the high water consumption leads to a lowering of the groundwater level and thus endangers the dune vegetation (Dworak, et al., 2021b).

Another perspective can be to try and see things from the point of view of the visitors: on the one hand, visitors travel for pleasure and associate a relaxed time without too many worries and restrictions with their travel time, where they want to enjoy their experience and not limit their activities. On the other hand, tourists are not left unaffected, especially those with a higher environmental awareness: how dedicated would they be for saving water, especially in the case of drought? May it be that they would consider a different destination altogether, where they might have to care less about restricting their water use? Various travel portals discuss that in a situation of water scarcity 'Travellers sympathetic to our plight might reason that their visit may worsen the water crisis, and as a sign of support will choose not to visit', leading to an income loss for the tourism industry in the respective region.

9 Diversifying water supply through alternative sources

Harvested rainwater, reclaimed water from treated wastewater and desalinated brackish or sea water constitute the so-called alternative water sources. Measures to exploit these resources differ from the measures discussed in the previous chapters in that they are supply-side and not demand-side measures. They do not reduce the use or consumption of water, but they can reduce water abstraction pressures on specific water bodies. Diversifying water supply sources, on the other hand, enhances resilience to droughts and water scarcity, especially during seasons of low water availability and high-water demand. As each case is individual, the balances of upstream and downstream impacts of such measures should also be assessed before their application. For example, treated wastewater discharges may constitute a significant share of river flows during the driest season of the year. Therefore, diverting this amount of water for reuse in irrigated fields could lead, due to evapotranspiration, in a much lower quantity of reclaimed water infiltrating into the river and usually with a lag time, compared to the initial direct discharge from the wastewater treatment plant.

9.1 Rainwater harvesting

Rainwater harvesting has been used for thousands of years in various parts of the world. It can be a sustainable and cost-effective way to meet water needs, especially in areas with limited access to fresh water. It includes a variety of measures aimed at storing surplus precipitation in a small pond or reservoir or in the soil, while decreasing surface runoff and interflow. The measures involved may range from low-input, no-regret modifications of tillage practices to improve the infiltration capacity of the soil surface, to more elaborate (though still small-scale) investments in collection and storage facilities (HYDROUSA, 2024a). Harvesting and eventual use usually take place at the same location. Rainwater harvesting may reduce the amount of available water downstream, so its assessment should include a review at the catchment level.

Rainwater harvesting is applied in agriculture, industry, public water supply and tourism. As an example, Oaks Prague golf course was able to design an efficient system from the outset, which now enables them to use collected rainwater for around 90% of course irrigation, and at Belas Clube de Campo in Portugal, all course run-off is collected into lakes before being used for irrigation (Sustainable.Golf, 2022). Significant efforts have been made in some countries to promote rainwater harvesting in hotels (Ramkrishna, 2022). Rainwater harvesting options were also modelled in 2014 for meeting non-potable water demand on a large scale (21.5 km^2) at Amsterdam Airport Schiphol. With sufficient storage, all of the non-potable water demand of Schiphol can be supplied, reducing freshwater abstraction for drinking water by up to 58%; however, the current low water charges are barriers to the high investment costs for supply networks and storage infrastructure (Kuller, et al., 2017). Also, Berlin has set out to manage rain as a resource, instead of simply draining the rainwater into the sewer system. The goal is to roll out thousands of measures distributed throughout the city, together leading to a better microclimate, more groundwater recharge, cleaner water, less flooding and healthier urban greenery (Berliner Regenwasseragentur, 2024).

A specific and more intense form of rainwater harvesting is atmospheric water condensation, which fosters the condensation process including approaches such as fog harvesting, dewing, and sorption (Meng, et al., 2022); and thus, adding complementary water resources to those available in the basin. So far, its applications have been small-scale, but is very promising, despite research needed, including on its costs and environmental effects (Kumar, et al., 2023). Atmospheric water condensation has been applied through innovative vapor condensation units for an ecolodge facility which combines tourism and agriculture (HYDROUSA, 2024b).

The measures taken for rainwater harvesting often have multiple benefits, such as erosion and flood prevention, soil structure improvement, or reduction of energy consumption (see Text box 9.1).

Text box 9.1: Rainwater harvesting with multiple benefits in Vrijburcht, Amsterdam

Due to limited permeability of the city surface, intense rain showers cause flooding in Amsterdam. It is estimated that, due to climate change, the rainfall volume during extreme precipitation events could increase by more than 14% in the future. However, summer months are also expected to be drier. Therefore, public and private green spaces will require more irrigation. Vrijburcht is a sustainable and attractive multipurpose complex in Amsterdam for living, working and socialising, whose core area includes a courtyard garden with trees, a vegetable garden, lawns, flowers, benches and a greenhouse. The complex includes residential apartments, offices, ateliers and meeting places. Rainwater from the roof tops is collected and stored in two underground tanks with a total capacity of 6000 litres, which is sufficient to cover the annual irrigation needs of the garden and the plants of surrounding terraces/balconies. Furthermore, the car parking garage is paved minimally to create maximum permeability for rainwater. A relief allows water to flow from higher parts to a marsh-like environment, which both prevents flooding and enhances vegetation diversity, because drier and wetter environments are created across the courtyard garden. Drainpipes are detached from the facades at the ground-floor level, forming a pergola construction for creeping plants. Creeping plants are also used on the building exterior, where they cover wind screens to form green facades. The trees in the garden provide shade and offer residents and visitors a cool environment on warm days. At the same time, the risk of pluvial flooding is reduced significantly. The Vrijburcht complex was primarily financed by the future residents, who jointly develop the project design.

Climate-ADAPT, 2016

9.2 Reuse of reclaimed water from treated urban wastewater

The reuse of reclaimed water from treated urban wastewater includes the process of removing contaminants and pollutants, to enable the reclaimed water to be safely used by other users / sectors according to their purposes. Urban wastewater treatment typically involves several steps, such as screening to remove large solids, sedimentation to remove suspended particles, biological treatment to remove organic matter and pathogens and further treatment to remove high portions of nutrients that cause eutrophication (nitrogen and phosphorous). After that, the process of producing reclaimed water additionally includes disinfection using chemicals (e.g. chlorination, ozonation), disinfection using ultraviolet light or other disinfection technologies to eliminate any remaining pathogens. The reclaimed water can be used for a variety of purposes, such as irrigation of crops, landscaping, cooling of industrial or electricity generating plants and recharge of aquifers, especially in those cases where coastal aquifers are impacted by sea water intrusion.

The EU regulation on minimum requirements for water reuse (EU, 2020) is in place since June 2023 to guarantee that reclaimed water is safe for agricultural irrigation, thereby ensuring a high level of protection of the environment and of human and animal health. It sets standards for the quality of treated water for different types of agricultural use, aiming to boost the use of the unexploited potential for water reuse. National standards and legislation are also in place in many EU Member States.

Water reuse has significantly increased over the past decade in the EU, with 787 schemes operating in 2017 (Water Reuse Europe, 2020). Schemes cover both non-potable and indirect potable uses. Water reuse for irrigation remains the most common application of reclaimed water in Europe (39% of the schemes) followed by water reuse in industry / manufacturing (15%) and water reuse for recreational purposes (11%)[Error! Bookmark not defined.], including irrigation of golf courses (see Text box 9.2). According to the latest available data (Eurostat, 2024i), about 650 million m^3 of reclaimed water are reused annually in the EU-27, which accounts for 2.4% of the urban wastewater receiving tertiary treatment annually and less than 0.3% of the annual abstractions of fresh surface water and groundwater in the EU-27. It is noted that Cyprus and Malta already reuse more than 90% and 60% of their wastewater, respectively (see Text box 9.3).

Text box 9.2: Water reuse for irrigation of golf courses in Southern Europe

Several golf courses in Southern Europe apply reclaimed water for their irrigation. For example, in Spain, reclaimed water amounts to 57.3% of the irrigation water used in golf courses with 18 or more holes (EGA, 2019). In the Andalusian Marbella area, 24 golf courses are irrigated with reclaimed water supplied from wastewater treatment plants performing secondary or tertiary treatment (IAGUA, 2017).

Text box 9.3: Water reuse for irrigation in Malta

Given the lack of surface waters in the Maltese islands, Malta's agricultural sector is dependent on rainfall and groundwater for irrigation. Therefore, water saving measures are aimed at increasing the range of water which can be supplied (through non-conventional water resources) and continuous maintenance and upgrades of rainwater harvesting structures. The aim of these measures is to reduce the pressures of the agricultural sector on groundwater, which are increasing, due to the changing climate. The reuse of reclaimed water is an opportunity for farmers to use water with lower salinity or nitrate levels compared to groundwater. Moreover, this measure contributes to the goals of the EU Circular Economy.

The reuse of reclaimed water is supported by the following measures:

- Development of demonstration sites.
- Development and implementation of a branding campaign.
- Commissioning of wastewater treatment plants and distribution facilities for reclaimed water to secure its availability at the point of use.
- Allocation of reclaimed water to farmers, depending on their respective crop plans.

Currently, treated water is provided to locations close to the wastewater treatment plants, in the North and South of the island of Malta and throughout the island of Gozo. The measure is considered successful as the annual amount of reclaimed water has reached 1.4 million m^3. As an indication, if this amount is averaged over the total area of irrigated and non-irrigated agricultural land, which is 88 km^2 (World Bank, 2024), then it would be equivalent of 10 mm/year; small, but not negligible.

