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Use of Freshwater Resources in Europe 2002–2014

An assessment based on water quantity accounts

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List of Acronyms

CIS	Common Implementation Strategy
CSI	Core Set of Indicators (EEA's indicators system)
DG ENV	Directorate-General for Environment (European Commission)
ECA&D	European Climate Assessment and Dataset
ECRINS	European Catchments and Rivers Network System
EEA	European Environment Agency
E-OBS	Daily gridded observational dataset under the ENSEMBLES project
ETC/ICM	European Topic Centre on Inland, Coastal and Marine Waters
EU	European Union
FRBD	Functional River Basin District (ECRINS spatial reference scale)
JRC	Joint Research Centre
LISFLOOD	GIS based distributed model for river basin scale water balance & flood simulation developed by JRC
NACE	Nomenclature Générale des Activités Économiques dans les Communautés Européennes (EU classification system)
NUTS	Nomenclature of Territorial Units for Statistics (Eurostat's geocode standard)
Q1–Q4	The four quarters of the calendar year
RBD	River Basin District (Water Framework Directive)
SB	Sub-basin (ECRINS spatial reference scale)
SEEA	UN System of Environmental Economic Accounting
SEEA-CF	UN System of Environmental Economic Accounting – Central Framework
SEEA-WUN	System of Environmental Economic Accounting – Water
SoE	State of Environment
SNA	UN System of National Accounts
TWG	Technical working group
UN	United Nations
UWWTP	Urban waste water treatment plant
WEI+	Water Exploitation Index (plus)
WISE 3	Water Information System of Europe – Water quantity
WFD	Water Framework Directive
WG	Working Group

Executive summary

Water quantity accounting is one of the most useful tools in assessing and informing the policy implementation on the state of renewable water resources, further on water scarcity and resource efficiency. The United Nations System of Environmental Economic Accounting (United Nations, 2012) and the UN SEEA Central Framework (United Nations, 2014) provide guidance on how to implement flow and assets accounts for water resources among other types of resources. The European water quantity accounting is implemented by the European Environment Agency (EEA) based on the conceptual framework of the environmental-economic accounting of the United Nations. This can only happen by means of using organized databases. These databases are mainly updated either with reported or modelled data from EU Member States, EEA member countries and from European Institutions; EEA (WISE – 3), Eurostat, Joint Research Centre (LISFLOOD data), European Climate Assessment and Dataset (ECA & D – E-OBS, climatic data).

The hydro-climatic assessments (EEA, 2014e, 2016a) indicate that precipitation particularly in southern Europe for summer months is decreasing and the temperature across Europe and notably in southern Europe is increasing. Similarly, long-term trends in streamflow on a seasonal scale, has shown a decrease in summer and an increase in winter. River flow on an annual scale is also projected to decrease in southern and south-eastern Europe and increase in northern and north-eastern Europe. The snow cover extent in the Northern Hemisphere has declined significantly over the past 90 years, with most of the reductions occurring since 1980. Snow cover extent in the Northern Hemisphere has decreased by 7% on average in March and April and by 53% in June over the period 1967–2012.

All these changes in hydro-climatic conditions have a number of impacts on renewable water resources particularly on the volume of water, which may be exploited for human use. In turn, change in renewable freshwater resources per capita from 1962 to 2014 particularly in Western and Southern Europe has decreased by around 24%. No significant change in renewable water resources per capita has been identified for Eastern parts of Europe during the same time period. This overview has emerged, most likely due to climate change (EEA, 2014e) on one hand particularly for southern Europe, but it is also related to population change in Europe but particularly in Eastern Europe. A similar trend has also been observed on a global scale. According to the World Bank assessment (World Bank, 2016) renewable freshwater resources have substantially decreased on a global scale from 13,200 m^3/year/capita in 1962 to 5,920 m^3/year/capita in 2014.

Eventually, to reduce the impacts of declining water availability particularly in summer months, two major measures are widely implemented across Europe; constructing more dams and reservoirs to store more water for summer months and to use increasingly more water from groundwater resources. Additionally, the use of desalinated water and water reuse are also nowadays increasingly implemented in the Mediterranean countries. Groundwater and rivers meet 83% of the total water demand of Europe. While the first implementation is causing a substantial diversion from the natural hydrological regime (hydro morphological pressures and modifications) in rivers, the second has also long-term impacts on water quality and water availability.

It should be noted that water abstraction across Europe has decreased by about 7% in 2014 compared to the level of water abstractions in 2002. That is a good achievement. However, measures particularly in southerly and easterly located countries have to be put effectively in place to improve the efficiency of water use.

About 140 km^3 of water is annually abstracted to meet the water demand for socio-economic activities such as for households, agriculture, industry, mining and quarrying, as well as, energy production. However, all the water abstracted is not consumed. After abstraction, water is used for different purposes. For instance, water used for a shower is returned back to the environment via urban waste water treatment plants. About 78% of water abstracted is later returned back to the environment. In other words, 22% of water is consumed for different socio-economic activities in Europe. However, regional and seasonal differences in water abstraction and use are highly variable. For instance, during the winter around 15% of total water abstraction is consumptive while this ratio increases up to 29% in summer. In general, agricultural and household activities increase water use during spring and summer.

Still there is a need to improve water use efficiency in water irrigation particularly in southern Europe. There is a contradictory development in southern Europe in terms of the irrigated area and crop yield. There is a slight decoupling in Western and Eastern Europe between the irrigated areas and harvested agricultural production. Despite that, in southern Europe development with the irrigated area and crop yield has shown to be moving in the opposite direction. Harvested agricultural production has decreased in southern Europe, while the irrigated area for the same time period has increased.

In general, it should be concluded that Europe provides a sufficient amount of water for household activities, while resource efficiency remains a concern. For instance, high water use per capita in southern Europe is emerging from tourism on one hand, but on the other, decoupling between population and water use per capita is still a concern for a number of southern countries e.g. Greece, Cyprus, Croatia.

It should also be noted that due to increased tourism arrivals, small Mediterranean islands and some of the metropoles are facing seasonal water scarcity conditions i.e. the Canary Islands, Mallorca, Thames Basin (London) etc. However, some countries have already achieved decoupling between the number of tourists and water use per capita (based on household activities and the service sector). For instance, Malta, Spain, France are those examples for the decoupling of water use from the number of tourists.

Despite the fact that cooling processes are causing a negligible amount of water loss to evaporation, water abstraction for cooling is high. Nuclear and combustion plants demand increased volumes of water, 62% of which is abstracted only from rivers. This has impacts on the natural hydrological regime of rivers on the one hand, but on the other hand it is increasing the water temperature compared to natural conditions. Between 1990 and 2014, electricity production by hydropower has increased by 39%. Hydropower is not taken as consumptive water use, and thus water abstraction for hydropower is excluded from the water accounts. However, the environmental impacts of dams remain a subject for integrated assessment.

Water is essentially either a raw material or process facilitator in Europe’s industry. About 66% of total water abstraction for manufacturing goes for cooling. Despite a 10 % decrease in water abstraction having occurred for cooling in the manufacturing industry, Eastern Europe has shown development in the opposite direction. Between 2005 and 2012, Eastern Europe abstracted 14% or more water compared to the level of 2005 with a linear correlation with the production value.

Water abstraction for mining and quarrying has continued (2007–2010) to create increasing pressure on groundwater resources. However, water abstraction has substantially decreased by 45% compared to the level of 1991. In Eastern Europe, the water abstraction trend remains more or less constant compared to that of western or southern Europe, even an increase in some countries like Latvia.

1 Introduction

1.1 Building block of the EEA water accounts

The European Topic Centre on Inland, Coastal and Marine Waters published the first report on water accounts and regionalized WEI+ in March 2016 (ETC/ICM, 2016). This report is the updated version of that report by means of new data involvement. The current update covers spatial and temporal expansion of the European water quantity accounts with special focus on water use by economic sectors. The spatial cover of the European water quantity accounts expands to all EEA Member and Cooperating countries, while temporal coverage has been expanded from 2002 up to 2014. However, it should be noted that this report is a building block of the EEA water accounts, which was started longer than a decade ago and resulted with different publications (EEA, 2013b, 2012e, 2010, 2009; Estrela, et al., 2001) and many other types of products e.g. graphs, leaflets etc.

In fact, this report should be regarded as a supporting document to the EEA's CSI 018 "Use of freshwater resources" indicator web page, and discusses in more detail the status of renewable water resources, water abstractions by environmental assets, water use by economic sectors.
The report has been organized into six chapters. In Chapter 1, water scarcity is explained in terms of water availability versus water demand, and how water assets (quantitative) accounts are used to assess water scarcity under current EU policies and programs.

In Chapter 2, the EEA's water scarcity indicator CSI 018 (WEI+) results are presented at sub-basin and river basin district scales, based on the latest updates up to 2014. Additionally, water abstraction and use by economic sectors are described in seasonal resolution to emphasize the variability of water uses, mainly for agricultural and water collection treatment and supply sectors.

In Chapter 3, renewable water resources parameters such as river flows, precipitation, actual evapotranspiration etc. are assessed while changes in trends and the development of artificial storage were discussed.

In Chapter 4 the water abstractions from freshwater resources is discussed under the prism of water abstractions either from surface or groundwater bodies, while a specific analysis was conducted at country scale.

Chapter 5 presents the results of the assessment on water use by all economic sectors namely; agriculture (irrigation), water collection treatment and supply (households and tourism), water used by energy sector, construction and manufacturing and the mining and quarrying industries.

Concluding, Chapter 6 provides the general outcomes of the assessment as well as future works that will allow us to expand the time series of water accounts in the future, while increasing their integration with other environmental assessments in the water quantity area.

1.2 Policy context

The 7th Environmental Action Programme[1] sets three key objectives; protection and enhancing natural capital, promoting resource efficiency and safeguarding citizens from environment-related pressures. In the water quantity context, these key objectives are directly relevant to inform the policy makers on the state of physical water accounting (water quantity) and to assess the use of renewable water resources (volume and hydrological cycle) across Europe. Water is an important component of environmental

[1] Decision No 1386/2013/EU of the European Parliament and of the Council on a General Union Environment Action Programme to 2020 'Living well, within the limits of our planet'

assets accounting as commodity. Water is also used as a facilitator in production processes by other economic sectors. Thus, it has a strong link with policy the implementation of resource efficiency.

Protecting, conserving and enhancing the Union's natural capital

Water is one of the key components of natural capital accounting. In the context of water quantity, environmental accounting relates to the volume of renewable water resources (assets accounts) and the hydrological regime of surface and groundwater (condition accounts). The hydrological regime may be diverted from its natural condition either by water abstraction or by hydraulic infrastructures developed for water management and transport. Hydraulic infrastructures (dams, weirs, canals etc.) mainly alter the hydro-morphology of surface waters (rivers and lakes) which are known as hydro-morphological pressures within the Water Framework Directive.

Resource-efficiency, green and competitive low-carbon economy in Europe

The 7th EAP encourages some certain sectors i.e. agriculture and energy to prioritize resource-efficient use of water via technological innovations and business models. In addition, reducing the leakages in the water distribution system for improving the efficiency by market mechanism are also among the proposals set by the programme.

Safeguarding citizens from environment-related pressures and risks to health and wellbeing

Water scarcity is identified as one of the environment-related pressures creating risk to well-being. Indeed, water scarcity conditions would not only have an impact on public health but also would cause a drastic recession in the economy, as water is used as a raw material and process facilitator in different economic sectors.

The 7th EAP set objectives for reducing the pressures of water abstraction over renewable water resources, but also encourages resource efficiency to maintain the level of wellbeing of the society. In addition to that, floods and droughts are also linked with changes to the hydrological cycle and land uses which have impacts on human health and economic activities. The EAP suggests to the Member States that action should be taken to ensure that citizens have access to clean water and that water abstractions are limited and adjusted to the available renewable water resources, by 2020, with a view to maintaining, achieving or enhancing good water (quantitative and chemical) status in accordance with the Water Framework Directive.

Other actions and policy instruments include the "Resource Efficient Roadmap" and the action plan for the "Circular Economy". The Resource Efficiency Roadmap[2] provides the framework of proposed actions and policy instruments to be implemented in order to overcome the barriers in the economic and societal transformation. These actions are promoting sustainable consumption and production of goods and services, efficient re-use of waste, supporting research and innovation etc. Water is a key component in the resource efficiency agenda particularly due to its crucial involvement in the agriculture, tourism, energy and industrial sectors under the prism of changing and shifting patterns due to climate change. Both dimensions of quality and quantity have been co-assessed by the Blueprint to safeguard Europe's Water Resources[3] and Water Framework Directive[4], while the goal is to sustain water abstraction below 20% of renewable water resources.

The Circular Economy Strategy[5] is a promising policy instrument which is promoted at the EU and international level in order to support the transition of economy in the EU. Circular economy is also aligned with the UN 2030 Agenda for Sustainable Development and the G7 Alliance on Resource

[2] The Roadmap to a Resource Efficient Europe (COM(2011) 571) outlines how Europe's economy will be transformed into a sustainable one by 2050, by increasing productivity and decoupling resource use from economic growth.

[3] The Blueprint to Safeguard Europe's Water resources

[4] EU Water Framework Directive

[5] Circular Economy Strategy

Efficiency. The main target of the initiative is to “close the loop” and promote the industrial symbiosis which allows waste or by-products of one industry to become a useful resource for another. It foresees to direct and enhance the production and consumption schemes in a variety of economic activities that cover waste management, water re-use, plastics, electronics, food waste, construction, biomass production etc. Several tools will implement the Circular Economy in the years to come while they are also necessary to assess the progress. Water as a resource plays a fundamental role in the environment – life – economy connections are expected to be used in a more sustainable manner, while recycled or re-used water standards are going to be established in the coming years for use in the agricultural and industrial sectors.

Water scarcity is one of the major issues, which Europe has been encountering in a water quantity context particularly in southern parts and around metropolises. In 2012, water directors agreed to regularly carry out an indicator based assessment of water scarcity conditions and droughts (Faergemann, 2012). Such an assessment requires the understanding of relations between water availability in the environment and water use by the economic sectors. The use of freshwater resources (CSI 018) known also as Water Exploitation Index Plus (WEI+) is one of the core set of indicators regularly updated by the EEA with the purpose of informing policy makers on the water scarcity conditions across Europe. The WEI+ compares water use with the renewable water resources in a given territory and time. Initially the WEI+ was calculated as water abstraction compared to long term annual average of the water availability mainly at the national scale. However, this approach had a limited capacity to capture regional and seasonal differences and variations in water scarcity conditions, hence it had been argued by the Working group on water scarcity and drought (Faergemann, 2012) to be replaced with the “Regionalized Water Exploitation Index” – WEI+.

1.3 Methodology for water quantity accounting

Environmental accounting is a method, currently implemented globally by international institutions supported by the United Nations and other organizations’ initiatives, with the ultimate purpose of monitoring, assessing, protecting and enhancing the environmental assets and their natural resources. On a European scale, water accounting is being implemented by the European Environment Agency (EEA) under the United Nations System of Environmental and Economic Accounting for Water (SEEA-W) conceptual framework (United Nations, 2012) by using an organized system of databases. These databases are mainly updated either with reported or modelled data from European Institutions; EEA (WISE – 3), Eurostat, Joint Research Centre surface runoff from the LISFLOOD model (Burek, et al., 2013) and phenology data (Ivits, et al., 2013; Cherlet, et al., 2013), European Climate Assessment and Dataset, ECA & D – E-OBS, climatic data (Haylock, et al., 2008).

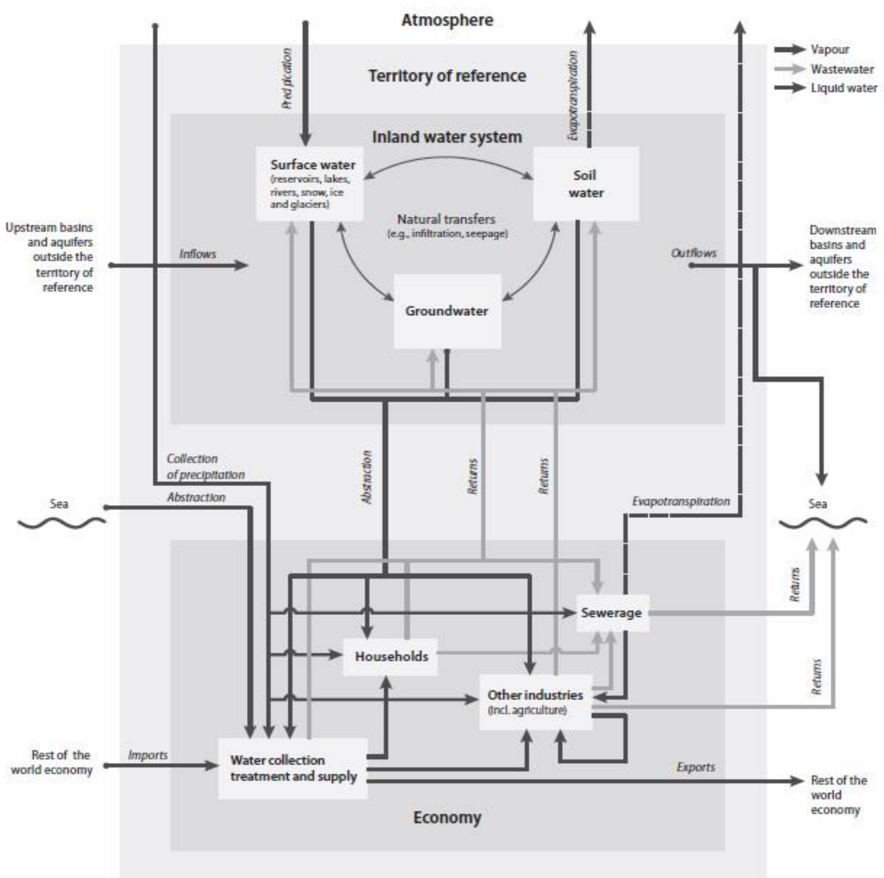
The core of this system is to quantify the stocks of natural resources (e.g. water, wood, energy etc.) used by the economy to produce value for the society and how the residuals of the economic and production cycles are returned back to the environment. Environmental accounting allows also the quantification of depletion of a natural resource both in quantitative and qualitative terms. This system is bringing together environmental and statistical information under a common framework of terminology, scales and time resolution, which allows better monitoring of the water systems and the use of their water assets (rivers, groundwater bodies, natural lakes and artificial reservoirs). The water accounting system could potentially be expanded in order to achieve better integration and support combined assessments in a broader environmental context. For the years to come, and with the significant improvements in data reporting that currently are taking place, water accounts could be a concrete foundation and component in the assessments of water – food – energy nexus. Additionally, water accounts can support current EU policies in the water area; Water Framework Directive, Europe 2020, 7th Environmental Action Programme, Circular Economy and Resource Efficiency Roadmap.

Environmental accounting is one of the useful tools in assessing and informing the policy implementation on the state of natural resources and further on resource efficiency. The United Nations System of

Environmental Economic Accounting (United Nations, 2012) and the UN SEE Central Framework (United Nations, 2014) provide guidance on how to implement flow and assets accounts for water resources among other types of resources. The EEA water quantity accounting is implemented based on the conceptual framework of the environmental-economic accounting of the United Nations. The conceptual framework of the UN SEEA-Water focuses on quantifying assets accounts and exchange of water resources between the environment and the economy (Figure 1.1).

Each of the processes in which water quantity (asset) accounts are elaborated, as shown in Figure 1.1, are analysed in two main components; inland water systems and the economy that makes use of the latter. The main transactions and interconnections between these two systems have their own internal structure, following natural processes, such as the hydrological cycle and the economic system that exploits the water resources (stocks and renewable). The water accounting system, takes into account all the above mentioned processes, mechanisms and particularities applied in each of the unique conditions which are defining the hydrologic regions across EEA areas. The stepwise approach that is followed by SEEA-W is; define natural input and the stock of the water assets, estimate the use of water by the economy in order to support production processes and quantify the residuals that return back from the economy. The SEEA-W accounts the variation of water stocks (broken down into assets of surface, ground and soil waters) occurring either in the same or between two neighbouring areas (upstream-downstream relationship) due to natural conditions or anthropogenic needs by the economy. The main interaction processes between the water system and the economy are those of water abstractions and returns. The latter create the water flows and by consequence the variations in natural or artificial water stocks. External exchanges of water between the water system and/or the economy have also to been taken into account (e.g. imports, exports, and outflow to the sea).

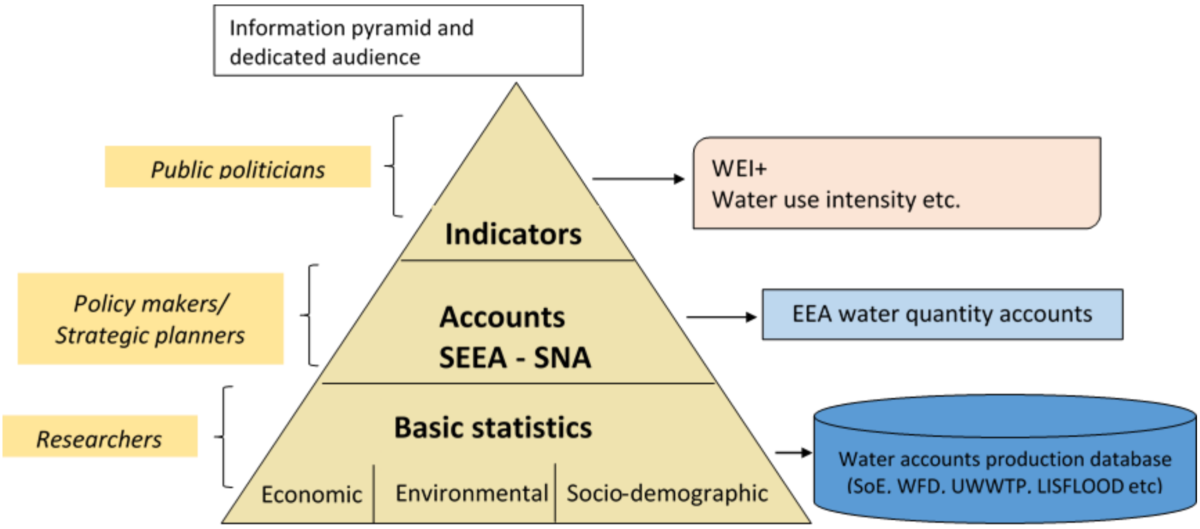
Figure 1.1 Flows between the economy and the environment



Source: From System of Environmental-Economic Accounting for Water published by the United Nations Department of Economic Affairs, with print ISBN 978-92-1-161554-8, ©(2012) United Nations. Reprinted with the permission of the United Nations.

Despite that the UN SEEA-Water framework is providing a concrete and harmonized conceptual approach to estimate/calculate the water assets accounts, there is still capacity for further improvements at the operational level. For instance, opening and closing stocks are difficult to quantify due to a lack of detailed datasets, monitoring human activities and/or natural processes associated with water assets. Hence, it was difficult to quantify the opening and closing stocks of the European water quantity accounts. However, information derived from water quantity accounting is very useful for assessing availability of renewable water resources and water use efficiency by economic sectors. The figure below illustrates the production chain, from data collection up to developing the WEI+ for assessing the water scarcity conditions in Europe (Figure 1.2).

Figure 1.2 Information pyramid from data to the implementation of WEI+



Source: Modified from Nordic Council of Ministers et al., 2013

In terms of data needs, the water accounting methods require a lot of data to be collected, analyzed and processed in such a way as to feed mostly the standardized physical supply and use tables. The system is also supported by analytical geospatial information systems data (delineation of the hydrologic regions and surface water bodies) as well as with socio-economic data collected or estimated by international and European institutions (FAO, OECD, Eurostat, EEA etc.). The time resolution of the input data varies depending on the parameters, but the minimum input that could be used after the elaboration of the water accounts tables is the monthly resolution. Further aggregations have also been used both in temporal and spatial parts of the water accounts

It should be noted that, despite the UN SEEA – Water being followed as a methodological guide while implementing the European water quantity accounting, the outputs are not presented with the same structure of the assets accounts and physical supply and use tables as suggested. The reasons are to keep the report from becoming too exhaustive and also limiting it to focus on renewable water resources and water scarcity assessments. Thus, the following chapters are aligned with the main components of water scarcity assessment i.e. assessing availability of renewable water resources, water use by economic sectors as well as WEI+ assessment across Europe.

The basic spatial units which are used in the water scarcity assessment are sub-basin (SB) and functional river basin district (FRBD) as defined by the Ecrins (EEA, 2012a), while the temporal resolution is monthly for computation and seasonal for assessing the results. As water scarcity assessment is dependent on large scale data, intensive data integration and assimilation have to be implemented before running the computation.

1.4 What does water scarcity mean?

Water scarcity refers to the imbalanced relation between renewable water resources and water demand. Water scarcity occurs when the demand for water by different socio-economic sectors exceeds the certain level of water availability (exploitable) in nature or in any other infrastructure (artificial storage). Therefore, water scarcity is generally regarded as the most relevant to the consequences of water management practices, rather than the availability of renewable water resources in the environment. Drought appears when the availability of renewable water resources could be decreased because of natural processes alterations e.g. declines in precipitation or increases in actual evapotranspiration due to temperature rises etc.

We assess water scarcity by implementing indicators. The results of indicators then can be classified from non-stress up to severe stress conditions referring to the level of water scarcity occurring in a certain area at a certain time.

In that context, WEI+ is the indicator applied for assessing the water scarcity conditions in a given area. This indicator shows how total water use exerts pressure on renewable water resources. The water scarcity assessment can be conducted either at the selected administrative units such as NUTS2, national scale or hydrological units. However, administrative boundaries, in fact, do not follow the physical principles of hydrology. For instance, a river would draw a border between two countries and the water is just shared by those respective countries. Thus, water scarcity assessment conducted according to administrative boundaries would involve more uncertainties than those of hydrological units such as river basins or catchments.

During a year, usually two different seasons appear in terms of water availability. Almost half a year can be assigned as wet while the second half could be dry. Similarly, temperature is substantially higher during summer and lower in winter which would have an impact on actual evapotranspiration. Mean annual values of precipitation and actual evapotranspiration usually shadow the seasonal variations. Thus, you can't see the impact of low precipitation and the high temperatures of summer conditions over renewable water resources. Hence, it was proposed, by the technical working group (TWG) introduced under the 2010–2012 CIS period, that water scarcity assessment assessments have to be conducted on a seasonal scale instead of annually (Faergemann, 2012). By means of which, it could be possible to capture seasonal variations in water scarcity conditions at local level across Europe.

Water scarcity can be assessed with two different approaches. The first approach is mainly taking water abstraction into account with its potential environmental impacts. The second approach is more linked with environmental accounting. Environmental accounting is looking for an input and output or for another term for stock changes. In the water quantity context, this corresponds to water use rather than water abstraction. As we know, water is withdrawn from mainly freshwater resources and supplied to society and economy. After its use, water is returned back to the environment with a certain level of deterioration in quality. The difference between water abstraction and return in quantitative terms, is defined as "water use". The TWG has proposed the second approach to be implemented in line with the environmental-economic accounting framework.

In order to easily define the differences between the first and the second approach, the Water Exploitation Index Plus therefore has been named as the "Regional Water Exploitation Index or WEI+. It has to be mentioned here that WEI+ also has the possibility of assessing the environmental impacts of water abstraction. Because if we look at the definition of water use implemented with the new WEI+, water abstraction is one of the two major variables involved in estimating water use.

There are no specific formal quantitative targets directly related to the WEI+. However, the Water Framework Directive (2000/60/EC) requires Member States to promote sustainable use of water resources based on long-term protection of available water resources and ensure a balance between abstraction and recharge of groundwater, with the aim of achieving good groundwater (quantitative and chemical) status by 2015.

On the other hand, having agreed thresholds of the WEI+ it is very important in assessing the level of water scarcity from low stress to severe stress areas. However, so far, there are no commonly agreed thresholds which can be applied in identifying the water scarcity level. Raskin (Raskin, et al., 1997) has suggested that water use to resource indicators above 20% designates water scarcity whereas a value higher than 40% indicates severe water scarcity. Nevertheless, no agreed threshold for the WEI+ is available, these thresholds suggested by Raskin are commonly used in scientific studies (Alcamo, et al., 2000). Besides, (Smakhtin, et al., 2005) suggests that a 60% withdrawal from the annual total runoff would cause environmental water stress. Since no formally agreed thresholds are available for assessing the water scarcity conditions across Europe, in the current assessment 20% threshold as proposed by (Raskin, et al., 1997) is applied to distinguish stress and non-stress areas while 40% is used only as the highest threshold for mapping purposes.