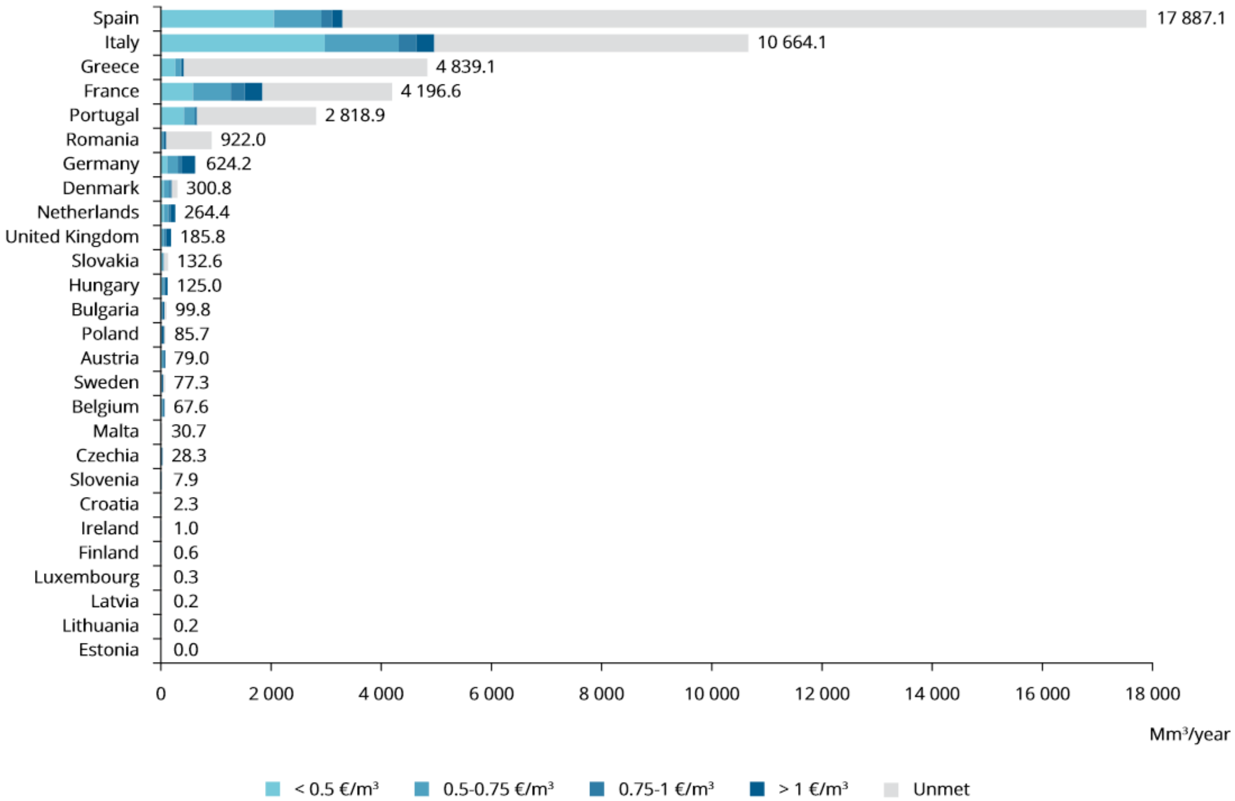
EU funds were used as the financing mechanism for the investment costs of the treatment plants, combined with national funds to operate the plans on an annual basis. Envisaged follow-up actions are:

- Increase the production of reclaimed water.
- Extend the existing distribution networks of reclaimed water.

In the EU-27, the potential for reusing reclaimed water for irrigation is estimated in the order of 6 600 million m^3 with a production cost of up to 0.50 Euro per m^3 and in the order of 10 400 million m^3 with a production cost up to 0.75 Euro per m^3 (Figure 9.1)[41]. This can make a significant contribution to water availability, particularly in water stressed areas across Europe. Reclaimed water could potentially cover 45% of agricultural abstraction volume in France and Italy, 20% in Portugal and Spain, and 10% in Greece, Malta and Romania. In all other EU countries, due to lower irrigation abstraction, the potential water reuse could be sufficient to replace almost all the volume of current agricultural abstraction. However, the estimated potential for water reuse may not be technically and economically feasible to reach, due to local reasons related to landscape conditions, absence of irrigation networks and investment gaps for new storage, pipe and pumping infrastructure (JRC, 2017).

[41] Production costs include the costs for additional treatment, storage facilities, pipework and pumping.

Figure 9.1 Potential volume of water reuse for irrigation (in million m3 per year) for different levels of production costs (in € per m3)



Note: The volume of reclaimed water that can be potentially deployed for irrigation at different production costs for 26 EU Member States (Cyprus not included due to missing irrigation estimates) and the United Kingdom. 'Unmet' indicates that the segment of the irrigation demand estimated for the country that cannot be covered with the potential supply of reclaimed water.

Source: JRC, 2017

Recycling of grey water

The recycling of grey water within the facilities of the same user can reduce the amount of freshwater that needs to be abstracted. For example, slightly polluted wastewater from sinks, showers and washing machines can be used again (recycled) for toilet flushing or irrigation, after appropriate treatment. A separate pipe system and a multi-stage cleaning system are required for its recycling (see Text box 9.4).

Text Box 9.4: Recycling of greywater in Samba Hotel, Spain

During the demEAUmed project, the Samba Hotel in Spain was used as a demonstration site to implement a closed water system that treats grey water (e.g. from shower effluent or sand filter backwash swimming pool water) and then recycles reclaimed water for toilet flushing and the irrigation of green spaces. Greywater showed limited daily and weekly variation, higher conductivity than tap water, medium organic content, limited solid content, presence of some pharmaceutical compounds (e.g. ibuprofen, acetaminophen), limited presence of Endocrine-Disrupting Chemicals and some microbiological contamination for the shower effluent. Greywater was treated with four different technologies. The demonstration followed the requirements of the national legislation framework RD 1620/2007. The parameters E. coli and turbidity were monitored twice a week, total suspended solids were analysed once a week and helminth eggs every two weeks. Legionella spp. was analysed once a month. Regarding other contaminants, the water basin organisation assessed the analytical frequency based on the effluent disposal permit and the water reclamation treatment. An on-line monitoring system was installed to keep track of the water quantity and quality analysis and optimize the different fluxes in the demonstration site.

CORDIS, 2022

9.3 Desalination

Desalination is the only one of the measures discussed in this report that notably increases the volume of freshwater available for use in a river basin. However, its application faces three major challenges (Biswas, and Tortajada, 2022): the high energy demand, the question of how to deal with the brine, and the carbon footprint of the necessary infrastructure. A recent summary of the state-of-play in desalination in Europe is included in (EEA, 2021b) and (EC DG MARE and EC JRC, 2022), informs that 2,309 desalination plants are operational in the European Union.

Desalinated brackish or seawater is mainly used by public water supply. In total, the volume of desalinated water made available for public water supply in the EU-27 exceeds 500 million m^3 with trends to increase (EurEau, 2022; Eurostat, 2024i). Although this volume represents only a very small fraction of the total abstraction of fresh surface water and groundwater for public water supply at the EU-27 level (1.4%), it exceeded 50% of the total abstraction for public water supply in Cyprus and Malta in 2021. Desalination for public water supply is also practiced in Greece, Italy, Portugal and Spain. Desalinated water is also used by industry and agriculture. In agriculture, desalination is an option that was traditionally restricted to capital-intensive crops. However, due to technical developments, with the cost of water production below 1 €/m^3 (EC DG MARE and EC JRC, 2022), and significant subsidies of up to 60% of operational costs[42], the field of application of desalination continues to broaden. No data are available on the volume of desalinated water used by industry and agriculture in the EU-27. However, the currently installed desalination capacity in the EU-27 is shared between 63% for public water supply (excluding tourism), 3% for tourism, 23% for industry and 12% for agriculture (EC DG MARE and EC JRC, 2022).

In the case of a high-ambition desalination development scenario, the water scarcity risk is expected to decrease more in Catalonia and northern Spain, central and southern Italy and Sicily, the broader Athens metropolitan area, southern France, eastern Bulgaria and Croatia (De Roo, et al., 2023; EurEau, 2022).

[42] e.g., up to 30% by regional authorities in the Canary Islands for different types of water users (Gobierno de Canarias, 2023) or up to 60% by regional authorities in Andalusia for irrigation (Junta de Andalucía, 2023) or 0.1€/m^3 by local authorities in Torrevieja (Ayuntamiento de Torrevieja, 2023).

10 Conclusions and outlook

Enabling measures are essential for effective water saving

Water saving measures must always be implemented in close coordination with economic measures, financial arrangements, raising awareness or market development, and be embedded in an adequate governance, involving stakeholders from all stages of the production chains.

Economic pricing strategies combined with policy tools can be effective as incentives for water users to save water. The optimal mix of measures is site specific and needs to be tailor-made.

Legal and governance arrangements must be put in place to guarantee that the environment is the beneficiary of the measures. Otherwise, there is a risk that the saved water will be used to enhance economic growth, resulting in no reduction of water abstraction.

For a future regionalized assessment of water-saving options, a comprehensive overview of water-dependent economic activities is crucial. Including details on current water saving measures and estimating remaining potential, along with assessing the economic viability of selected measures over an extended time horizon, will inform strategic opportunities. This holistic approach contributes to a more informed and forward-looking regional water management strategy.

There is room for improvement in data management. Gaps exist in reported data, information, and knowledge at the European level regarding the potential impacts and efficiency of water-saving measures. Improved information would enable comparisons of successful implementations across sectors or large-scale ecosystems, fostering an upward spiral of progress. Making more detailed analyses on sectoral water use efficiency is found to be often hampered by confidentiality issues (Ricardo, 2018). This is notable, for instance, in the manufacturing sector.

Data availability on water consumption (with due regard to confidentiality issues) will improve upon adoption of the new Industrial Emissions Portal Regulation, as industrial operators will need to report it as of 2028.

The implementation of water saving measures in the WFD's Programmes of Measures is lagging behind

Measures for water efficiency, including technical measures for irrigation, industry, energy and households (Key Type of Measures - KTM 08) have been planned in 14[43] out of 19[44] EU Member States, according to the available electronic reporting of the 3rd RBMPs' Programmes of Measures. In 9 out of the 119 RBDs with available electronic reporting, basic basin-wide water efficiency measures were not planned either in the 2nd or the 3rd RBMPs, as they were not deemed necessary. Also, in 48.7% of the RBDs with available electronic reporting, basic basin-wide water efficiency measures were already implemented with the 2nd RBMPs, and new basic measures have not been planned with the 3rd RBMPs. However, in these cases, local water scarcity issues with individual groundwater and surface water bodies are tackled with supplementary water efficiency measures based on a case-by-case approach. Furthermore, in 43.7% of the RBDs, the basic basin-wide water efficiency measures already implemented with the 2nd RBMPs, have been enhanced with newly planned basic measures with the 3rd RBMPs. New supplementary water efficiency measures for individual groundwater and surface water bodies have also been planned in cases of existing or emerging local water scarcity issues.

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[43] Relevant EU Member States: Belgium, Croatia, Czechia, France, Germany, Italy, Latvia, Luxembourg, Netherlands, Poland, Portugal, Romania, Spain, Sweden.