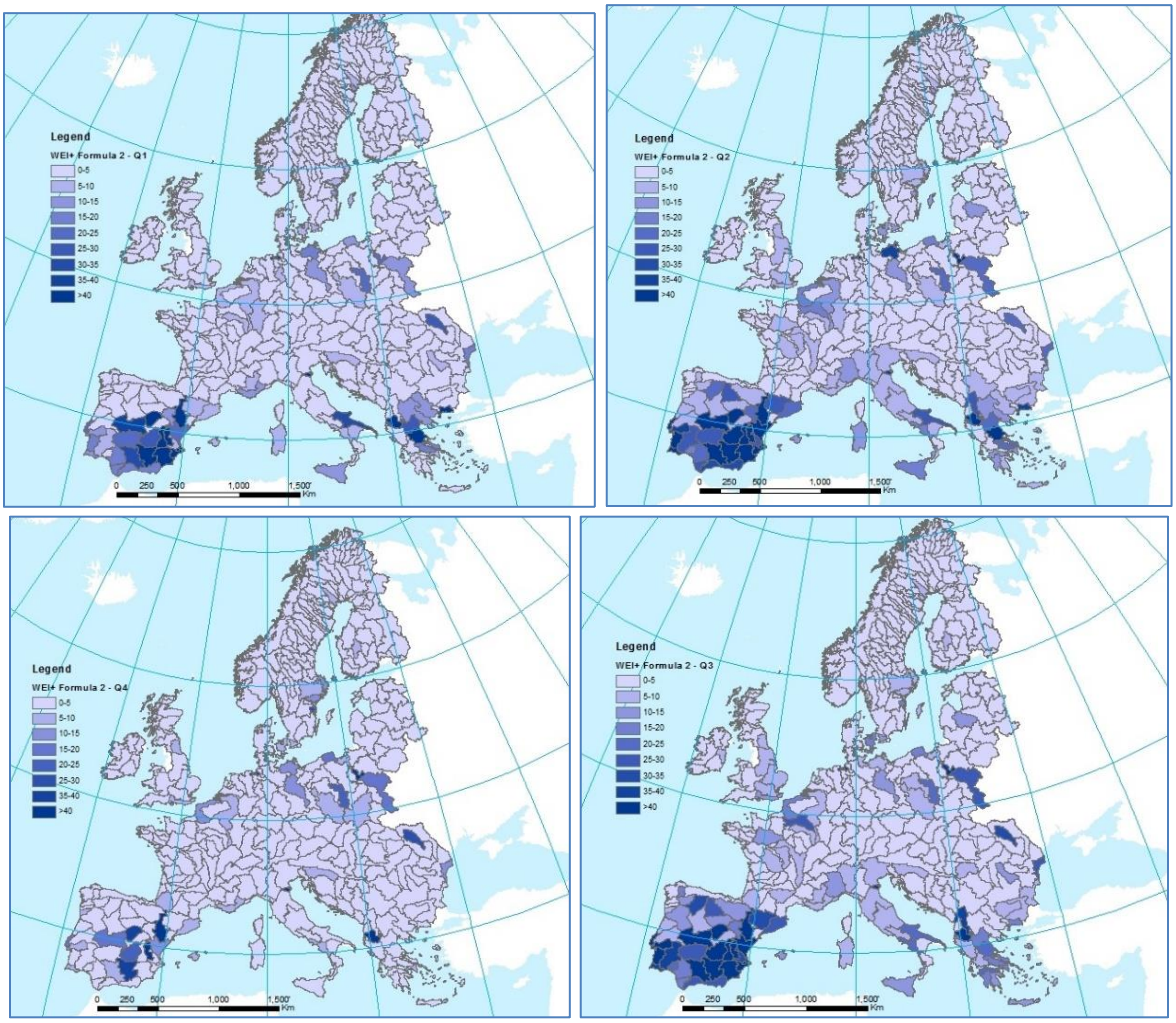
2 Water scarcity in Europe

Water scarcity is the lack of sufficient available water resources to meet water needs within a region; it involves water shortage, water stress or deficits, and water crisis. The relatively new concept of water stress[6] is the difficulty in obtaining freshwater resources for use during a period of time; it may also result in further depletion and deterioration of available water resources. Water shortages may be caused by climate change, increased pollution, and increased human demand and the overuse of water. There are two main types of water scarcity; physical water scarcity results from inadequate natural water resources to supply a region's demand, and economic water scarcity results from poor management of the sufficient available water resources.

If precipitation would be distributed evenly throughout the year across Europe, as well as if each European citizen would use the same amount of water, we most likely would come up with the conclusion that Europe is not experiencing water scarcity. According to the Falkenmark thresholds (Brown, and Matlock, 2011), if the total amount of renewable water resources is greater than 1,700 m^3/year/per capita, then there is no water stress condition, while 500 m^3/year/per capita refers to absolute scarcity. The annual total amount of renewable water resources across Europe is estimated at around 6,879 m^3/year/per capita. However, previous experiences have already shown that assessments of water scarcity conditions over the mean annual values of renewable water resources and water use generally hide the actual magnitude of water scarcity conditions across Europe. Despite this, on a European scale annual mean values do not point out water scarcity conditions in many locations in Europe, water scarcity is a fact that Europeans are faced with particularly in certain seasons like summer and also constantly in certain areas such as in southern Europe and in highly densely populated areas (Map 2.1 and Map 2.2).

[6] Water stress; Water stress occurs when the demand for water exceeds the available amount during a certain period or when poor quality restricts its use. Water stress causes deterioration of fresh water resources in terms of quantity (aquifer over-exploitation, dry rivers, etc.) and quality (eutrophication, organic matter pollution, saline intrusion, etc.)

Map 2.1 Seasonal WEI+, Year of reference 2014, sub-basin scale



Note: Q1: January, February, March, Q2: April, May, June, Q3: July, August, September, Q4: October, November, December

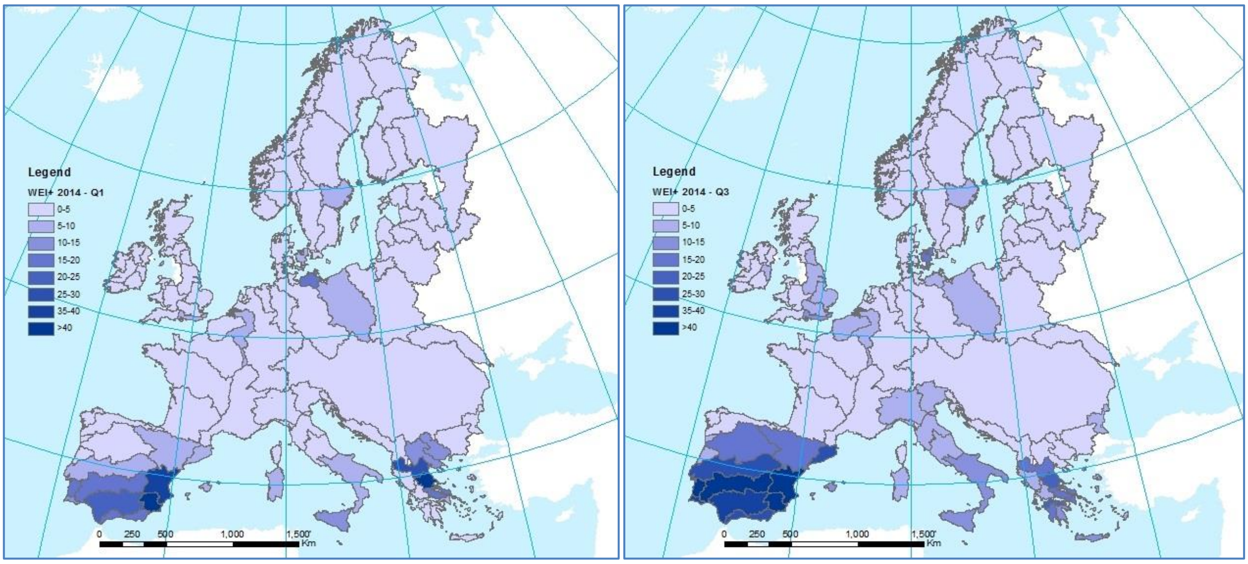
The spatial and temporal assessment of water scarcity across Europe has already shown that water scarcity is generally driven by climate conditions and population pressures. Around 86 million inhabitants have been living under water scarcity conditions (defined as WEI+ values greater than 20%) during the summer in 2014, which corresponds to 12.8% of the total population of Europe. But this information should not mislead the fact that water scarcity is only having an effect in the summer. In spring, 11.4% of European citizens and even in winter 6.6% of the total European population were living under water stress conditions across Europe (Table 2.1).

Table 2.1 Affected area and population by water scarcity conditions across Europe (2014)

Season	Population (%)	Area (%)
Winter	6.6%	6.7%
Spring	11.4%	11.5%
Summer	12.8%	11.0%
Autumn	3.0%	3.3%

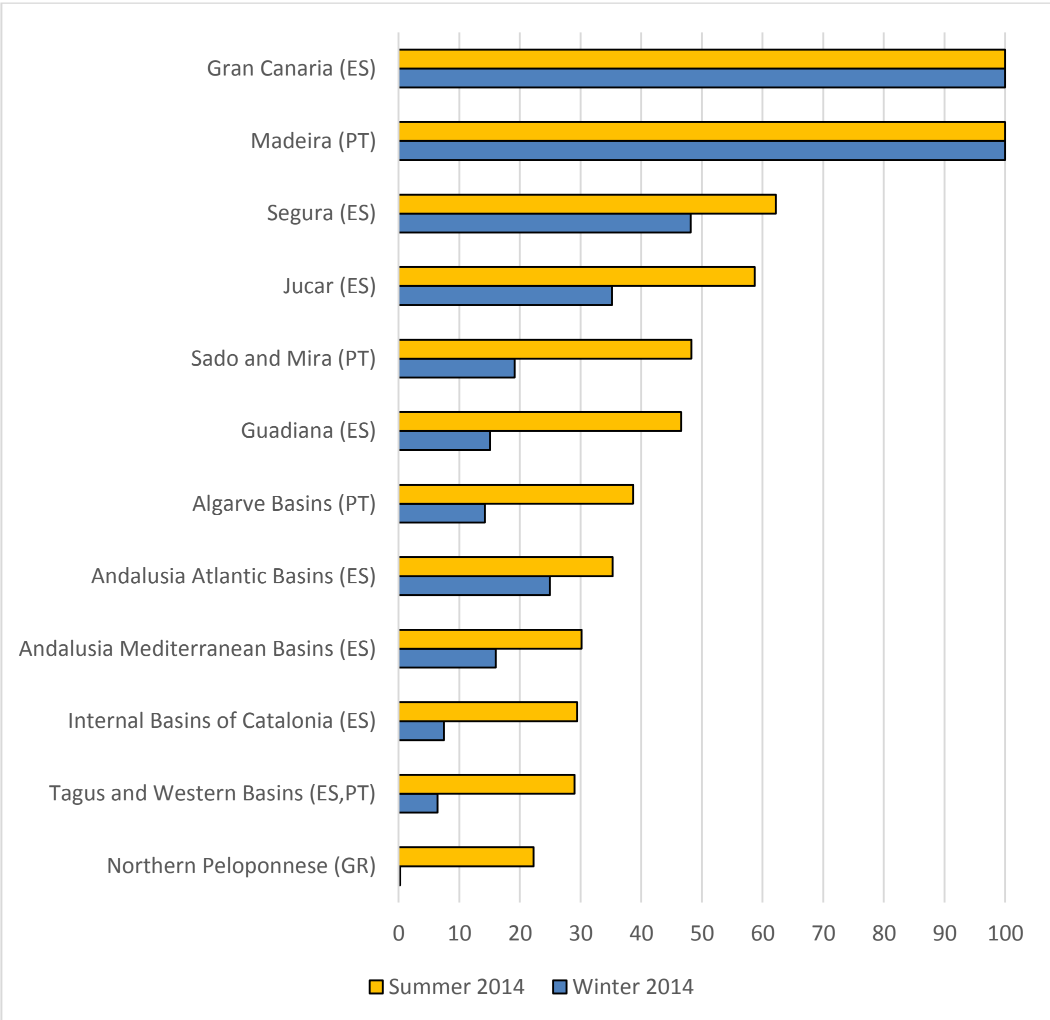
Scaling up the analysis of water scarcity to the River Basin Districts level indicates that 12 River Basin Districts are experiencing water stress with higher than 20% of WEI+ in 2014 as shown in the Map 2.2 and Figure 2.1.

Map 2.2 Seasonal WEI+, Year of reference 2014, Ecrins Functional River basin districts



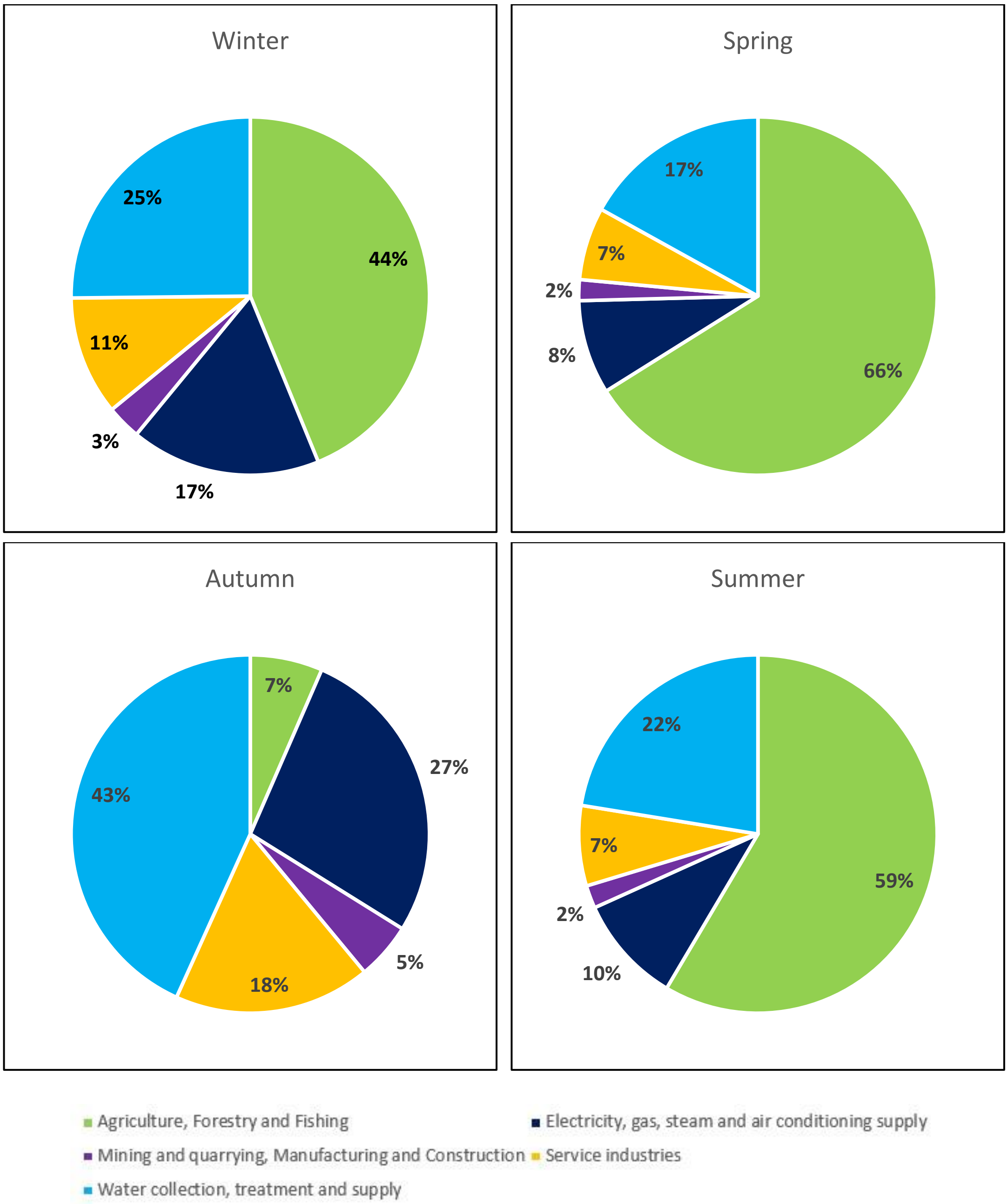
Note: Q1: January, February, March, Q2: April, May, June, Q3: July, August, September, Q4: October, November, December

Figure 2.1 FRBDs where average summer WEI+ (%) is greater than 20% for 2014



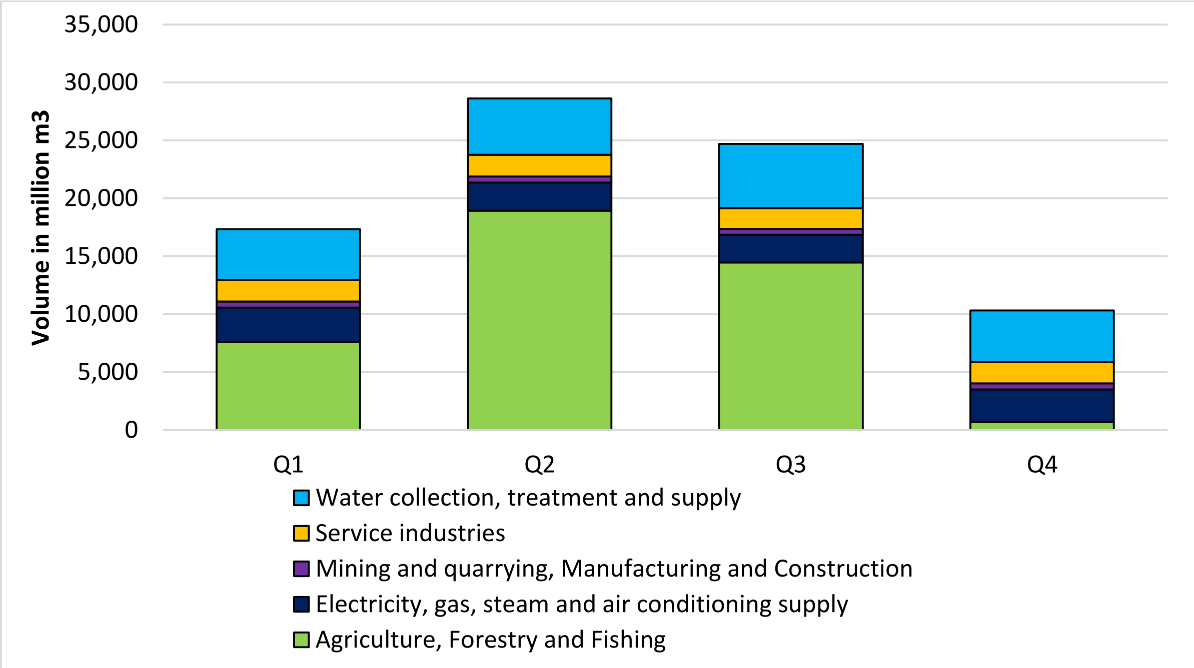
Analyses on water use by economic sectors have revealed that the agriculture and water collection, treatment and supply sectors continue to be the major pressure on renewable water resources compared to other sectors during 2014 (Figure 2.2).

Figure 2.2 Seasonal water use by economic sectors 2014



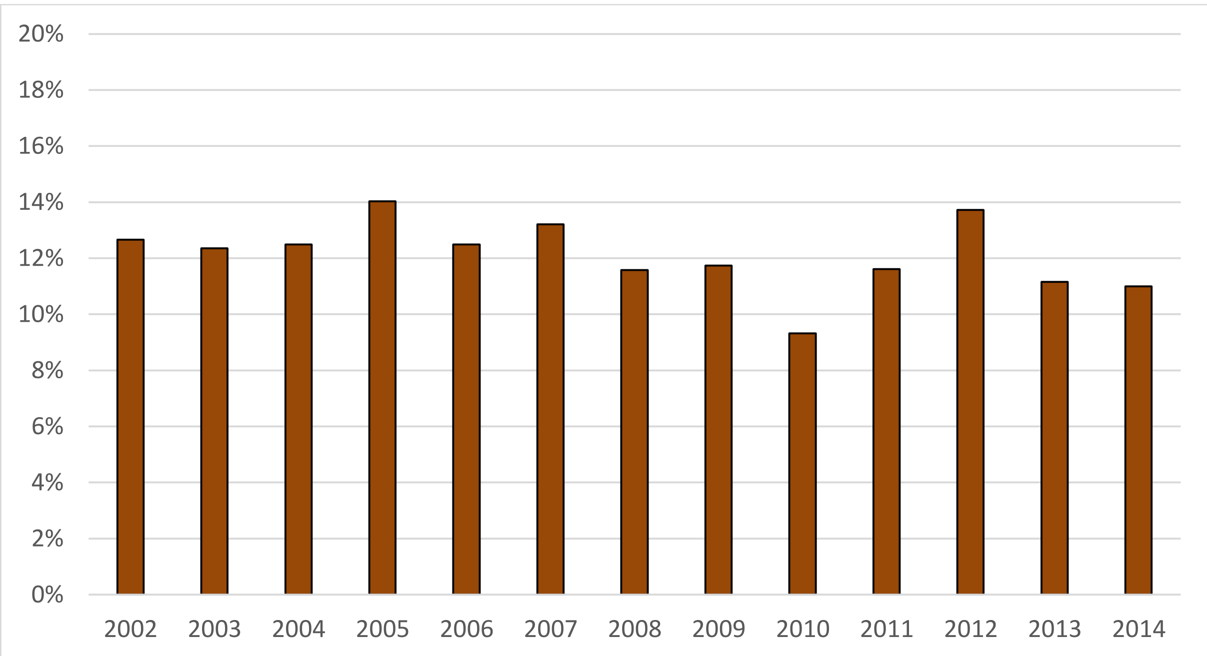
Particularly in spring and summer agriculture is a highly water demanding sector, while the energy sector keeps up its high share in autumn and winter (Figure 2.3).

Figure 2.3 Average seasonal water use (million m³) by sectors in Europe (2014)



The time series of WEI+ covers 13 years (2002–2014). The time length of this time series is considerably short for assessing water scarcity at a pan European level. Although, Europe was mostly affected by water stress conditions in the years 2005 and 2012 according to the current EEA WA database results (Figure 2.4).

Figure 2.4 Annual percentage of area (%) affected by water stress conditions (WEI+ >20%) in summer months (Q3) in Europe

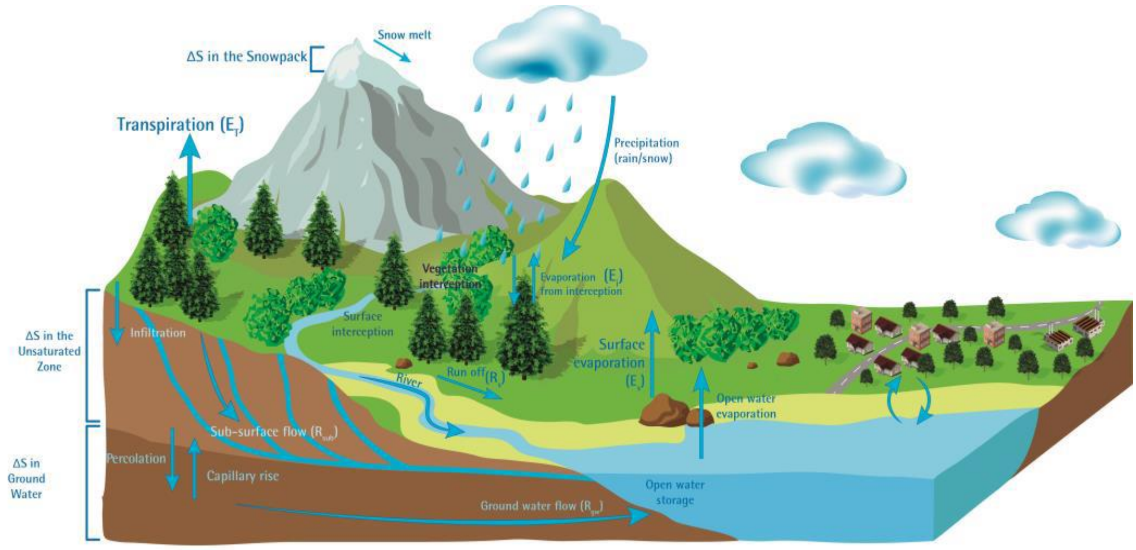


Eventually, it is likely the target set in the water scarcity roadmap as well as the key objectives of the 7th EAP in a water quantity context have not been achieved in Europe for the years 2002–2014. This overview provides many justifications in terms of renewable water resources and water use by different economic sectors. The following chapters outline drivers and pressures of water scarcity conditions across Europe.

3 Renewable water resources in Europe

Renewable freshwater water resources are generated from precipitation at the global scale (Figure 3.1). A portion of precipitation is returned back to atmosphere via evapotranspiration. The remaining precipitation is known as effective precipitation which defines the total renewable freshwater corresponding to the maximum theoretical yearly amount of water available for a given area (FAO 2016). On a local scale, renewable water resources can be estimated as the difference between precipitation, actual evapotranspiration and the change in water storage. External inflow which is one of the important variables of renewable water resources on a local scale is not included on a continental scale.

Figure 3.1 Key components of the hydrological cycle



Source: European Commission, 2015)

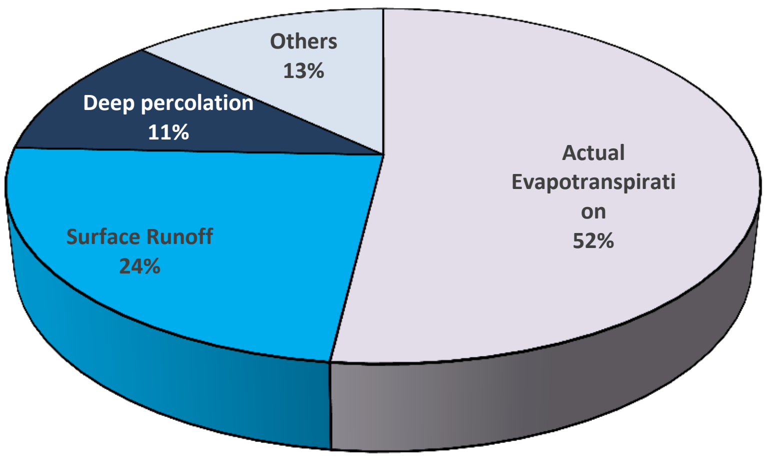
In terms of renewable water resources, water availability and exploitable water, they are often used interchangeably. Exploitable water is the volume of water feasible to store for economic and environmental purposes (FAO, 2003) while water availability is about the hydrological capacity of a water source (surface water or groundwater body) to sustain additional water demands after considering other current water uses and water conditions[7]. As for renewable water resources, effective precipitation (precipitation minus actual evapotranspiration) defines the global boundary of renewable water resources, while external inflow has to be factored in at the local scale. External inflow is the water coming in from upstream territories. In a European context, water storage in reservoirs is also included into the quantification of the renewable water resources (Faergemann, 2012).

Europe[8] receives around 4,000 km^3 of water from precipitation on an annual scale which corresponds to 4.1% of the precipitation received on a global scale (FAO, 2014). More than half of the precipitation (52%) is returned back to the atmosphere via evapotranspiration. About 13% of water either is used by ecosystems or contributes to soil-water balance. Around 11% of water goes into soil (deep percolation) and feeds groundwater aquifers. The remaining water (24%) feeds surface runoff and stream flow as well as meets the immediate water demands of ecosystems (Figure 3.2).

[7] GEMI, Local Water Tool

[8] Europe is delineated as EEA member countries; the EU 28 plus Iceland, Norway, Switzerland and Turkey including West Balkan countries. The total area is 6.6 million km^2

Figure 3.2 Natural water balance of Europe (2002–2012)



Source: EEA water accounts production database based on Burek, et al., 2013; Haylock, et al., 2008

3.1 Precipitation and actual evapotranspiration

The pattern of precipitation varies among the biogeographical regions of Europe ranging from 997mm in the Atlantic to 507mm in the Black Sea region. The Alpine region receives around 783 mm of precipitation annually which makes it the second highest precipitation rich region while the Continental (699mm), Mediterranean (688mm) and Boreal (655mm) regions provide a similar precipitation pattern. Mountainous areas such as the Alps, Carpathians and Norwegian coastal areas usually receive higher precipitation compared to lowland areas across Europe. As a general trend due to climate change impact precipitation increases in north-eastern and north-western Europe, particularly in winter, and decreases in southern Europe, in the summer (EEA 2014).

It is reported that temperature has also been rising in Europe. The average temperature on the European land area during the last decade (2005–2014) was 1.5°C above the pre-industrial level, which makes it the warmest decade on record. 2014 was the hottest year on record in Europe with mean annual land temperatures of between 2.11 to 2.16 °C, higher than the pre-industrial average (EEA 2015). As a result of these changes in precipitation and temperature pattern, soil moisture content (modelled estimation) has significantly increased since 1951 in parts of northern Europe and decreased in the Mediterranean region (EEA 2015). This observation can also be seen by comparing the actual evapotranspiration with precipitation on an annual scale. For instance, while the Atlantic region returns around 35% of total precipitation back to the atmosphere, this rate increases approximately up to 65% in the Continental regions and 70% in the Mediterranean. Higher actual evapotranspiration generally occurs on lowland areas compared to mountainous areas.

Actual evapotranspiration is deeply affected by land cover types as well. For instance, forested areas usually cause 5% higher actual evapotranspiration compared to other land cover types. However, water percolation from forested areas into soil is also 4% higher compared to other land cover types. In return, forests contribute positively to water balance in the long run.

Local studies indicate that temperature on impervious surfaces is relatively higher compared to other land cover types (Yuan, and Bauer, 2007; Obiakor, et al., 2012). Rising temperature causes an increase in actual evapotranspiration. Climatic predictions show that annual average land temperature over Europe is projected to continue increasing by more than the global average temperature (EEA, 2015a). In addition, the impervious surfaces are also rapidly increasing in Europe. Between 2006 and 2009, soil sealing, or imperviousness, increased in all EEA – 39 countries by a total of 4,364 km^2 (EEA, 2015b). The highest changes occur in Norway, Cyprus, Malta, Sweden and Spain while Malta, Cyprus and Spain are already experiencing water scarcity conditions on a seasonal and annual scale.

Human intervention with the environment particularly in the context of renewable water resources is not limited only to soil sealing. Changes in crop pattern, land conversion, shortening in agro phenology etc. are also increasing the actual evapotranspiration and hence decrease effective precipitation particularly in the southern part of Europe.

Snow, ice and glaciers are different forms of precipitation storing water during winter and releasing it in summer via melting. An EEA study (EEA, 2015d) has found that snow cover extent in the Northern Hemisphere has declined significantly over the past 90 years, with most of the reductions occurring since 1980. Snow cover extent in the Northern Hemisphere has decreased by 7% on average in March and April and by 53% in June over the 1967–2012 period; the observed reductions in Europe are even larger at 13% for March and April and 87% for June. Snow mass in the Northern Hemisphere has decreased by 7% in March from 1982 to 2009 (EEA, 2015d).

Increasing extreme irregularities in climatic and hydrological events are another type of pressure on water availability in Europe. Extreme precipitation events mostly occur in central and Eastern Europe particularly in winter, while summer dryness has increased in central and southern Europe (EEA, 2014d). As a result, in large parts of Europe, summertime temperature records, which are associated with prolonged heat waves, have increased by more than a factor of ten in the last three decades (EEA, 2014a).