[44] By the time of drafting this report, electronic data from the 3rd RBMPs were available only for 19 out of 27 EU Member States: Austria, Belgium, Croatia, Czechia, Denmark, Estonia, France, Germany, Italy, Latvia, Lithuania, Luxembourg, Netherlands, Poland, Portugal, Romania, Slovakia, Spain, Sweden.

Overall, the planning, evaluation and implementation of water efficiency measures seems to progress between the 2nd and the 3rd RBMPs. However, as mentioned above, a large portion of the RBDs still needs to implement new measures at the RBD level or for specific groundwater and surface water bodies. Considering that the percentage of groundwater bodies in poor quantitative status has changed only slightly from 12% in the 1st RBMPs (2009) to 9% in both the 2nd RBMPs (2015) and the 3rd RBMPs (2021), it is not likely that that all groundwater bodies will reach good quantitative status by 2027, as required by the WFD.

On the one hand, the measures already implemented still need more time to achieve more tangible results and close the gap to environmental targets. For example, the available data from the EEA WAT 007 indicator show that water abstraction has decreased by 19% in the EU-27 between 2000 and 2022 (EEA, 2024b). However, the recovery of groundwater levels to normal can be a (very) slow process, extending maybe to decades in aquifers of low permeability. In parallel, over the course of time, climate change is hampering the recovery of groundwater levels, due to reduced surface flows and recharges. Therefore, measures have to overcome this additional burden, which partly offsets their effectiveness. On the other hand, implementation of the planned measures should become more vigorous and supported by sufficient and uninterrupted funding. Lack of funding was the key reason reported by Member States as blocking their progress in implementing the WFD.

Water saving measures have a significant remaining potential

The ***agricultural sector*** is with 50% of the EU-27's total the largest consumer of water in the EU, and therefore a key sector in water saving strategies. The current focus point of such strategies is Southern Europe, which is responsible for 74% of the EU-27's total consumption for agriculture. Under the impact of climate change, an increasing percentage of the total agricultural area in Europe is expected to require irrigation in the future, extending the interest in improved water use efficiency to these new areas also. There is a significant remaining potential in further prevention of leakage losses, higher application of best management practices (e.g. deficit irrigation, avoiding sprinkling under warm or windy conditions), and in improved water application technologies (subsurface irrigation and precision farming). Precision farming and deficit irrigation practices are still in development. A good body of evidence is available from pilot projects, indicating potential water savings in the order of 20 to 40% from individual measures. The degree to which these measures already have been implemented varies widely. There are indications that in some river basins, typically those affected by a high degree of water stress, the most feasible water saving measures have already been taken (Expósito and Berbel, 2017; Fundação Gulbenkian, 2020; Wencki, et al., 2020), reducing the room for further savings. Theoretically, the water saving potential in irrigated agriculture is up to 20% of the total water abstraction. In practice, the actual achievable saving can be much lower (e.g. 5%) due to technical and economic constraints. Literature points to several cases where water use was not reduced after the implementation of these measures, due to rebound effects. Water saving measures must therefore be accompanied by awareness campaigns to foster behavioural change or even be embedded in an adequate governance structure that ensures that the saved water is used for increased resilience.

A decreasing but still considerable share of Europe's ***electricity production*** relies on water for cooling. Some 36% of the abstracted and 20% of the consumed freshwater is for cooling water for electricity production. The water demand of the sector will be reduced strongly by the anticipated energy transition in the coming decades. Technologies like wind and solar power will reduce the total volume of water required, but biofuels require more water than the currently used fossil fuels, if the water needed for crop production is included. These developments in combination with changes in cooling systems could theoretically reduce cooling water abstraction by 45-95%. Air cooling can reduce water consumption to virtually zero, albeit at the cost of higher CO_2-emissions. Related to energy source, even within the group of fossil fuels there are marked differences in water use. Savings of 30% or more are possible when natural gas is used instead of coal or oil. Water savings can also be obtained by technical modifications to increase the energy conversion. The related case studies indicate an extremely wide range of water savings, from

1 to 100%. Consumption of cooling water can be reduced very effectively, by almost 100%, when there are opportunities for heat integration with other processes, or for use of waste heat in district heating systems (CHP, Combined Heat and Power). A last option considered is to build power stations near the sea where they use salt water rather than fresh water for cooling. This can save up to 100% of freshwater consumption, but the viability of the option is limited as it depends on the presence of a coastline, sea water temperatures (which are impacted by climate change), options to get rid of brine and/or blowdown, and permitting procedures.

In the ***manufacturing industry***, the analysis shows that considerable savings, in the order of 30-50%, are possible in the sectors that are considered in this report, if the necessary investments are made. Water reuse and recycling are key measures for water saving in these sectors. However, the lack of detailed information on implemented water-saving measures versus the remaining potential introduces uncertainties in assessing the remaining potential water savings. Nonetheless, sector organisation reports indicate a significant remaining potential if the necessary investments are made. The use of water efficiency measures by industry is supported by the determination of Best Available Techniques in the framework of the Industrial Emissions Directive (IED), for the production industry as well as the energy industry. This will be complemented by water-related benchmarks and binding target values in permits, as introduced by the on-going revision of the IED.

The analysis of water saving options in the ***public water supply*** sector suggests that more than 33% of water abstraction for public water supply is lost between the point of abstraction and the point of supply, with the losses ranging in the EU-27 from below 15% (e.g. in Austria, Denmark and Netherlands) to more than 40% (e.g. in Bulgaria, Croatia, Italy and Romania). The non-revenue water for water utilities, including physical losses due to leakages, apparent losses due to metering inaccuracies and data handling errors and unbilled authorized consumption, reaches up to 25% of the input water to the urban distribution networks. However, they cannot be eliminated for various technical and economic reasons. Leakages and other losses in the internal distribution systems of buildings ('indoor water leakages') could be more than 10% of the supplied water. Furthermore, it is estimated that the daily household water use per person could potentially decrease by 10-40% in each European region from its current levels, if the lowest daily household water use per person was attainable in all countries within the same region.

Recent trends indicate a 3% reduction in daily household water use per person in Europe between 2017-2021 (EurEau, 2022). The above estimates are in line with previous studies, which estimated that individual measures could reduce domestic water use by 20-50% (Dworak, et al., 2007; Benito, et al., 2009). Water abstraction and use in the public water supply sector can be reduced by improving water infrastructure, upgrading monitoring equipment, optimising water billing and reducing water demand by individual users and households. The expected reduction is enough to justify rebate programmes for households and other domestic users with a short payback period for the installation of water saving devices. Furthermore, water utilities could benefit from the reduced energy costs to transfer, treat and distribute the saved water, which could remain unmetered or unbilled in various cases. A more recent EU-wide modelling study by the JRC (De Roo, et al., 2023) estimated that the planned public investments in urban leakage reduction between 2016-2027 could save marginal amounts of water at the national level (<1%). Furthermore, the same study estimated that desalination could cover more than 20% of the water use for public water supply at a cost up to 1 Euro per m^3 in Croatia, Greece, Italy, Malta, Portugal, Slovenia and Spain.

Tourism, as a segment of the public water supply sector, relies on water for various purposes, including hotels, resorts, restaurants, and recreational activities. Tourists often enjoy water-intensive experiences like swimming pools, spa treatments, and golf courses. As the tourism sector in Europe is expected to grow up to 7.5 % until 2034, the demand for water in tourism activities will also grow, exerting pressure on local water supplies and ecosystems. The overall direct water use by the European tourism sector can be estimated at 1,800 million m^3 per year corresponding to about 5% of the total water abstraction by public water supply in the EU. Compared to other economic sectors, this is a minor figure; however, it often places additional stress on already water-scarce areas, such as small Mediterranean islands, coastal areas or high mountains.

Accommodation of tourists is the most water-using tourism segment (1700 million m^3 per year) and the corresponding water abstractions place pressures on local water resources. However, part of this water is reused or taken from alternative water sources such as desalination. Water consumption is highest in green areas, such as golf courses and parks, as well as in snowmaking due to wind and evaporation losses. The priorities of water saving in tourism should be in holistically assessing per water use(r), how to minimize the respective water use, and special attention shall be placed on systematic reduction changes in the accommodation sector, including cooling systems. Plenty of water-saving measures such as water audits, the repair of leaks, the replacement of water-consuming devices, the water-saving design of installations, improved water-use practices and deficit irrigation have been implemented in the past in the different tourism segments. But the level of implementation should be improved towards a more water efficient and resilient tourism sector in Europe. Given the many uncertainties of available data and information, the rough overall figure for the water-saving potential in the tourism sector of 10-30% should be handled with caution.

Diversifying water supply through alternative water sources

Water saving measures are often combined with the exploitation of alternative water sources: rainwater harvesting, water reuse / recycling and desalination. Using alternative sources does not reduce water consumption but can help relieve abstraction pressures on surface and groundwater bodies. Alternative water sources are, with variable intensity, applied in all economic sectors.

Rainwater harvesting has been applied in agriculture for centuries and is also applied in industry, urban water supply and tourism. An example from the tourism sector: rainwater harvesting options were modelled for meeting non-potable water demand at Amsterdam-Schiphol Airport. With sufficient storage, all non-potable water demand of the airport can be supplied, reducing freshwater abstraction for drinking water by around 60%.

Water reuse has significantly increased over the past decade in the EU. Water reuse for irrigation remains the most common application of reclaimed water in Europe (39% of the total schemes) followed by water reuse in industry / manufacturing (15%) and water reuse for recreational purposes (11%). The annual volume of reclaimed water in the EU-27 is 650 million m^3, which accounts for 2.4% of the urban wastewater receiving tertiary treatment annually or less than 0.3% of the total annual abstraction of fresh surface water and groundwater in the EU-27. It is noted that Cyprus and Malta already reuse more than 90% and 60% of their wastewater, respectively.

Desalinated water is mainly used in public water supply, followed by industry, agriculture and tourism. In agriculture, desalination is an option that was traditionally restricted to capital-intensive crops, but technical development, with the cost price of water production well below 1 €/m^3 as well as the significant subsidies of up to 60% of the operational costs continue to broaden the field of application considerably. Although desalination represents a very small fraction of the total volume of water use in Europe (around 1%), between 2017 and 2021, there has been a significant increase in desalination for public water supply in some Mediterranean countries. Especially in Cyprus and Malta, desalination exceeds 50% of the total public water supply.