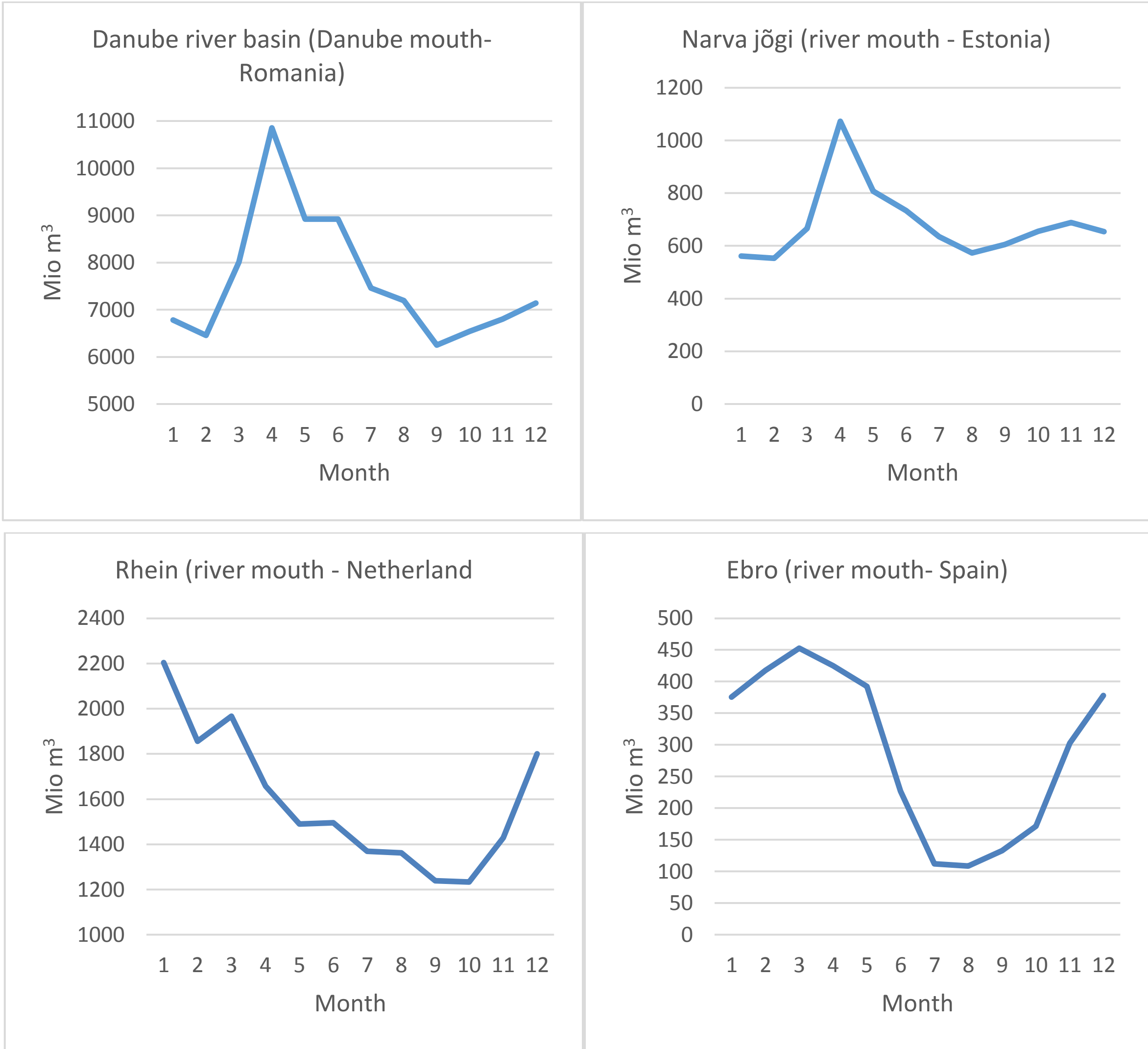
Based on the above findings, a shortage in renewable water resources particularly in the southern part of Europe e.g. mainly in the Mediterranean would be frequently expected in the near future due to climate change and land uptake driven conditions.

3.2 River Flows

3.2.1 River flow regime

Rivers are a very important water supplier in Europe. Around 41% of water is abstracted from rivers (EEA, 2016b). The hydrological cycle occurs throughout a 2 million km length of river network flooding within 118 large river basins. On average Europe annually discharges around 1,620 km^3 of water to sea. Typical hydrological regime in European rivers show peak seasons in winter and spring while lower stream flow occurs in summer and autumn (Figure 3.3). Late spring, summer and early autumn are characterized with a high water demand for different socio-economic needs i.e. for agriculture and households, particularly for tourism. That means high water demand is associated with low stream flow conditions during the summer months across Europe, but particularly in the south and south-eastern Europe.

Figure 3.3 Monthly river flows in million m³ in different European rivers



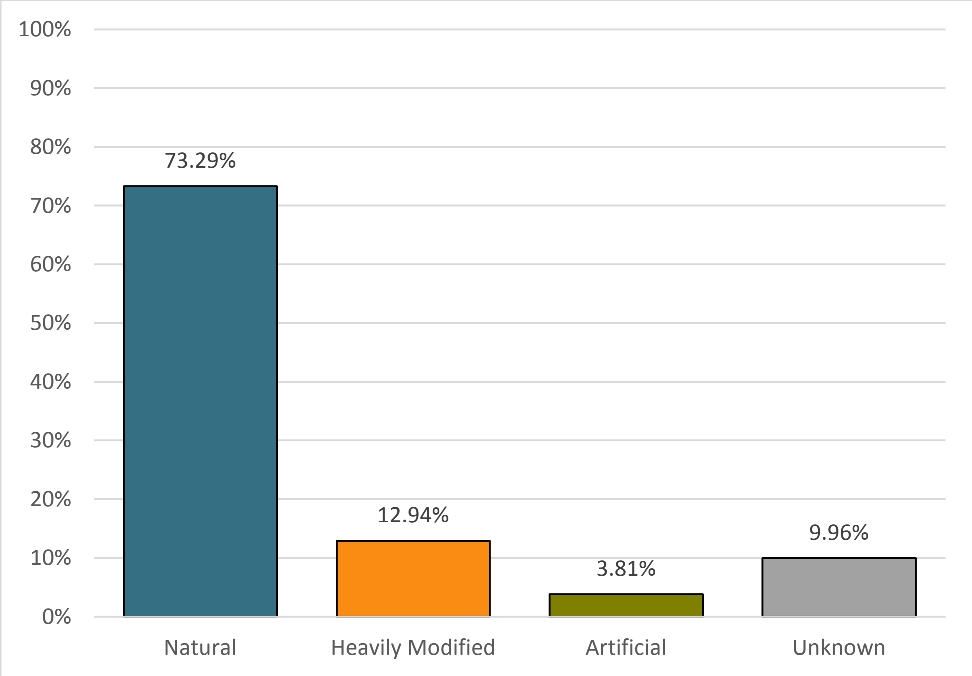
Data source: Burek, et al., 2013; EEA, 2014f
Note: multi-annual monthly average for 2002–2012

Long-term trends of stream flow on a seasonal scale show a continued decrease in summer and an increase in winter (EEA, 2014e). Similar observation has been made for instance in the Danube (Stagl, and Hattermann, 2015). River flow on an annual scale is also projected to decrease in southern and south-eastern Europe and to increase in northern and north-eastern Europe (EEA, 2014e). This is in line with the findings on the changing in spatial and temporal patterns of precipitation and temperature in southern parts of Europe.

Diverting from the natural hydrological regime also impacts on the temporal and spatial pattern of renewable water resources. Alterations with the hydrological regime occur due to water abstraction, hydro-morphological alterations (e.g. construction of hydraulics infrastructures to store water in reservoirs or to regulate water transports etc.), converting land cover into high water demanding land use types etc. Around 73% of European rivers are natural water bodies while 13% of rivers are heavily modified and about 4% of rivers are artificial (Figure 3.4). The highest proportion of the HMWBs and AWB are found in the Netherlands, Belgium, Hungary and Germany (EEA, 2012b)[9].

[9] This information is only relevant to the EU Member States covered by the Water Framework Directive

Figure 3.4 Percentage of natural, heavily modified, artificial and unknown status for river water bodies



Source: EEA, 2012c and data reported under WFD

Extreme streamflow events have an impact on the hydrological regime and also mislead the results of water assets accounts. For instance, extreme precipitation may occur within 5 min. or 24 hours and usually contributes to surface waters (floods) rather than percolating into the soil. Despite very sudden appearance and loss of precipitation, it is counted as “normal” input increasing the stocks in the water accounts. However, floods don’t have a contribution to the regular and normal hydrological cycle in the respective basin. Extreme temperature events in winter may cause rapid melting of snow or ice cover. These conditions are also increasing the irregularity in the hydrological regime of rivers. In general, the highest irregularity coefficients are seen in the Boreal and Mediterranean regions (1,190 and 490 respectively) which are also consistent with the assessment of extreme climatic and hydrological events (EEA, 2014d). The occurrence of more than twenty flood events on an annual scale have been found in the Mediterranean and Norwegian coastal areas (Map 1.1) The irregularity coefficient in other regions provide comparatively lower values; Alpine (29), Atlantic (12) and Continental (8).

Natural water retention measures are considered an effective tool in regulating the flow regime of rivers as well as protecting society from floods. An EEA study (EEA, 2015f) has revealed that the expansion of forest cover in catchments increased water retention by around 25%. In recent years, the Commission has also developed a catalogue of natural water retention measures serving as a community of practice with a number of case studies for sharing knowledge and experiences[10].

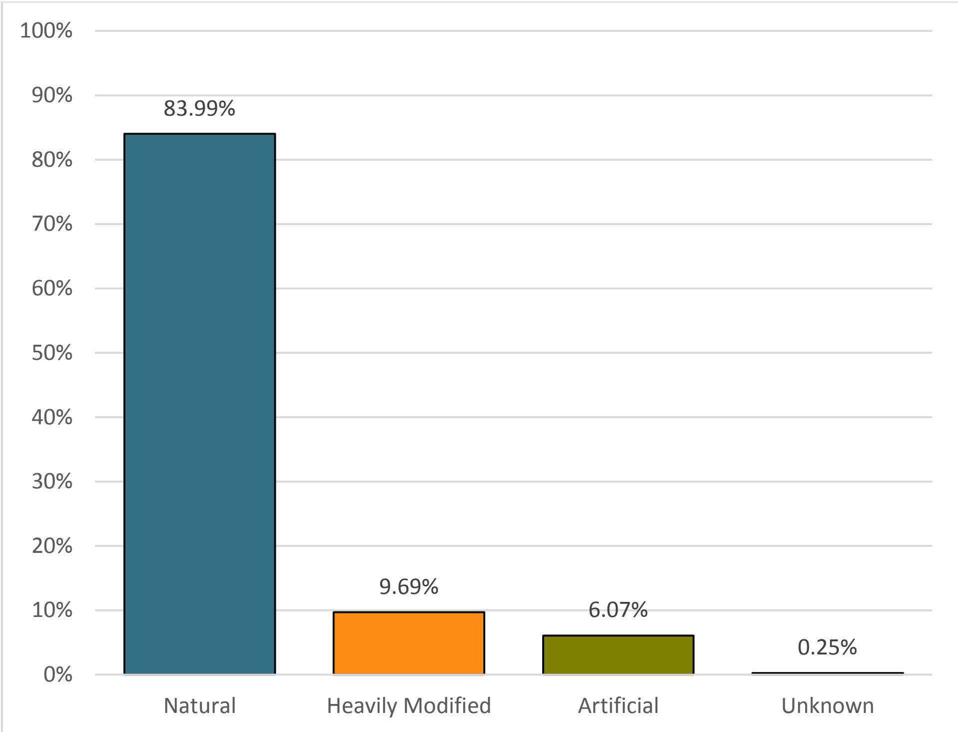
Several extreme events in floods as well as drought have also happened across Europe in recent years. Over the past 40 years, Europe has been affected by a number of major droughts, most notably in 1976, 1989, 1991, and more recently, the prolonged drought over large parts of the continent associated with the 2003 summer heat wave and the 2005 drought in the Iberian Peninsula. However, there is no evidence that river flow droughts have become more severe or frequent over Europe in general in recent decades (EEA, 2012d).

[10] European Natural Water Retention Measures Platform

3.2.2 Water storage in reservoirs and lakes

Water storage in reservoirs is one of the applications widely used in managing water resources. Europe hosts around 375 thousand lakes (natural and artificial) [11] with a total area of 186,000 km^2. About 84% of lakes are natural while 10% are heavily modified and 6% are artificial (Figure 3.5). The largest lake in the EU is Vänern (Sweden) with an area of 5,655 km^2.

Figure 3.5 Percentage of natural, heavily modified, artificial and unknown status for lake water bodies



Source: EEA, 2012c and data reported under WFD

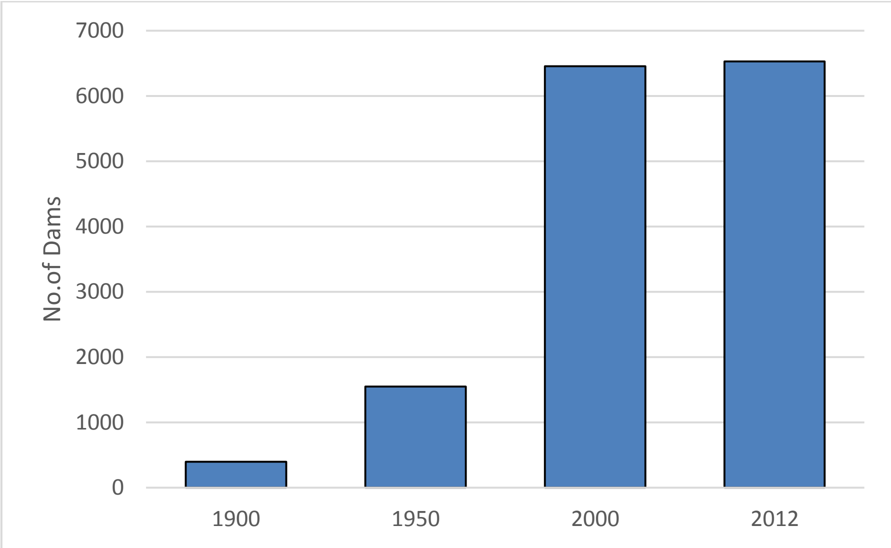
In addition to lakes, Europe hosts a number of dams which are some of the most important infrastructures used to control the hydrological cycle. Despite the EEA Dampos database[12] , which holds the records of dams dated from 1900 (1,272 dams/reservoirs) until 2012 it doesn't cover all data providing a comprehensive spatial and temporal evolution of the water storage in Europe. Currently Dampos hosts records of 6,649 dams and reservoirs with the potential capacity of 1,355 km^3 of water storage. This is more or less equal to 34% of the total annual precipitation of Europe and enables theoretically the storage of water equal to 57.5% of the total outflow of water to the sea in Europe within a year.

Europe has a long history in implementing hydraulic structures, which even dates back to ancient times. Nevertheless, construction of dams and reservoirs gained impetus particularly after the 2000s. More than 75% of all dams and reservoirs in Europe have been constructed as of the 2000s (Figure 3.6). The construction of new dams and reservoirs has continued in many parts of Europe.

[11] The EU Hydro spatial data

[12] DAMPOS: dam positioning database was developed by the EEA for ad-hoc and informal data collection which then could be used in the European water accounts. This database is not active yet as the necessary data is collected under the State of Environment data flows from the EEA member countries.