The prospectives for a wider implementation of water-saving measures can be limited by financial constraints. Such constraints have not consistently been taken into consideration in this report, but may have a considerable impact, as a recent report by the JRC (De Roo, et al., 2023) suggests. This report found that the implementation of water saving measures in the agricultural area to the degree that is covered by the planned budgets will increase irrigation efficiency by 1-4% in the five EU Member States with the largest areas of irrigated land (Spain, Italy, Greece, France and Portugal). For water savings in the public water supply, the findings are similar. Another example of the role of investment levels, from the pulp and paper industry. The EU-funded project 'PaperBREF' (cited in JRC, 2015) showed that with a very low investment a potential saving rate of 12.3% of the water used could be reached; savings of 22% are possible with an improved water usage and some important investments; and with significant investments it is possible to reach a savings rate of 40% (JRC 2015). These examples underline the fact that water saving requires a prolonged effort, concerted action and broad support.

Outlook

Directing our glance to the future, we recapitulate that, what was said in chapters 4 to 8 on the future trends of the economic activities and their water demand, as driven by socio-economic development and climate change.

- Despite the overall decreasing trend of total water abstraction between 2000 and 2022, water abstraction for agriculture, industry, and public water supply shows an increasing trend since 2010, indicating the need for increased efforts to improve overall water use efficiency. (EEA, 2024b).
- The area of irrigated agriculture and the required irrigation per ha are expected to gradually increase over the coming decades, as drought events are expected to intensify and proliferate under climate change. Currently, available evidence, however, is not univocally supporting this conclusion, so continued monitoring is needed.
- Electricity demand is expected to grow, while its water abstraction and consumption may decrease as a result of the shift towards wind and solar power, which are less water-dependent.
- The output of the manufacturing industry is very diverse and the future trend of water use and consumption for the whole sector will depend on whether improvements in water use efficiency manage to outpace economic growth.
- Public water supply in the EU-27 shows an overall increasing trend between 2000 and 2022. Future trends are rather uncertain, as some drivers point towards a further increase of water demand and others towards a decrease.
- The tourism sector is expected to grow, but how growth will affect the sector's water use and consumption is uncertain.

With regards to the water supply side, the signal emerging from recent IPCC-reports is that water availability will decrease in many parts of the EU, in some cases only during summer, in other cases year-round.

The combination of a relatively uncertain decrease of water demand for economy and a relatively certain decrease of future water availability reconfirms the conclusion that Europe must prepare for increasing water stress. Water saving measures offer potential, as this report demonstrates. In some regions of Europe water saving may be sufficient to keep pace with decreasing water availability due to climate change (although this cannot solve water stress problems in, for example, rainfed agriculture and rainfall-dependent ecosystems). In other regions saving water will at least buy time to prepare for more structural changes in water use and consumption. A tentative storyline of how water saving measures may contribute:

In 2035/2040, Europe's economy saves water by the best available technical options, accompanied by operational management practices that reflect a mature 'water-awareness', and supported by adequate governance arrangements at all relevant levels. This is valid in at least the EU regions that are regularly water-stressed or will become regularly water-stressed within the coming decades. Whenever major investments in renewal or reconstruction of existing infrastructure are upcoming, water saving is given due weight. Working along these lines, in 2035 30% less water will be used in Europe's economy. Long-term sustainability considerations have precedence over short-term economic gains, and the principle that problems may no longer be passed on to future generations is strictly followed. Therefore, the saved water is used to build buffers, to accommodate the progressing impacts of climate change, and to increase *drought resilience. This has demonstrable positive impacts on society, which has avoided societal unrest and breakdowns of local economies during several severe drought events. It also has demonstrable positive impacts on the environment: extremely low flows in rivers are avoided, heat emissions are kept at acceptable levels, and parents catch fish species with their children that they once caught with their own parents, but which had disappeared until not so long ago. In the meantime, preparations for even worse climate change are ongoing, including, for example, fundamental modifications of production-consumption chains.*

To arrive at such outcomes many boxes must be ticked. The technical and operational management measures that are discussed in this report are only one link in a large network. It starts with awareness, employs enabling measures and capitalizes on synergies with transitions in energy, food production and consumption. Water must become an integrated element of any environmental, economic and spatial development.

Glossary

Terms are used in this report for different types of water stress situations, as determined by their primary causes and their duration or frequency.

Available water resources	That part of surface water and groundwater resources that is available for use (EC, 2015b).
Concentrating Solar Power (CSP)	Concentrating Solar Power (CSP) plants use mirrors to concentrate sunlight onto a receiver, which collects and transfers the solar energy to a fluid acting as heat transfer, which supplies heat for end-use applications or to generate electricity through conventional steam turbines. Large CSP plants can be equipped with a heat storage system to allow for heat supply or electricity generation at night or when the sky is cloudy. (IEA-ETSAP and IRENA, 2013)
Decoupling	Decoupling refers to the ability to sustain economic growth while reducing the amount of resources used, such as water or fossil fuels, and stopping environmental deterioration at the same time. Decoupling may be relative (indicating decreasing resource use per unit of production value) or absolute (absolute decrease in resource use while production value increases).
Deficit irrigation	Application of irrigation water during drought-sensitive growth stages of a crop. Outside these periods, irrigation is limited or even unnecessary if rainfall provides a minimum supply of water. Water restriction is limited to drought-tolerant phenological stages, often the vegetative stages and the late ripening period. (FAO, 2000))
Drought	A drought refers to a temporary water shortage. A meteorological drought starts with reduced levels of precipitation compared with normal. When prolonged, this may then cause reduced levels of soil moisture in agricultural land (agricultural drought) and reduced levels of natural water flows to surface water and groundwater (hydrological drought). Long-term drought conditions (e.g. seasonal or year-round) cause aridity, whereas longer periods of drought (multi-annual) may cause desertification. (IPCC, 2019)
Drought risk	Drought risk is the potential for adverse consequences due to drought. It is the combination of three determinant factors: hazard, exposure and vulnerability (IPCC, 2019)
Infrastructure Leakage Index (ILI)	The Infrastructure Leakage Index (ILI) is an operational indicator defined as the ratio between the current annual losses and unavoidable real losses. Unavoidable real losses express the reference leakage level, which is the lowest technically achievable value for a well-maintained and well-managed system. (adapted from Lenzi, et al.,2014).
Irrigation efficiency	Ratio of the required and abstracted volumes of water for irrigation
Jevons paradox	The Jevons paradox describes the case, where an improvement in the efficiency of the use of a resource, results in a higher net resource consumption.
Rebound effect	Improvements in the efficiency of resource use do not always translate into net savings, because producers and consumers adapt their behaviour. The rebound effect refers to the situation in which behavioural change following efficiency gains prevents a reduction in resources used (Paul et al., 2019).
Renewable water resources	The renewable water resources are estimated as the average annual amount of outflow of surface water and groundwater from one river basin or country into neighbouring river basin or country or directly to the sea, plus the net difference of water abstraction from and water returns to surface water and groundwater within the river basin, plus the net change in water storage in lakes and reservoirs,

	i.e. Renewable Water Resources = Outflow + Water Abstractions - Water Returns - Change in water storage (EC, 2012b).
Resilience	Resilience is the ability of a system, community or society exposed to hazards to resist, absorb, accommodate, adapt to, transform and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions through risk management (UNDRR, 2017).
Subirrigation	An irrigation method that delivers water to the root zone, below the soil surface.
Sustainable Economic Level of Leakage (SELL)	Sustainable Economic Level of Leakage (SELL) is the optimum level of leakage, when balancing both the cost of leakage management and the cost of lost water. Costs incorporate both the internal costs of water utilities, and externalities such as the cost of carbon. However, the resource cost of lost water is included only where this component is calculated and integrated in water prices (PWC, 2019).
Water abstraction	Extraction of water from the environment for human and socio-economic purposes; usually assuming that this occurs with the use of artificial means (e.g. canals, pipes, diversions, pumping) (adapted from (UN, 2012)).
Water consumption	The part of water used that is not returned to groundwater or surface water because it is incorporated into products (e.g. food and beverages) or consumed by households (e.g. drinking water) or livestock. Thus, it may include transpiration of water from crops, the losses due to evaporation during distribution and the apparent losses due to unauthorised tapping and malfunctioning meters. The term is equivalent to 'consumptive water use' (adapted from (UN, 2012)). Water consumption = Water abstraction minus returns before site of use (e.g. conveyance losses) minus returns on site of use (e.g. application losses and discharges) minus any supply of treated wastewater to other sectors = Water abstracted and not directly returned to the water environment (frequently also mentioned as 'net abstraction').
Water recycling and water reuse	Water recycling is wastewater used again for the purposes of the same user (e.g. household / economic unit) with or without prior treatment. Water reuse is wastewater supplied to another user for further use according to their purposes with or without prior treatment (adapted from (UN, 2012)).
Water scarcity	Water scarcity defines a mid-term water stress condition (e.g. seasonal, annual or multi-annual) occurring when the water demand for human needs frequently exceeds the sustainable supply capacity of the natural system in river basins. Water scarcity is the consequence of anthropogenic impacts on the availability of water resources. Water scarcity can be measured as the ratio between renewable freshwater resources and water abstraction or water use. The occurrence of droughts in river basins exacerbates the impacts of water scarcity on both ecosystem and socio-economic conditions (as regards resilience, maintenance and restoration/development). (adapted from (EC, 2012b)).
Water stress	Water stress refers to the ability, or lack thereof, to meet the human and ecological demand for water. Compared with scarcity and shortage, water stress is a more inclusive and broader concept. As well as water scarcity, it also considers water quality, ecological flows and the accessibility of water (UN Global Compact, 2014).
Water supply	Delivery of water to end users, including self-supply for own final use (EC, 2015b).
Water use	The total volume of water intake by a socio-economic activity (e.g. water intake for household needs, including drinking water, irrigation of crops, cooling at industrial and energy production plants). Water use includes both consumptive and non-consumptive activities. Consumptive activities result in evaporation and transpiration of water or its integration into products. Non-consumptive activities use water and then return it to surface water and groundwater but with potential

	changes to its physico-chemical properties. Water use may incorporate excess water intake ('water waste'), which does not serve the needs of the activity (adapted from (UN, 2012)). Water use = Water abstraction minus returns before site of use (e.g. conveyance losses).
Water use efficiency	The ratio of either the net or the gross value added of a socio-economic activity and its water consumption (adapted from (UN, 2012)).

List of abbreviations

Abbreviations	Name
8th EAP	Eight Environment Action Programme
BAT	Best Available Technique
BREF	BAT Reference document
CAP	Common Agricultural Policy
CCS	Carbon Capture and Storage
CSI	Core Set of Indicators (EEA's indicators system)
CSP	Concentrating Solar Power
EEA	European Environment Agency
EEA-38 and the UK	The 32 member countries and six cooperating countries of the EEA and the United Kingdom
EIONET	European Environment Information and Observation Network
EIP	European Innovation Partnership
E-PRTR	European Pollutant Release and Transfer Register Regulation
ESG	Environmental, Social, Governance
ETC-BE	European Topic Centre on Biodiversity and Ecosystems
EU	European Union
EU-27	The 27 Member States of the European Union
EU-27 and the UK	The 27 Member States of the European Union and the United Kingdom
FDM	Food, Drink and Milk
GDP	Gross Domestic Product
GVA	Gross Value Added
IED	Industrial and Livestock Rearing Emissions Directive (IED 2.0)
ILI	Infrastructure Leakage Index
IPBES	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
IPCC	Intergovernmental Panel on Climate Change
JPI	Joint Programming Initiative
JRC	Joint Research Centre
KTM	Key Type of Measures
MAES	Mapping and Assessment of Ecosystems and their Services
NbS	Nature-based Solutions
NGO	Non-Governmental Organisation
NUTS	Nomenclature of Territorial Units for Statistics (Eurostat's geocode standard)
NVA	Net Value Added
NWRM	Natural Water Retention Measures
OECD	Organisation for Economic Cooperation and Development
Peseta	Projection of economic impacts of climate change in sectors of the European Union based on bottom-up analysis
PPS	Purchasing Power Standard
PV	Photovoltaic
RBD	River Basin District
RBMP	River Basin Management Plan
RCP	Representative Concentration Pathway
RDP	Rural Development Programme
SDG	Sustainable Development Goal
SELL	Sustainable Economic Level of Leakage
WEI+	Water Exploitation Index plus
WFD	Water Framework Directive
WG	Working Group
WISE	Water Information System for Europe

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ANNEX 1 (to Chapter 2) Data on water abstraction and consumption by sector and country

Table A.1.1 Distribution of water abstraction by economic sector at country, regional and EU level. (% as average of 2000-2022)

	Agriculture	Cooling water in electricity production	Manufacturing, including cooling water in industry	Public water supply, including tourism and other services	Mining, quarrying and construction
Eastern Europe	**12.6%**	**53.8%**	**12.3%**	**20.4%**	**0.9%**
BG	15.7%	64.0%	3.3%	16.6%	0.4%
CZ	3.2%	34.0%	17.1%	43.5%	2.2%
HU	8.1%	74.8%	2.2%	13.3%	1.6%
PL	11.1%	62.5%	4.9%	20.7%	0.8%
RO	18.7%	25.4%	34.7%	21.2%	0.0%
SK	7.1%	15.3%	36.2%	37.7%	3.8%
Northern Europe	**8.3%**	**32.7%**	**29.5%**	**27.2%**	**2.3%**
DK	52.4%	0.3%	3.5%	43.3%	0.5%
EE	1.2%	82.4%	2.4%	4.0%	10.0%
FI	2.1%	16.9%	62.8%	18.0%	0.3%
IE	3.0%	34.6%	4.0%	57.1%	1.2%
LT	5.5%	81.3%	2.3%	10.0%	1.0%
LV	26.7%	3.6%	12.8%	51.7%	5.1%
SE	4.2%	4.2%	54.0%	36.4%	1.2%
Southern Europe	**59.7%**	**9.9%**	**11.0%**	**19.4%**	**0.0%**
CY	71.9%	0.9%	1.7%	25.5%	0.0%
ES	84.6%	0.7%	1.6%	12.8%	0.3%
EL	65.1%	17.5%	2.0%	15.3%	0.0%
HR	4.6%	18.1%	4.5%	72.4%	0.4%
IT	49.0%	1.8%	23.8%	25.4%	0.0%
MT	60.2%	0.0%	2.6%	37.2%	0.0%
PT	61.7%	16.0%	8.5%	13.7%	0.0%
SI	0.4%	75.7%	5.9%	18.0%	0.1%
Western Europe	**5.6%**	**57.9%**	**15.9%**	**17.5%**	**3.2%**
AT	2.6%	43.2%	37.6%	16.6%	0.0%
BE	1.0%	62.2%	21.4%	13.2%	2.2%
DE	1.1%	57.2%	16.2%	17.6%	7.8%
FR	12.7%	60.3%	7.4%	19.4%	0.2%
LU	1.4%	0.0%	6.5%	92.1%	0.1%
NL	1.4%	56.1%	28.8%	13.7%	0.0%
EU-27	**29.4%**	**35.9%**	**14.0%**	**19.2%**	**1.5%**

Source: EEA, 2024b

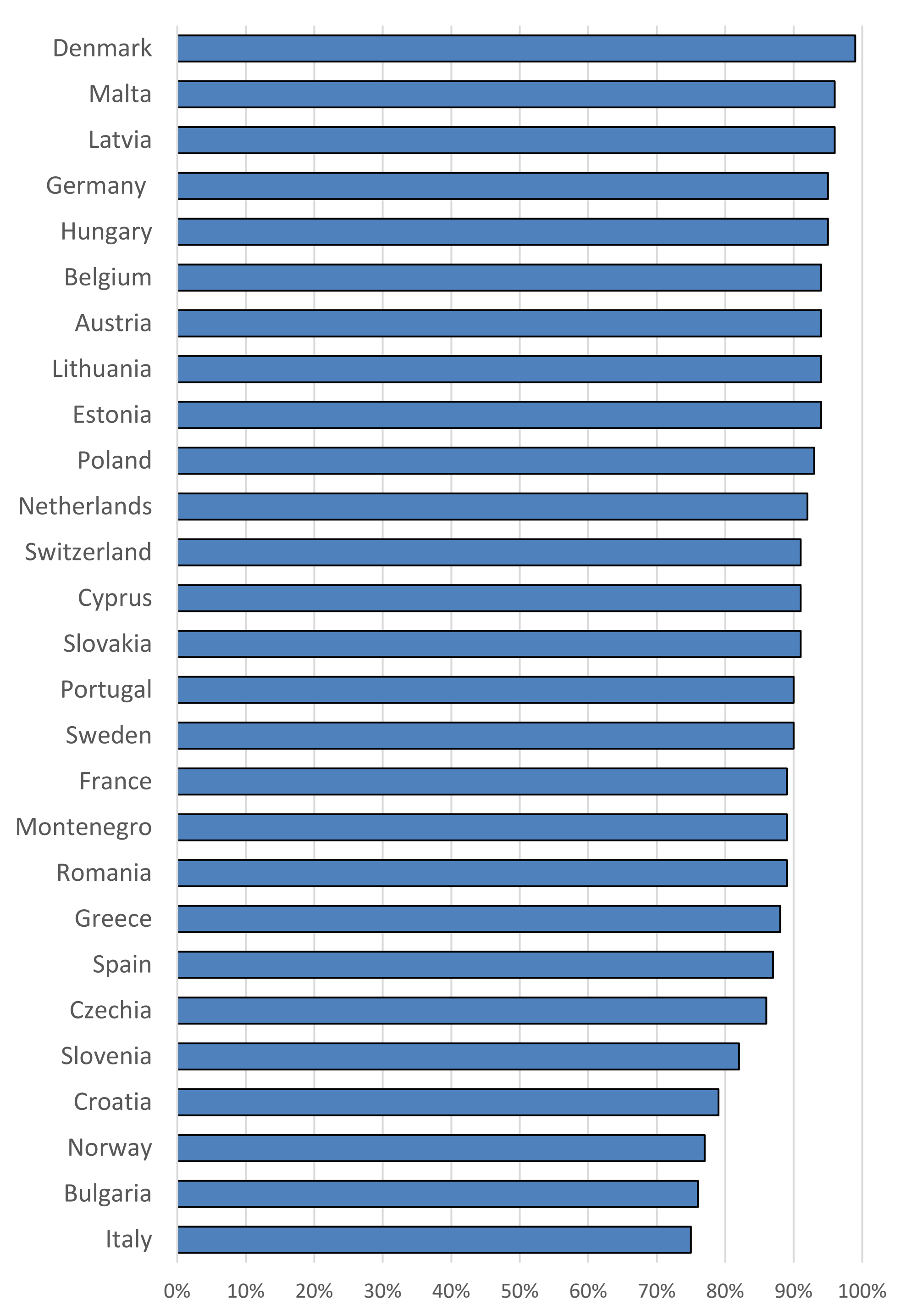
Table A.1.2 Distribution of water consumption by economic sector at country, regional and EU level (% as average of 2000-2022)

	Agriculture	Cooling water in electricity production	Manufacturing, including cooling water in industry	Public water supply, including tourism and other services	Mining, quarrying and construction
Eastern Europe	**22.3%**	**44.6%**	**20.4%**	**11.2%**	**1.5%**
BG	38.1%	34.5%	8.9%	17.4%	1.2%
CZ	7.8%	12.6%	42.8%	31.4%	5.4%
HU	11.9%	81.2%	3.0%	1.7%	2.2%
PL	23.0%	53.3%	8.5%	13.9%	1.4%
RO	28.1%	15.6%	46.3%	9.9%	0.0%
SK	11.0%	4.3%	60.2%	18.2%	6.2%
Northern Europe	**16.5%**	**34.8%**	**36.3%**	**8.7%**	**3.8%**
DK	93.0%	0.1%	3.6%	2.8%	0.6%
EE	2.3%	74.7%	4.0%	2.1%	16.9%
FI	3.8%	14.7%	71.7%	9.5%	0.3%
IE	4.6%	63.4%	4.8%	25.7%	1.4%
LT	11.3%	77.9%	3.5%	5.8%	1.5%
LV	62.2%	3.5%	22.4%	3.3%	8.6%
SE	9.2%	0.4%	82.4%	6.1%	1.9%
Southern Europe	**74.4%**	**9.1%**	**9.4%**	**7.1%**	**0.0%**
CY	89.1%	0.5%	2.1%	8.3%	0.0%
ES	93.6%	0.5%	1.4%	4.2%	0.2%
EL	78.3%	16.5%	1.5%	3.7%	0.0%
HR	9.6%	24.2%	6.3%	59.4%	0.5%
IT	62.5%	2.6%	23.2%	11.7%	0.0%
MT	82.4%	0.0%	3.2%	14.3%	0.0%
PT	77.2%	6.8%	8.6%	7.3%	0.0%
SI	1.3%	67.9%	9.6%	21.1%	0.2%
Western Europe	**16.0%**	**26.1%**	**35.7%**	**14.1%**	**8.1%**
AT	5.0%	27.7%	58.5%	8.8%	0.0%
BE	3.6%	31.0%	41.3%	19.7%	4.5%
DE	3.6%	16.3%	43.8%	15.4%	21.0%
FR	38.2%	28.4%	16.2%	16.9%	0.3%
LU	4.7%	0.0%	5.5%	89.7%	0.1%
NL	3.5%	43.1%	49.7%	3.8%	0.0%
EU-27	**49.8%**	**19.6%**	**18.8%**	**9.5%**	**2.4%**