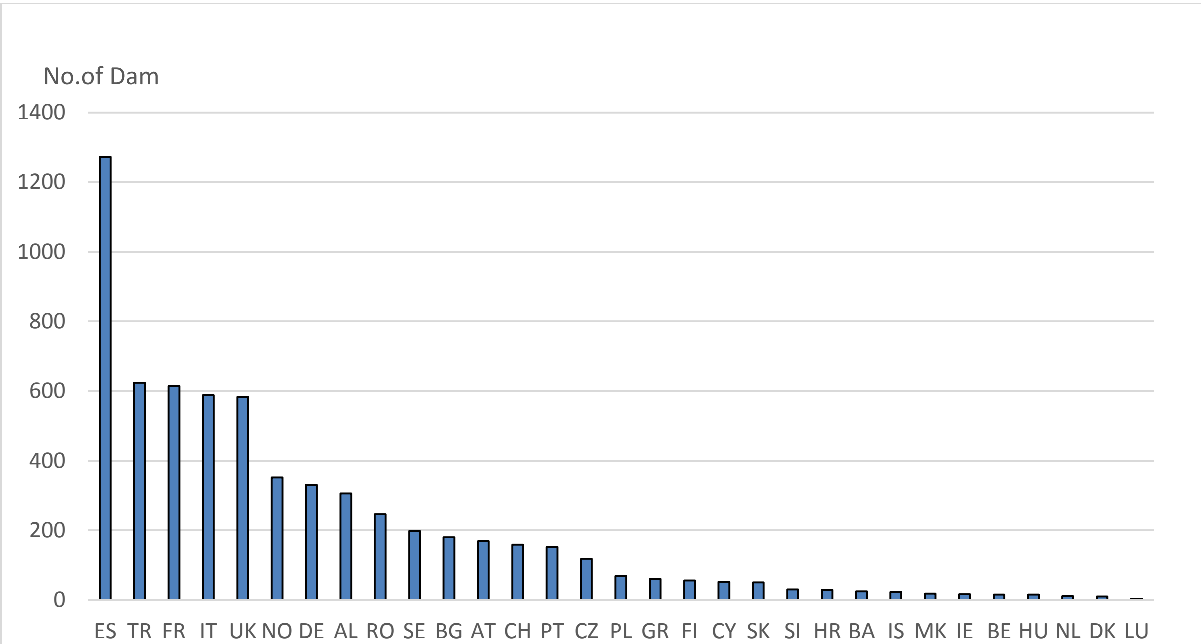
Figure 3.6 Dam construction – cumulative in Europe (1900–2012)



Data source: EEA Dampos

For instance, Spain hosts almost 20% of all dams and reservoirs in Europe. Only 5 countries like Spain, Turkey, France, Italy and the UK host around 57% of the total dams found in Europe (Figure 3.7).

Figure 3.7 Dams per country in Europe



Data source: Dampos

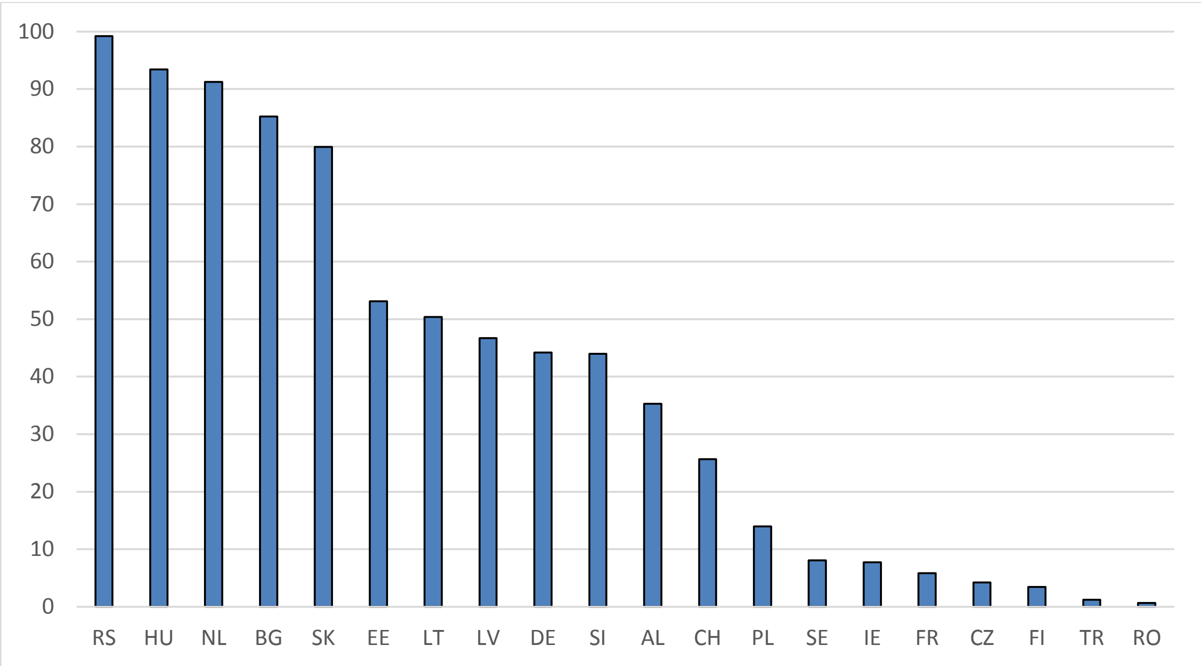
Water storage in reservoirs is widely used to tackle the seasonal irregularity of renewable water resources. However, this method is debated. It is estimated that the volume of water evaporated from reservoirs exceeds the combined freshwater needs for industry and domestic use particularly in hot regions (UNEP, 2008). It has been observed that under increasing water scarcity conditions, particularly in southern Europe, construction of new dams and reservoirs are still taken on-board as one of the most viable solutions. However, it should also be mentioned that not all dams and reservoirs are constructed only just for water storage, but also for hydro-power purposes.

3.2.3 External inflow and dependency ratio

External inflow defines the water coming from upstream territories (e.g. upstream catchments, sub-basins or countries). On a catchment or country scale, external inflow together with effective precipitation contributes to renewable water resources. It is also one of the important variables of the water assets accounts. As many rivers in Europe are transboundary water courses such as the Danube, it is important to know upstream-downstream relations among the countries in a hydrological context. This relation is mainly elaborated by means of developing a dependency ratio or dependency index[13]. Dependency ratio estimates how much water comes from the external inflow (upstream) compared to the total renewable water resources in a given area. This ratio theoretically ranges between zero percent (no water from upstream) and 100 percent (all water from upstream). Despite this ratio involving quite a considerable amount of uncertainties in terms of groundwater and surface separation, it can still give quite a simple but powerful indication on the level of cooperation needed between upstream and downstream areas. However, it should be carefully interpreted that this indicator doesn't assess water abundance or water scarcity in a given area.

Around six countries in Europe depend on more than 50% of their water being received from upstream countries; Serbia, Hungary, Netherlands, Bulgaria, Slovakia and Estonia have a high dependency ratio (higher than 90%) to the upstream basins. Latvia, Lithuania, Germany, Slovenia and Albania show between a 30% and 50% dependency. Poland, Sweden, Ireland, France, Czech Republic, Finland, Turkey and Romania provide a comparatively lesser dependency ratio to the upstream areas. In addition, only a few countries (namely islands) don't receive any water from the upstream catchments such as Malta and Cyprus (Figure 3.8).

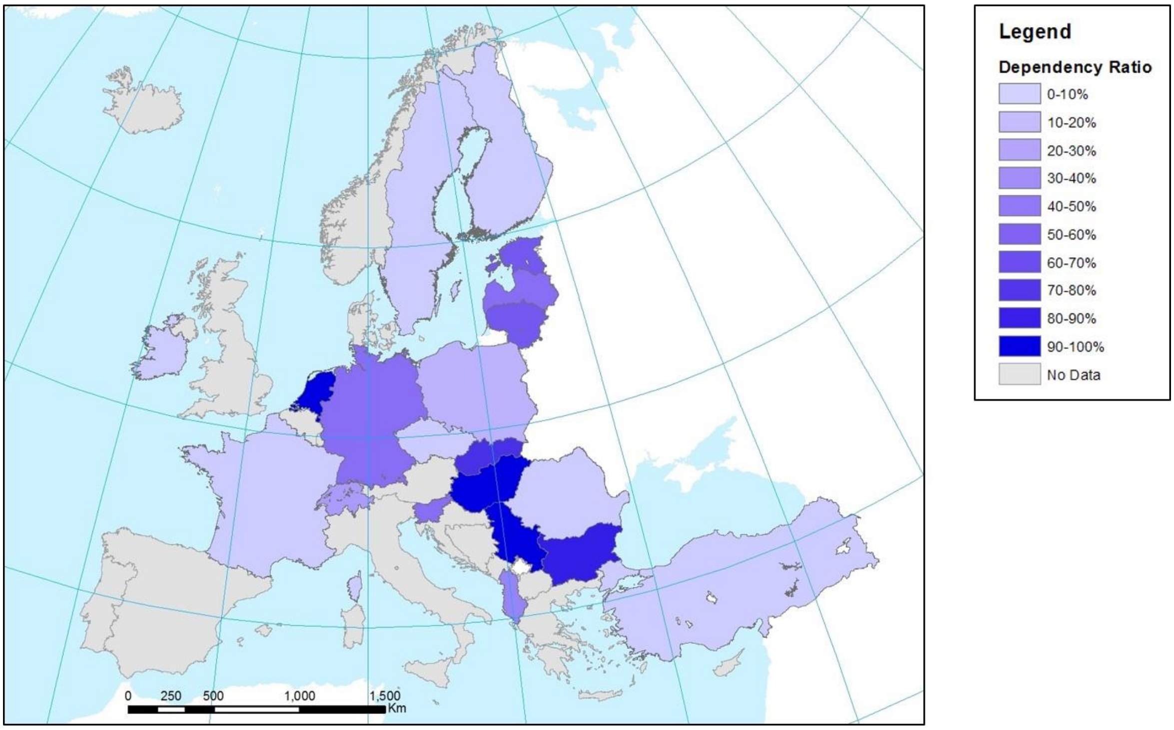
Figure 3.8 Dependency ratio between external inflow and internal renewable water resources



Data source: Eurostat, 2016m

[13] FAO AQUASTAT definition of dependency ratio; Indicator expressing the percent of total renewable water resources originating outside of a country. This indicator may theoretically vary between 0% and 100%. A country with a dependency ratio equal to 0% does not receive any water from neighbouring countries. A country with a dependency ratio equal to 100% receives all its renewable water from upstream countries, without producing any of its own. This indicator does not consider the possible allocation of water to downstream countries, last visited on 11.08.2016.

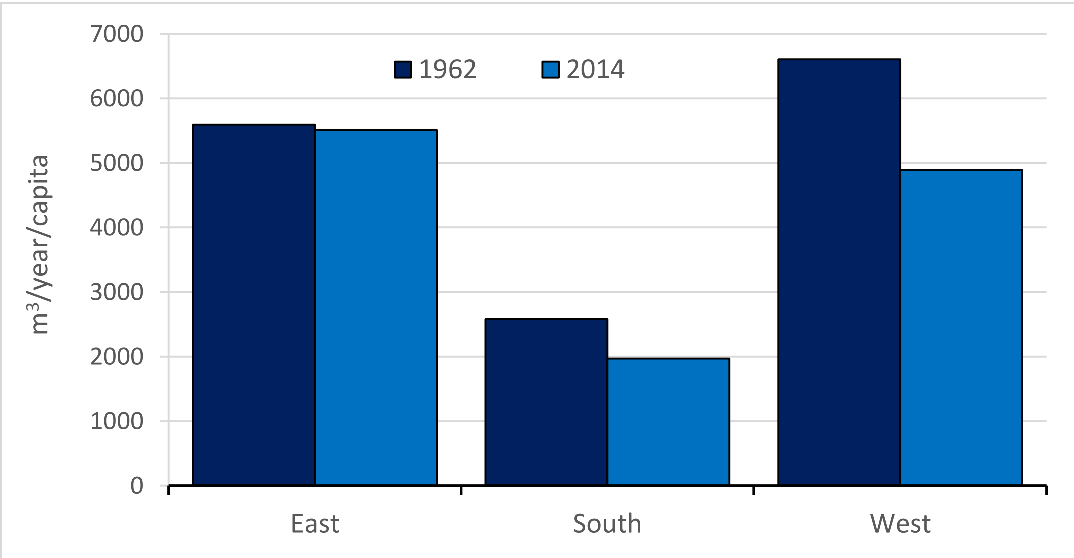
Map 3.1 Distribution of dependency ratio between external inflow and internal renewable water resources across Europe



3.3 Status and trends in renewable water resources across Europe

According to the World Bank assessment (World Bank, 2016) renewable freshwater resources have substantially decreased on a global scale from 13,200 m^3/year/capita in 1962 to 6,879 m^3/year/capita in 2014. Similar changes are also observed in Europe (Figure 3.9).

Figure 3.9 Trend in renewable water resources per capita in Europe[14] (1962–2014)



Data source: World Bank, 2016

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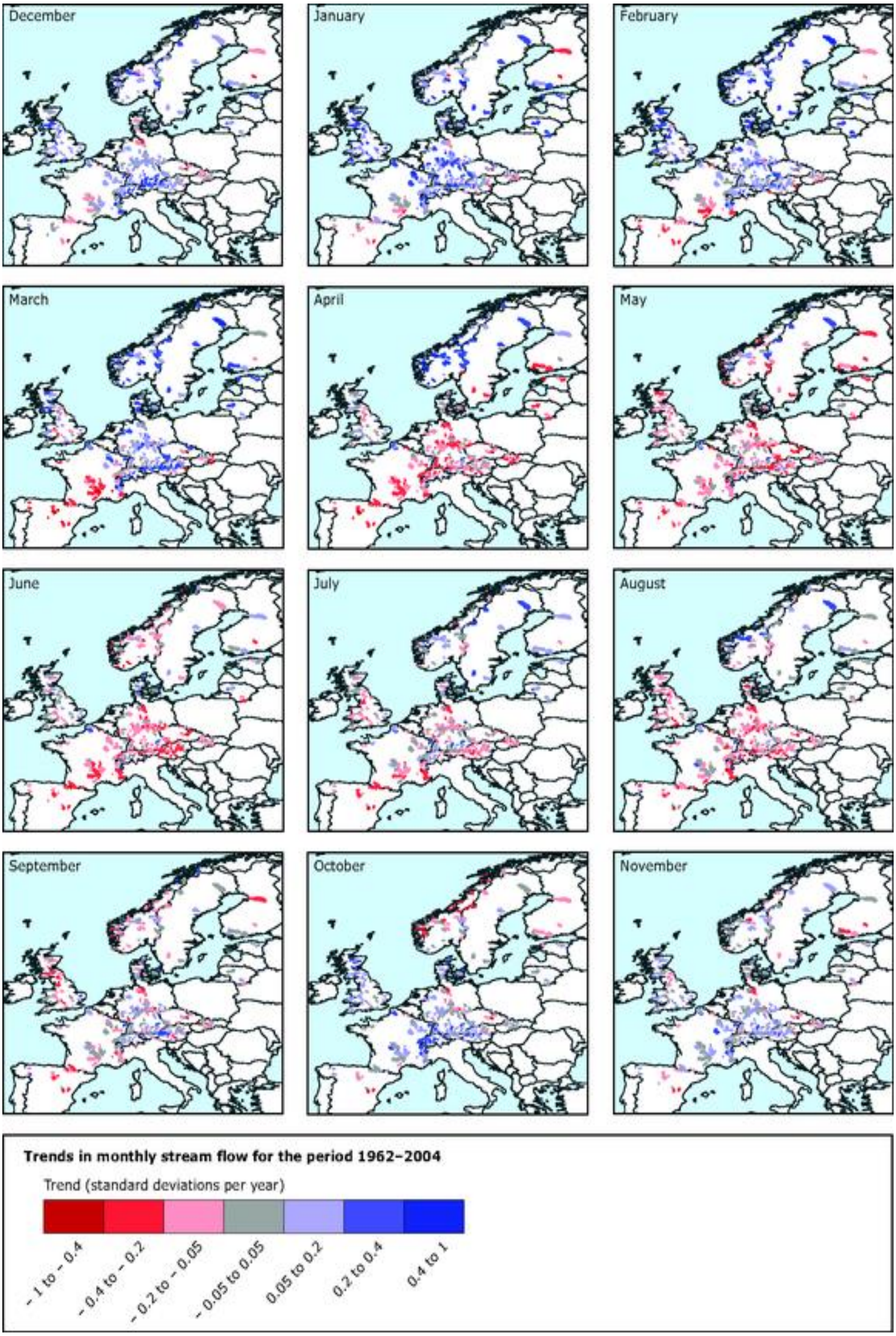
[14] East: Albania, Bulgaria, Czech Republic, Estonia, Croatia, Lithuania, Latvia, Poland, Romania, Slovenia, Slovakia
South: Cyprus, Spain, Italy, Malta, Portugal
West: Austria, Belgium, Germany, Denmark, France, Ireland, Netherlands, Sweden, United Kingdom

Renewable freshwater resources per capita from 1962 to 2014 particularly in Western and Southern Europe has decreased by around 24%. No significant change in renewable water resources per capita has been identified for Eastern parts of Europe during the same time period. There might be several reasons behind these substantial variations. Population changes in Europe over time seem to be one of the reasons. As a matter of fact, the population has increased by 11 % in the western part of Europe between 1987 and 2015 and similarly by 10 % in southern Europe, while it has been decreasing to around 6% in Eastern Europe.