Source: EEA, 2024b

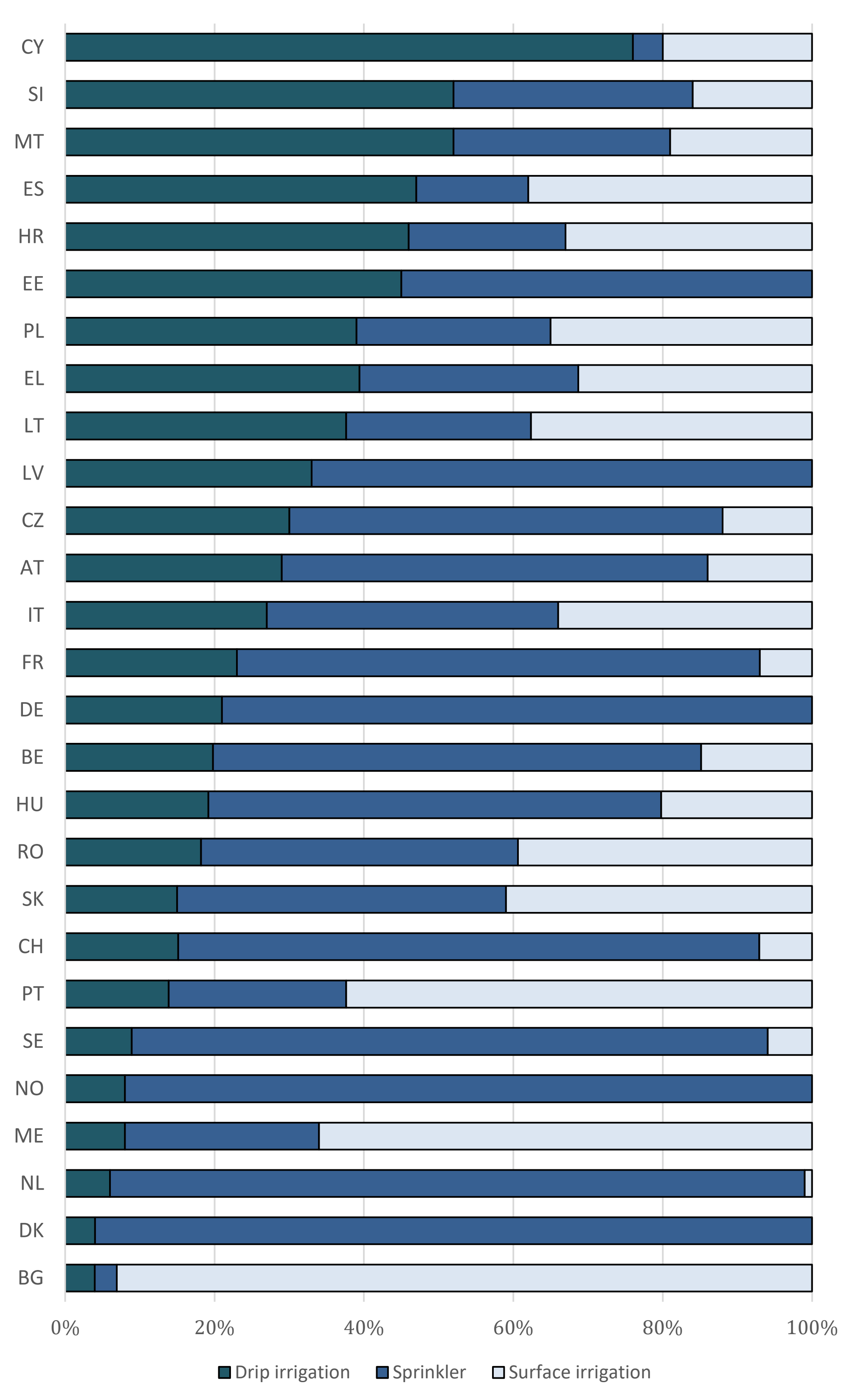
ANNEX 2 (to Chapter 4) Key data on irrigation systems in EU Member States

Figure A.2.1 Conveyance efficiency (%) of water distribution systems for irrigation at country level



Source : Eurostat, 2018 ; EEA, 2017; JRC, 2008; Phocaides, 2007; Brouwer, et al., 1989

Figure A.2.2 Distribution of types of irrigation systems in the agricultural sector at country level



Source: Eurostat, 2018

ANNEX 3 (to Chapter 5) Potential for water saving in electricity cooling per EU-country and per region

<table>
<tr><th>Region of the EU</th><th>Country</th><th>Where is the potential for water saving?</th></tr>
<tr><td rowspan="6">Eastern Europe</td><td>Bulgaria (BG)</td><td>- Only re-circulatory cooling yet used, still potential to save water by switching to a hybrid or dry cooling system.
- Stable and high presence of nuclear energy, and solids are largely present as a fossil fuel. Solar and wind still potential for increase. Hydropower largely present but stable number, and biomass present to a lesser extent. Potential to invest in natural gas, solar and wind, while decreasing the share of solids and nuclear energy.
- No use of seawater for cooling yet, and coastline is available, meaning there is potential for water saving through relocation to the coast.</td></tr>
<tr><td>Czechia (CZ)</td><td>- Only re-circulatory cooling yet used, still potential to save water by switching to a hybrid or dry cooling system.
- Increase in and high presence of nuclear energy, and solids are largely present as a fossil fuel. Solar and wind small potential for increase. Hydropower largely present but stable number, and biomass present and increasing. Potential to shift from nuclear and solids to natural gas and where possible still to solar and wind energy.
- No option to use seawater for cooling due to lack of coastline.</td></tr>
<tr><td>Hungary (HU)</td><td>- Only re-circulatory cooling yet used, still potential to save water by switching to a hybrid or dry cooling system.
- Nuclear energy and gas largely present. Share of solids and oil is decreasing fast. Mainly for wind still large potential for increase. Biomass largely present. Potential to save water by further investing in solar, wind, and natural gas. Further reduce the share of solids, oil, biomass, and nuclear energy.
- No option to use seawater for cooling due to lack of coastline.</td></tr>
<tr><td>Poland (PL)</td><td>- Mainly use of re-circulatory cooling systems, however hybrid and air cooling are to a very small extent already present. Once-through cooling still accounts for one third of the share. Potential to save water by switching to a closed-cooling system, but even better would be to switch to a hybrid or dry cooling system.
- No nuclear energy and the share of oil is very small. Share of solids and gas is large. Mainly potential for increase in wind energy. Hydropower and biomass are increasing. Potential to save water by largely investing in wind energy, by further investing in natural gas, and by further reducing the shares of solids and biomass.
- Almost no use of seawater for cooling yet, and coastline is available, meaning there is potential for water saving through relocation to the coast.</td></tr>
<tr><td>Romania (RO)</td><td>- Only re-circulatory cooling yet used, and one once-through cooling system. Thus, there is still potential to save water by switching to a hybrid or dry cooling system.
- Nuclear energy present and increasing, and gas is largely present as a fossil fuel, but decreasing. Share of solids is large still. Solar and wind still large potential for increase. Hydropower and biomass largely present and increasing for biomass. Potential to save water by further investing in solar and wind and stopping decrease of natural gas. Further reduce the share of solids and biomass.
- Almost no use of seawater for cooling yet, and there is (a short) coastline available, meaning there is some potential for water saving through relocation to the coast.</td></tr>
<tr><td>Slovakia (SK)</td><td>- Only re-circulatory cooling yet used, still potential to save water by switching to a hybrid or dry cooling system.
- Nuclear energy present and increasing, and gas is largely present as a fossil fuel, but decreasing fast. Share of solids is large still. Mainly for solar energy large potential for increase. Hydropower and biomass largely present. Potential to save water by further investing in wind and stopping decrease of natural gas. Further reduce the share of solids and biomass.
- No option to use seawater for cooling due to lack of coastline.</td></tr>
<tr><td>Northern Europe</td><td>Denmark (DK)</td><td>- Only uses once-through cooling systems, so very large potential to save water. This can already be done by switching to a closed-cooling system, but it would be even better to switch to a hybrid or dry cooling system.</td></tr>
</table>

Region of the EU	Country	Where is the potential for water saving?
		- No nuclear energy and the share of oil is very small. Share of solids is decreasing, however, still relatively large. Mainly potential for increase in wind energy. Hydropower share is small but stable and biomass share is quite large. Potential to save water by largely investing in wind energy, by further investing in natural gas, and by further reducing the shares of solids and biomass. - Already 2/3 of cooling done by salt water, so there is still some (but little) potential for cooling
	EE (Estonia)	- Only re-circulatory cooling, yet used, still potential to save water by switching to a hybrid or dry cooling system. - No nuclear energy and the share of oil is very small. Share of solids is decreasing, however, still relatively large. Mainly potential for increase in wind energy. Hydropower share is small but stable and biomass share is quite large. Potential to save water by largely investing in wind energy, by further investing in natural gas, and by further reducing the shares of solids and biomass. - No use of seawater for cooling yet, and large coastline is available, meaning there is high potential for water saving through relocation to the coast.
	FI (Finland)	- Re-circulatory cooling and once-through cooling systems both present. Thus, there is still large potential to save water by switching to a hybrid or dry cooling system, or even for some systems to switch to re-circulatory cooling. - Decrease in nuclear energy, however, share is still large. Gas and solids are largely present as a fossil fuel, but slightly decreasing for solids. Mainly in wind still potential for increase. Hydropower and biomass largely present and increasing. Potential to stop biomass development for water saving, further decrease nuclear energy and solids, and to invest mainly in wind and natural gas. - Almost half of the cooling done by salt water or brackish water, so there is still some potential for cooling through relocation to the coast.
	IE (Ireland)	- Mix of re-circulatory cooling and once-through cooling systems present. Thus, there is still large potential to save water by switching to a hybrid or dry cooling system, or even for some systems to switch to re-circulatory cooling. - No nuclear energy, and gas is largely present as a fossil fuel. Share of solids still large. Solar and wind still potential for increase. Hydropower and biomass largely present and still increasing for biomass. Potential to stop biomass development for water saving, reduce share of solids, and to invest in solar, wind and natural gas. - Half of the cooling done by salt water or brackish water, so there is still some potential for cooling through relocation to the coast.
	LT (Lithuania)	- Only re-circulatory cooling yet used, still potential to save water by switching to a hybrid or dry cooling system. - No nuclear energy, and gas is largely present as a fossil fuel. Share of solids and oil are little to none. Mainly potential for increase for wind. Hydropower and biomass largely present, but stable. Potential to save water by further investing in solar, wind and natural gas. - Almost no use of seawater for cooling yet, and there is a short coastline available, meaning there is some (but little) potential for water saving through relocation to the coast.
	LV (Latvia)	- Only re-circulatory cooling yet used, still potential to save water by switching to a hybrid or dry cooling system. - No nuclear energy, and gas is largely present as a fossil fuel. Share of solids and oil are little to none. Mainly potential for increase for wind. Hydropower and biomass largely present, but stable. Potential to save water by further investing in solar, wind and natural gas. - Almost no use of seawater for cooling yet, and relatively large coastline is available, meaning there is potential for water saving through relocation to the coast.
	SE (Sweden)	- Re-circulatory cooling and once-through cooling systems both present. Thus, there is still large potential to save water by switching to a hybrid or dry cooling system, or even for some systems to switch to re-circulatory cooling. - Nuclear energy and gas largely present and stable. Share of solids and oil is decreasing fast. Mainly for wind still large potential for increase. Hydropower and biomass largely

Region of the EU	Country	Where is the potential for water saving?
		present and increasing for biomass. Potential to save water by further investing in wind and natural gas. Further reduce the share of solids, oil, biomass and nuclear energy. - Almost half of the cooling done by salt water or brackish water, so there is still some potential for cooling through relocation to the coast.
Southern Europe	Cyprus (CY)	- Mix of re-circulatory cooling and once-through cooling systems present. Thus, there is still large potential to save water by switching to a hybrid or dry cooling system, or even for some systems to switch to re-circulatory cooling. - No nuclear energy, and gas is largely present as a fossil fuel. Oil and solids are decreasing. Mainly potential for increase in solar energy. Hydropower not present and biomass share is very small. Potential to save water by largely investing in solar energy and further investing in natural gas. - Already 2/3 of cooling done by salt water, so there is still some (but little) potential for cooling through relocation to the coast. In Southern Europe the potential is, however, generally lower due to the high sea temperatures.
	Spain (ES)	- Re-circulatory cooling accounts for 2/3, while once-through cooling accounts for 1/3 of the share. Thus, there is still large potential to save water by switching to a hybrid or dry cooling system, or even for some systems to switch to re-circulatory cooling. - Nuclear energy and gas largely present and stable. Share of solids and oil is large still. Solar and wind still large potential for increase. Hydropower and biomass largely present and increasing for biomass. Potential to save water by further investing in solar, wind, and natural gas. Further reduce the share of solids, oil, biomass, nuclear energy, and hydropower. For hydropower the potential for water saving is, however, dependent on local conditions, but in dry climates the large evaporation can result in large water losses. - 1/3 of cooling done by salt water or brackish water, so there is still potential for cooling through relocation to the coast. In Southern Europe the potential is, however, generally lower due to the high sea temperatures.
	Greece (GR)	- Re-circulatory cooling accounts for 2/3, while once-through cooling accounts for 1/3 of the share. Thus, there is still large potential to save water by switching to a hybrid or dry cooling system, or even for some systems to switch to re-circulatory cooling. - No nuclear energy, and gas is largely present as a fossil fuel. Share of oil and solids still large. Solar and wind still potential for increase. Hydropower largely present but stable. Biomass share is small. Potential to reduce share of oil, solids, and hydropower for water saving, and to invest in solar, wind and natural gas. For hydropower the potential for water saving is, however, dependent on local conditions, but in dry climates the large evaporation can result in large water losses. - 1/3 of cooling done by salt water, so there is still potential for cooling through relocation to the coast. In Southern Europe the potential is, however, generally lower due to the high sea temperatures.
	Croatia (HR)	- No information on water saving potential through switching to a different cooling system. - No nuclear energy, and gas is largely present as a fossil fuel. Oil and solids are decreasing. Solar and wind still potential for increase. Hydropower and biomass largely present, but stable or slightly increasing. Potential to save water by further investing in solar, wind and natural gas. - No information on water saving potential through relocation to the coast.
	Italy (IT)	- Mainly use of re-circulatory cooling, but also once-through cooling systems present. Thus, there is still large potential to save water by switching to a hybrid or dry cooling system, or even for some systems to switch to re-circulatory cooling. - No nuclear energy, and gas is largely present as a fossil fuel. Share of oil and solids is large still. Solar and wind still large potential for increase. Hydropower and biomass largely present and increasing. Potential to save water by further investing in solar, wind and natural gas and reducing the share of the other fossil fuels. - Seawater and brackish water already almost fully used for cooling, so no potential for water saving due to relocation to the coast.
	Malta (MT)	- Only uses once-through cooling systems, so very large potential to save water. This can already be done by switching to a closed-cooling system, but even better would be to switch to a hybrid or dry cooling system.

Region of the EU	Country	Where is the potential for water saving?
		- No nuclear energy, and gas is largely present as a fossil fuel. Share of solids and oil are zero. Mainly potential for increase for wind. Hydropower not present and biomass small share. Potential to save water by further investing in wind and natural gas. - Seawater already fully used for cooling, so no potential for water saving due to relocation to the coast.
	Portugal (PT)	- Mainly use of re-circulatory cooling systems, however air cooling is for one power plant present. Once-through cooling still accounts for one third of the share. Potential to save water by switching to a closed-cooling system, but even better would be to switch to a hybrid or dry cooling system. - No nuclear energy, and gas is largely present as a fossil fuel, but decreasing. Share of oil is large still. Solar and wind still large potential for increase. Hydropower and biomass largely present, but stable. Potential to save water by further investing in solar and wind and stopping the decrease of natural gas. Further reduce the share of oil. - 1/3 of cooling done by salt water, so there is still potential for cooling through relocation to the coast. In Southern Europe the potential is, however, generally lower due to the high sea temperatures.
	Slovenia (SI)	- Only re-circulatory cooling yet used, still potential to save water by switching to a hybrid or dry cooling system. - Nuclear energy present but stable. Gas not yet largely present as a fossil fuel and increasing. Share of solids is large still. Mainly for solar energy large potential for increase, but also some for wind. Hydropower largely present, biomass slightly increasing. Potential to save water by further investing in solar, wind, and natural gas. Further reduce the share of solids, biomass, and hydropower. For hydropower the potential for water saving is, however, dependent on local conditions, but in dry climates the large evaporation can result in large water losses. - No option to use seawater for cooling due to lack of coastline.
Western Europe	Austria (AT)	- Only re-circulatory cooling, yet used, still potential to save water by switching to a hybrid or dry cooling system. - No nuclear energy, and gas is largely present as a fossil fuel. Solar and wind still potential for increase. Hydropower and biomass largely present and still increasing. Potential to stop hydropower and biomass development for water saving, and to invest in solar, wind and natural gas. For hydropower the potential for water saving is, however, dependent on local conditions, but in dry climates the large evaporation can result in large water losses. - No option to use seawater for cooling due to lack of coastline.
	Belgium (BE)	- Mainly use of re-circulatory cooling systems (over 50%), however air cooling is also already used. Once-through cooling to a small extent present. Mainly potential to save water by switching to a hybrid or dry cooling system. - Decrease in nuclear energy, and gas is largely present as a fossil fuel. Mainly in wind still potential for increase. Hydropower and biomass largely present and increasing. Potential to stop hydropower and biomass development for water saving, and to invest mainly in wind and natural gas. For hydropower the potential for water saving is, however, dependent on local conditions, but in dry climates the large evaporation can result in large water losses. - No use of seawater for cooling yet, and some coastline is available, meaning there is potential for water saving through relocation to the coast.
	Germany (DE)	- Only re-circulatory cooling yet used, and four once-through cooling systems. Thus, there is still large potential to save water by switching to a hybrid or dry cooling system. - Share of nuclear energy has decreased to almost zero. Solids and oils still largely present. Gas is largely present as a fossil fuel and increasing. Both for solar and wind still potential for increase. Hydropower and biomass largely present and increasing. Potential to stop biomass development for water saving, to decrease the share of nuclear energy and hydropower, and to invest mainly in solar energy, wind, and natural gas. - Almost no use of seawater for cooling yet, and coastline is available, meaning there is potential for water saving through relocation to the coast.

Region of the EU	Country	Where is the potential for water saving?
	France (FR)	- Mainly use of re-circulatory cooling, but also once-through cooling systems present. Thus, there is still large potential to save water by switching to a hybrid or dry cooling system, or even for some systems to switch to re-circulatory cooling. - Nuclear energy largely present and stable. Gas is largely present as a fossil fuel but decreasing. Both for solar and wind still potential for increase. Hydropower and biomass largely present and increasing for biomass. Potential to stop biomass development for water saving, to decrease the share of nuclear energy and hydropower, and to invest mainly in solar energy, wind, and natural gas. For hydropower the potential for water saving is, however, dependent on local conditions, but in dry climates the large evaporation can result in large water losses. - 1/4 of cooling done by salt water, and relatively large coastline, so there is still potential for cooling through relocation to the coast.
	Luxembourg (LU)	- Only re-circulatory cooling yet used, still potential to save water by switching to a hybrid or dry cooling system. - No nuclear energy, and gas is largely present as a fossil fuel. Share of solids and oil are little to none. Mainly potential for increase for wind. Hydropower and biomass largely present, but stable or slightly increasing. Potential to save water by further investing in solar, wind and natural gas. - No option to use seawater for cooling due to lack of coastline.
	Netherlands (NL)	- Mainly use of re-circulatory cooling systems (50%), however air cooling is for two power plants present. Once-through cooling still accounts for one third of the share. Potential to save water by switching to a closed-cooling system, but even better would be to switch to a hybrid or dry cooling system. - Nuclear energy largely present and stable. Gas is largely present as a fossil fuel and increasing. Little potential for increase in solar and wind. Biomass largely present and increasing for biomass. Potential to stop biomass development for water saving, to decrease the share of nuclear energy, and to further invest in natural gas. If possible, further invest in solar and wind energy. - 1/4 of cooling done by brackish water and only very small share by salt water. Coastline is available, so there is still potential for cooling through relocation to the coast.