The second reason would more likely be the impact of climate change particularly in southern Europe. Indeed, in parallel to global warming, temperature in Europe is also increasing. For instance, between 2006 and 2015, the average annual temperature over the European land area increased by 1.45°C to 1.59°C, relative to the pre-industrial period (EEA, 2016a). In addition to that, precipitation trends since 1960 show an increase by up to 70mm per decade in north-eastern and north-western Europe, in particular in winter, and a decrease by up to 90mm per decade in some parts of southern Europe (annual average precipitation is around 688mm in the Mediterranean region), in particular during summer (EEA, 2014c). The impacts of these two observations from temperature and precipitation have already been identified by the changes in long term river flows from different parts of Europe (Figure 3.10). River flow decreases particularly in the summer months, which is usually associated with high water demand. The future projections speculate the continuation of the decrease in river flows in summer during the coming years.

Figure 3.10 Trends in monthly stream flow for the period 1962–2004



Source: EEA, 2012f

4 Water abstractions by source

Annually around 1,400 km^3 of freshwater is abstracted to meet the water demand for maintaining socio-economic vitality in Europe. However, all that volume of water is not only abstracted from surface water resources. Groundwater resources are also used in meeting the water demand. Around 58% of total water is abstracted from rivers, lakes and reservoirs while groundwater resources meet 42% of water abstraction (Figure 4.1).

Figure 4.1 Water abstraction by sources (2014)

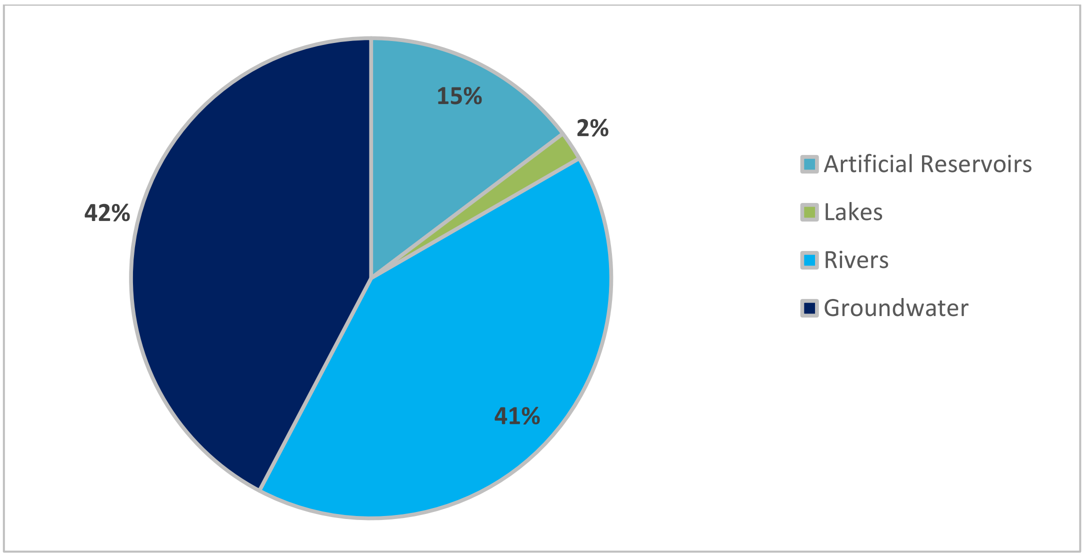
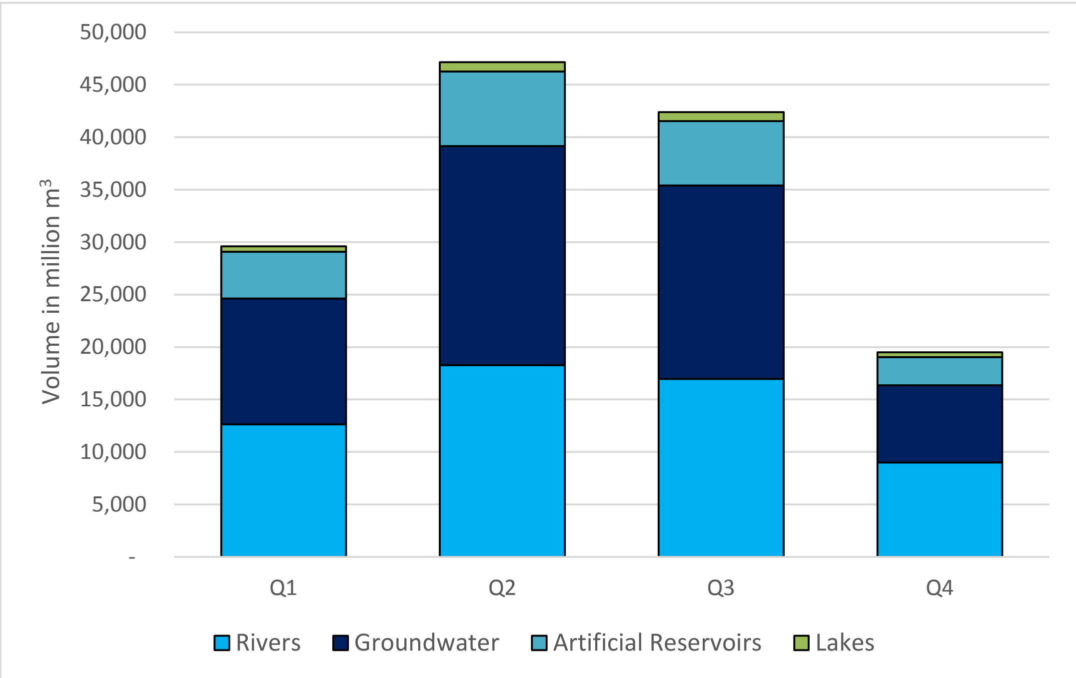


Figure 4.2 Seasonal freshwater abstractions in million m3 by water sources (2014)



Water is abstracted more in summer than compared to winter. Almost all surface and groundwater resources are receiving pressures from high water demand during summer months. But particularly, groundwater and rivers provide around 83% of the total water demand while reservoirs meet 15% of total water abstraction. Water abstraction from reservoirs is increased by 40% during spring compared with winter.

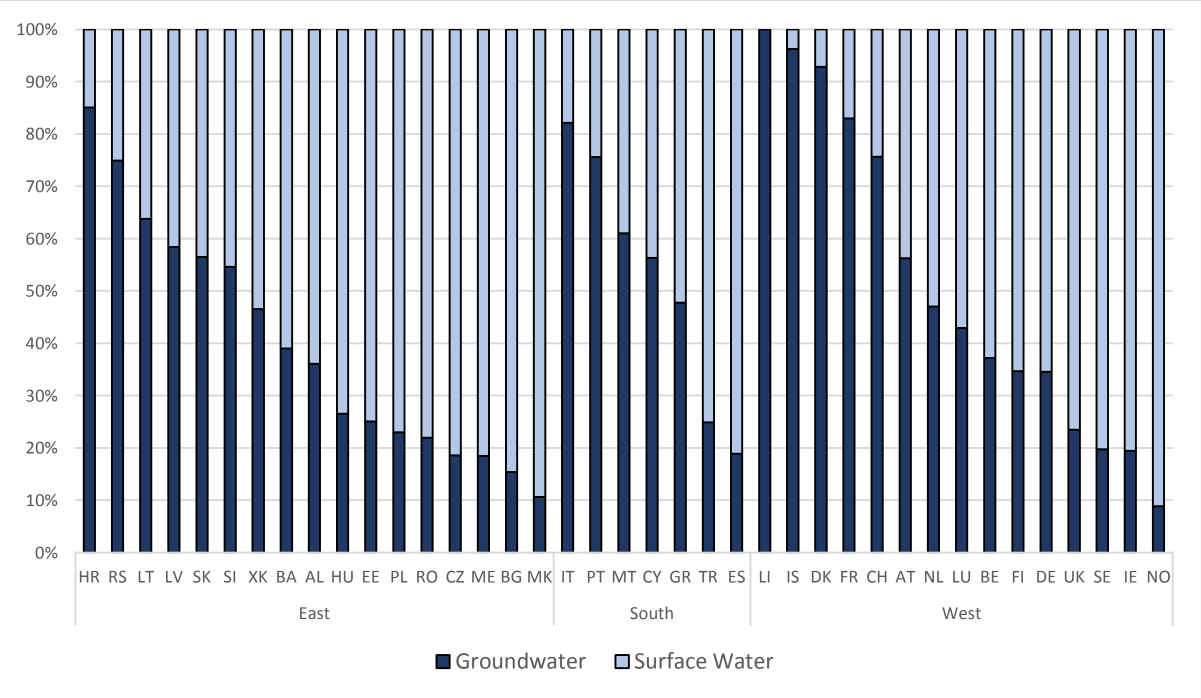
On a seasonal scale, for 2014, across all of Europe, around 34% of water abstraction occurs in the spring months, followed by the summer with 31%. Water abstraction during winter (21%) and autumn (14%) are comparatively lower. Further analysis at regional scales can reveal different patterns.

Water abstraction across Europe has decreased about 7.4% in 2014 compared to the level of water abstraction in 2002. Within the same time period the European population has increased by around 8.7%. It might be concluded by a slight relative decoupling between population and water abstraction in general. However, this conclusion should also be further validated with resource efficiency parameters.

Depending on the purpose of water supply, in general, groundwater resources are mainly used for drinking, while surface water are generally used for agricultural activities, hydropower, cooling, mining and manufacturing. In addition, transitional and sea waters are also used for cooling. Sea water is desalinated to meet water demand where freshwater can't be sufficiently supplied e.g. mainly in Malta, Cyprus and Spain. However, transitional and coastal waters are not covered by this study.

The ratio of water abstraction between groundwater and surface water resources changes from one country to another. Some countries have to rely on solely groundwater resources due to geographical and hydrological features of the countries concerned while some others can mainly abstract water from surface water resources. For instance, Denmark meets almost 98% of total water demand from groundwater resources. Similarly, Iceland abstracts 95% of water from groundwater resources while Finland abstracts 92% of total water from surface water resources (Figure 4.3).

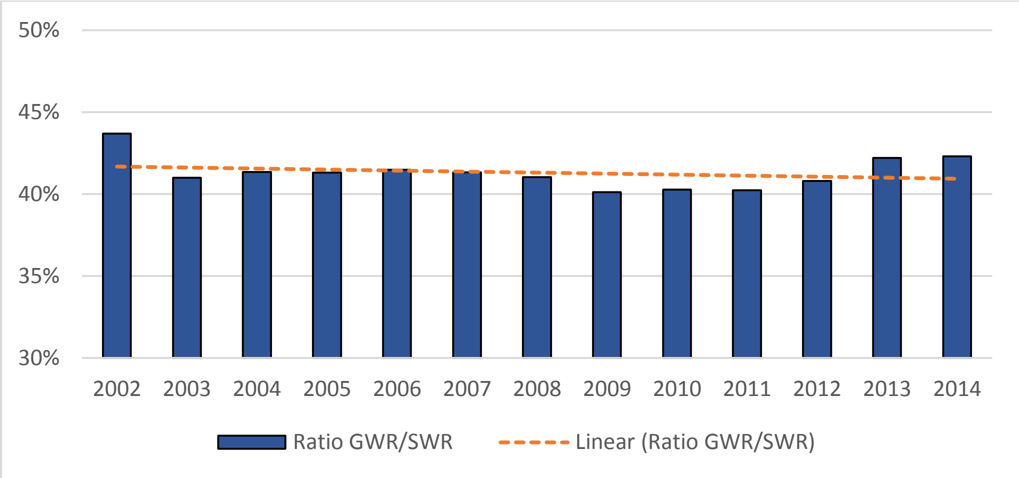
Figure 4.3 Share of groundwater and surface water in total water abstraction (2002–2014)



On average, southern countries rely on more groundwater resources (52%) compared to western (51%) and eastern countries (40%). That is likely due to seasonal variations in water availability during summer months, particularly in southern Europe.

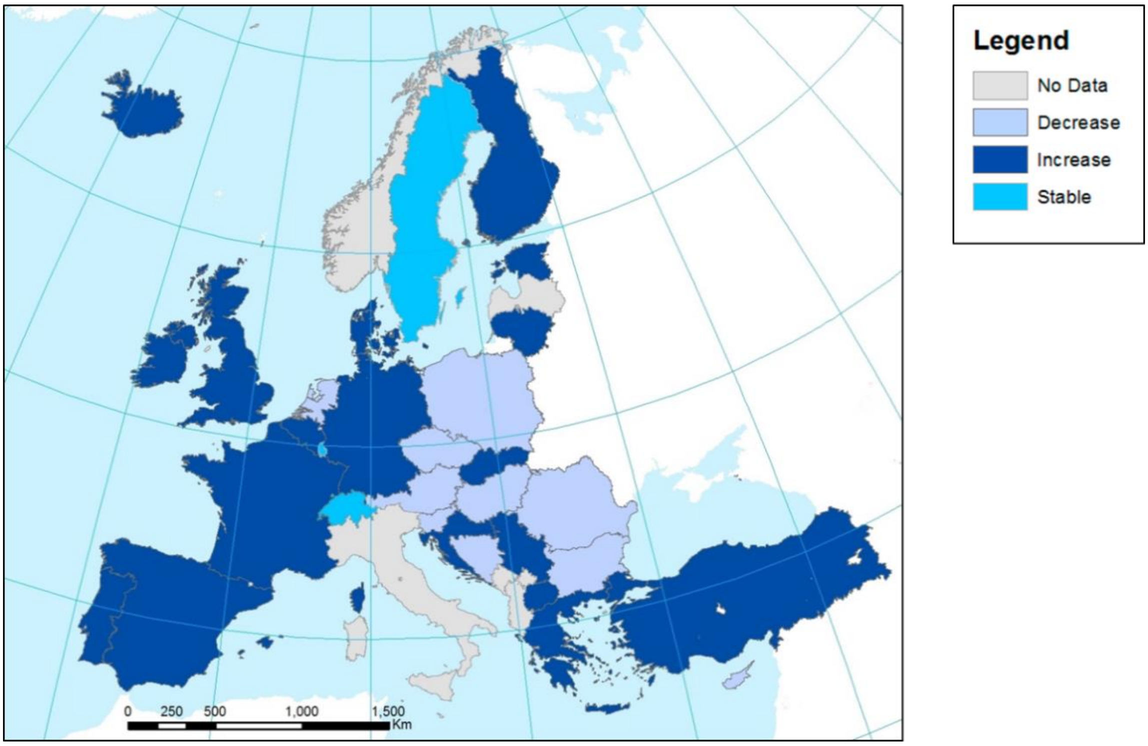
Despite a decreasing tendency (–7%) in total water abstractions across Europe between the years of 2002–2014, the ratio between groundwater and surface water resources has been increasing in favour of groundwater since 2010 (+5%) which creates additional pressures (Figure 4.4).