ANNEX 4 (to Chapter 7) Measures for water saving in household activities

A. Bathroom activities

In summary, water-related bathroom activities encompass a wide range of personal hygiene, grooming, and health-related routines that require the use of water within a bathroom or restroom setting. These activities are crucial for maintaining cleanliness, well-being, and overall health. Some of them are handwashing, face washing, teeth brushing, showering, toilet flushing and pet care. Bathroom activities are the most water intensive activities within a household.

Showering

(Water Footprint Calculator,2023; Waterwise, 2023; NIdirect, 2023; FDWD, 2023; Water Matters - HCMR, 2023a; DYEABA, 2020; EPA, 2013; Todt et al., 2019; PSCI, 2020)

- **Low-Flow Showerheads**: Low-flow showerheads are a simple and effective way to reduce water consumption during showers. These fixtures restrict the flow of water while maintaining adequate pressure, thus conserving water without compromising comfort.
- **Shower Timers**: Installing shower timers or using smartphone apps that monitor shower duration can help individuals become more aware of their water use. This simple tool encourages shorter showers, contributing to water savings.
- **Smart Shower Systems**: Advanced technologies like smart shower systems equipped with sensors and controls can adjust water flow based on real-time needs, reducing water wastage and enhancing user experience.
- **Greywater Recycling**: Capturing and recycling greywater from showers for non-potable uses, such as toilet flushing or landscape irrigation, is an innovative way to save water. Special systems can filter and treat greywater, making it safe for reuse.

Flushing toilets

(Water Footprint Calculator,2023; Waterwise, 2023; NIdirect, 2023; FDWD, 2023; Water Matters - HCMR, 2023a; DYEABA, 2020; EPA, 2013; Todt et al., 2019; PSCI, 2020)

- **Low-Flush Toilets**: also known as low-flow toilets, are designed to use significantly less water per flush compared to traditional models. Typically, they consume around 6 litres per flush, as opposed to the 13-26 litres used by older toilets. These water-efficient models help conserve water without compromising flushing performance.
- **Dual-Flush Toilets**: Dual-flush toilets provide users with two flushing options: a low-volume flush for liquid waste and a higher-volume flush for solid waste. This adaptable design allows users to select the appropriate flush, further reducing water consumption. These toilets are especially effective in conserving water, as they encourage conscious water use.
- **Toilet Tank Modifications**: In existing toilets, water savings can be achieved through simple modifications. Placing a displacement device, such as a plastic bottle filled with water or a brick, inside the toilet tank reduces the amount of water for each flush. This affordable and 'do it yourself' solution instantly lowers water usage per flush.

B. Laundry and other washing activities

Daily routines include various washing activities, such as laundry, dishwashing, and car cleaning. Laundry and other washing activities can use a lot of water, especially if you have a large family or do laundry frequently. There are a number of ways to save water while still getting clothes and other items clean.

Presented below are some of the most effective water-saving measures in laundry and other washing activities, by which individuals and communities can make a significant impact on water conservation.

Laundry and washing machines

(Water Footprint Calculator,2023; Waterwise, 2023; NIdirect, 2023; FDWD, 2023; Water Matters - HCMR, 2023a; DYEABA, 2020; EC, 2023)

- **Run full loads.** The most efficient way to wash clothes is to run full loads. This is because washing machines use the same amount of water for a small load as they do for a large load.
- **Choose the right water level.** Most washing machines have a variety of water level settings. Choose the setting that is appropriate for the size of your load.
- **Use a high-efficiency detergent.** High-efficiency detergents are designed to work in cold water and produce fewer suds, which means that less water is needed to rinse the clothes.
- **Skip the extra rinse cycle**. Most washing machines have an extra rinse cycle, but it is not necessary unless you have very dirty clothes.
- **Install modern and highly efficient washing machines**.
- **Use cold water whenever possible.** Heating water uses a lot of electricity, which is produced also using water. Therefore, using cold water can save both water and money.

C. Kitchen activities

The kitchen is a central hub of daily activities in any household, and it's also a place where water usage can be optimised. Whether it's for drinking, cooking, or dishwashing, there are several water-saving measures that can be easily incorporated into kitchen routine.

Drinking

(Water Footprint Calculator,2023; Waterwise, 2023; FDWD, 2023; Water Matters - HCMR, 2023b; DYEABA, 2020)

- **Use a jug with a lid:** When storing drinking water in the fridge, a jug with a lid can be used to prevent water from evaporating.
- **Fill a water bottle from the tap instead of running the water until it is cold**. This can save up to 15 litres of water per minute.
- **Install a water filter**: Rather than relying on bottled water, due to tap water quality concerns, the installation of a water filter system ensures clean and safe drinking water directly from the tap. This improves the taste of tap water, reduces the need for plastic bottles and saves water lost during bottled water production.

Cooking

(Water Footprint Calculator,2023; Waterwise, 2023; FDWD, 2023; Water Matters - HCMR, 2023b; DYEABA, 2020)

- **Wash fruits and vegetables in a bowl or sink filled with water instead of running water**. This can save up to 30 litres of water per minute.
- **Use minimal water for boiling**: When boiling vegetables or pasta, use just enough water to cover them. This reduces water consumption and ensures that fewer nutrients are lost through excess water disposal.
- **Steam instead of boiling**: Steaming food is an efficient cooking method that uses minimal water while retaining nutrients. Invest in a steamer or use a simple steaming basket to save water in your cooking process.

Washing in the sink

(Water Footprint Calculator,2023; Waterwise, 2023; FDWD, 2023; Water Matters - HCMR, 2023b; DYEABA, 2020)

- **Plug the sink:** When washing dishes, plug the sink to fill it with soapy water instead of letting the tap run continuously. This way, multiple items can be washed using the same basin of water and saving a significant amount of water.
- **Use a basin:** Place a basin or dishpan in the sink to collect water while washing vegetables or doing light cleaning. Collected water can be reused later for tasks like watering plants or cleaning outdoor equipment.
- **Smart handwashing**: When washing hands, avoid letting the tap run while lathering with soap. Wetting hands, turning off the tap, lathering with soap, and then turning the tap back on to rinse can save a substantial amount of water.

D. Other household uses

House cleaning

(Water Matters - HCMR, 2023c; FDWD, 2023; SES, 2023; ECJ, 2011; CS, 2023)

- **Sweep, don't hose**: A broom or a vacuum cleaner can be used for indoor and outdoor cleaning instead of hosing down driveways and sidewalks. This prevents unnecessary water waste.
- **Use a pressure washer sparingly**: Pressure washers are efficient for cleaning, but they can consume a significant amount of water. Their use can be limited to heavy-duty tasks only.

House gardening

(Water Footprint Calculator,2023; Waterwise, 2023; FDWD, 2023; Water Matters - HCMR, 2023c; DYEABA, 2020; NRDC, 2016; UIUC, 2023; RHS, 2023; MWMO, 2023)

- **Choose drought-tolerant plants for the household lawn and garden.**
- **Mulch**: Apply a layer of mulch around plants and in garden beds to retain soil moisture and reduce the irrigation frequency.
- **Drip irrigation**: Install a drip irrigation system to deliver water directly to plant roots, minimizing surface evaporation and runoff.
- **Water at the right time**: Watering early in the morning or late in the evening, when temperatures are cooler, reduces evaporation losses.
- **Replace tap water with rainwater for irrigation**: Set up rain tanks to collect rainwater for garden and lawn irrigation, reducing the need for tap water.

Pool Maintenance

(Water Footprint Calculator,2023; Waterwise, 2023; FDWD, 2023; Water Matters - HCMR, 2023c; DYEABA, 2020; NRDC, 2016)

- **Use a pool cover**: Keep the pool covered, when not in use, to reduce evaporation and limit debris, which can necessitate draining and refilling.
- **Regular maintenance**: Maintain proper chemical balance and filtration in the pool to extend the time between pool water refills.
- **Consider a saltwater pool:** Saltwater pools require fewer water refills than traditional pools because they recycle the water through a chlorine generator.

ANNEX 5 (to Chapter 7) Measures for water saving in non-household activities served by the public water supply

- **Offices, businesses, commercial sites**: In general, similar measures can be applied to those mentioned for household uses (Annex 4).
- **Tourism facilities**: In general, similar measures can be applied to those mentioned for tourism (Chapter 8).
- **Parks and other green spaces**: In general, similar measures can be applied to those mentioned for house gardening (see section 8.4.2 on Leisure infrastructure).
- **Manufacturing and industrial facilities**: In general, similar measures can be applied to those mentioned for the manufacturing industry (Chapter 6).
- **Agricultural holdings**: In general, similar measures can be applied to those mentioned for agriculture (Chapter 4).
- **Public fountains and taps:** Sound design and maintenance is needed to avoid leakages.
- **Street cleaning**: In areas with minimal dust generation, the use of brooms or dry sweepers is encouraged, as they do not rely on water. In other cases, mechanical sweepers and vacuum trucks can be employed to collect debris avoiding excess water use. Regular preventive maintenance of street cleaning equipment ensures their efficient operation, reducing water use. Adopting a well-structured cleaning schedule that considers traffic levels (e.g., off-peak hours) and environmental conditions (e.g., dry weather) can help avoid excess water use. The application of dust suppressants like calcium chloride, magnesium chloride, or vegetable oil on dusty roads aids in dust control, minimizing the need for constant wetting (EPA NPDES,2021, MPCA, 2023)
- **Urban firefighting**: Less water can be used, compared to conventional firefighting, where water is used in conjunction with environmentally friendly fire retarders and foam products. Urban rainwater harvesting can replace other freshwater sources (Page et al., 2023; FRIC, 2020; Chemguard, 2005; Martins Vaz et al., 2023).

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