Figure 4.4 Trend in water abstraction from groundwater resources (GWR) compared to surface water resources (SWR)



Trends in water abstraction from groundwater resources compared to surface water are quite diverse among the countries. As mentioned earlier ground water abstraction is increasing particularly in western and southern countries including Turkey (Map 4.1). On the other hand, groundwater abstraction was found to be decreased in Hungary, Bulgaria and Romania in the early 70s and 90s. Hungary has decreased 60% of its groundwater share in water abstraction since the 1970s while that ratio is 40% in Bulgaria and 33% in Romania. Today these countries show more or less a more stable trend. The transition period during the 1990s had impacted in using groundwater resources in those respective countries.

Map 4.1 Trend in water abstraction from groundwater resources vs surface water (1970–2012)



Data source: Eurostat, 2016e

The impact of changes in the temporal and spatial pattern of temperature, mean precipitation as well as river flow can easily be observed in shifting water abstraction from surface water to groundwater resources particularly in southern Europe. Eventually the trend with water abstraction from groundwater resources shows that pressures on groundwater resources may increase in the coming years. In addition, construction of more reservoirs and dams should also be expected in order to increase the storage capacity of surface water.

5 Water use by economic sectors

Freshwater is the most important resource for mankind, cross-cutting all social, economic and environmental activities. It is a condition for all life on our planet, an enabling or limiting factor for any social and technological development, a possible source of welfare or misery, cooperation or conflict (UNESCO, 2013). As outlined in the 7th Environmental Action Programme we need to ensure the sustainability of European natural capitals but also increase resource efficiency in order to live well within the planetary limits. Water is also an essential commodity within Europe's economy. Water is used either as a raw resource or process facilitator almost in all economic sectors. Therefore, some of the economic sectors create pressures over freshwater resources while meeting water demand in the manufacture of different products or in producing energy. For instance, agriculture (particularly through irrigation water), households, service sector including tourism, mining and quarrying, electricity production are all major economic sectors where water is intensively used.

Text box 5.1: Water use related terminologies

Water abstraction, water supply and water use are used interchangeably in many cases despite each of them being different terms. Water abstraction is the process of taking water from ground or surface water resources, either temporarily or permanently with the purpose of meeting water demand. Water supply is a source or volume of water available for use; also, the system of reservoirs, wells, conduits, and treatment facilities required to make the water available and usable (EIONET GEMET). Water use can be defined – for implementation purposes of water accounting – as the difference between water supply (abstractions) and returns. In that direction, the difference between water abstractions and returns can also be regarded as water loss which is one of the most important components of water resource efficiency.

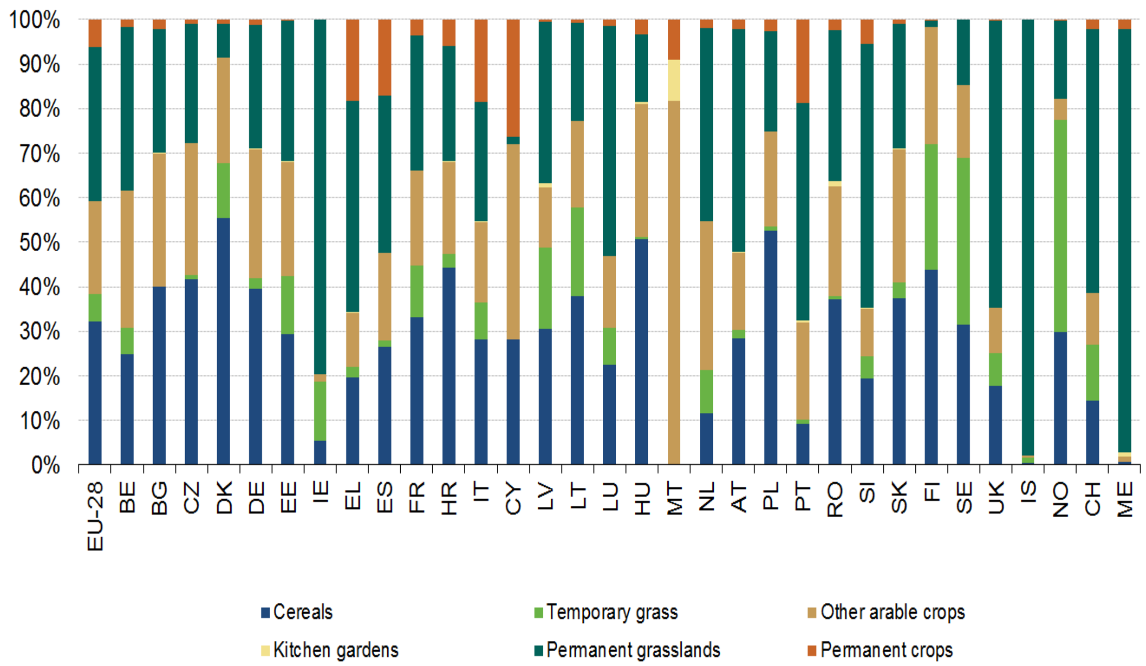
The route of water from the environment to economy and from economy back to environment requires four different steps to be followed; water abstraction, water supply, water use and return. During this route, water might be lost due to leakage in water distribution systems or not being efficiently used by economic sectors as well as returned back to the environment without treatment. All these processes would have an impact on water use intensity and efficiency.

5.1 Agriculture

The total area of arable land in Europe is around 113 million ha. About 70% of the total arable land is located in France (16%), Spain (11%), Poland (10%), Germany (10%), Romania (8%), Italy (7%) and the UK (6%). Slightly more than 30% of arable land can be irrigated. Depending on climate conditions of the respective year, the actual area of irrigation may change from one year to another between 8 and 9% of the total crop area (Eurostat Data), which corresponds with, more or less, half of the total irrigable area of Europe. Cereals and permanent grasslands are two major crop types occupying almost more than 60% of the utilised agricultural area. Permanent crops are mainly located in Mediterranean countries while temporary grasses are mainly found in northern countries (Figure 5.1).

Water use for irrigation in Europe has been studied in several publications included in those published by the EEA since the early 2000s (EEA, 2009). Despite the fact that a comparatively small portion of the total arable land is subject to irrigation (only 8–9% of the total crop area), on an annual scale, this limited area consumes about 51% of the total water use of Europe, while this ratio may increase by up to 66% in the spring. Particularly in the Mediterranean region, water use for irrigation consumes almost 80% of all water usage. In many locations of the Mediterranean region, obviously, agriculture is the main pressure on freshwater resources during the summer months.

Figure 5.1 Cropping pattern in Europe – share of main land types in utilized agricultural areas in 2010



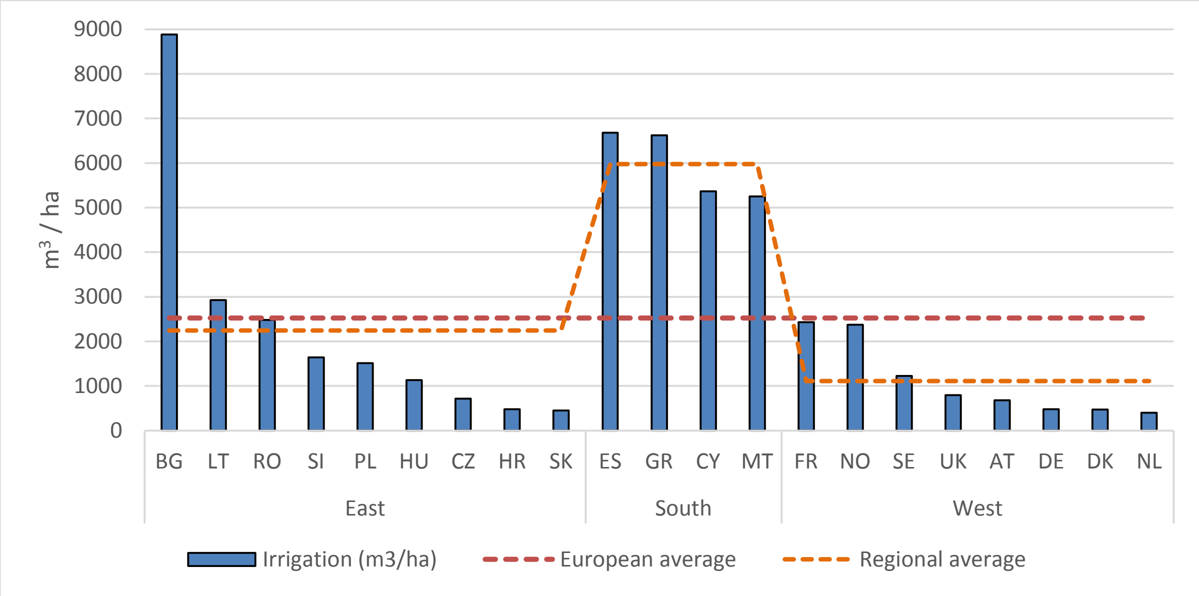
Data source: Eurostat, 2016a

Water irrigation is not used in all kinds of agricultural activities. Irrigation is implemented as a supplementary to rain fed when water deficit occurs between precipitation and actual evapotranspiration from the concerned crop types. However, water demand for irrigation depends on an – inter alia crop pattern and climatic conditions during the agricultural season (agro-phenology) the particular growing season and irrigation methods etc. In general, under similar conditions, more water is required for surface irrigation compared to sprinkler and drop irrigation. Defining the most appropriate irrigation method in a given area also depends on local socio-economic conditions, topography, climatic conditions as well as water availability.

Regardless of the crop type and pattern in a given area, a rough comparison of water use for irrigation with the irrigated area[15] indicates that the highest water irrigation is used in southern Europe with 6,584 m^3/ha on average which is three times more than the regional average of Eastern Europe and six times more than Western Europe (Figure 5.2). Bulgaria holds the record of the highest amount of water irrigation per hectare (8,883 m^3/ha) in Eastern Europe as well as in the whole of Europe. Lithuania (2,924 m^3/ha) and Romania (2,483 m^3/ha) follow Bulgaria in Eastern Europe with significantly less volumes of irrigation water. Bulgaria widely implements surface irrigation, their water supply system for irrigation needs further improvements.

[15] Water use intensity is an indicator which is mainly used for assessing economic efficiency of water used by economic sectors (UN 2006a and UN 2006b). We have modified the denominator (gross value added) by replacing it with the irrigated area ([ef_poirrig]) in order to quantify physical water use efficiency in a given area.

Figure 5.2 Irrigation water abstraction intensity across Europe (m^3/ha)



Data source: Eurostat, 2016g, 2016c

Water for irrigation in southern countries e.g. in Spain (6,676 m^3/ha), Greece (6,618 m^3/ha), Cyprus (5,368 m^3/ha) and Malta (5,250 m^3/ha), is approximately three times higher compared to the European average (2,522 m^3/ha). Southern countries hold also 59% of the total irrigated land area in Europe (Table 5.1).

Table 5.1 Share (%) of irrigated area of the total crop area and water abstracted for irrigation compared with the total abstractions of water per region in Europe

Region	Irrigated area (%)	Water abstraction for irrigation (%)
East	5.8	3.6
South	59.5	83.9
West	34.7	12.5

Data source: Eurostat, 2016g, 2016c[16]

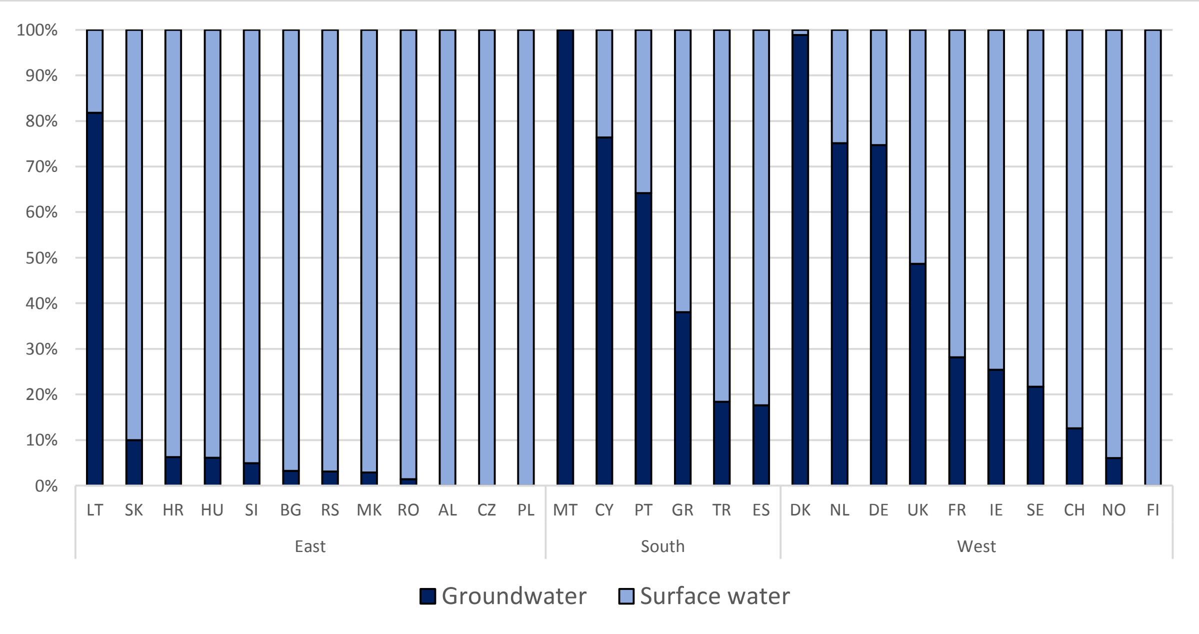
According to above table, it might be concluded that water irrigation intensity is more efficient in Western Europe compared to other regions by means of efficient water supply systems as well as by widely using sprinkler and drop irrigation systems. Despite 35% of total irrigated areas being located in Western Europe, only 12.5% of water irrigation is used in this region. However, it should be mentioned that France (2,428 m^3/ha) and Norway (2,371 m^3/ha) use approximately two times more water per hectare compared to the regional average (1,106 m^3/ha).

Regarding the use of surface or groundwater resources in irrigation, groundwater is the main water resource for many countries in Western Europe (Figure 5.3). Austria, Denmark, the Netherlands and Germany meet more than 75% of the total water abstraction for irrigation from groundwater resources. Similarly, in southern Europe, Malta, Cyprus and Portugal use groundwater resources for irrigation more,

[16] United Nations, 2006, 'Integrated Environmental and Economic Accounting for Water Resources Draft For Discussion', (https://unstats.un.org/unsd/envaccounting/ceea/PImeetings/Handbook_Voorburg.pdf) accessed June 02, 2017.

compared to surface water. Eastern Europe mainly uses surface water resources in irrigation, except Lithuania. In general, Spain and Greece mainly use reservoirs, particularly in the summer months to meet their water demands for irrigation.

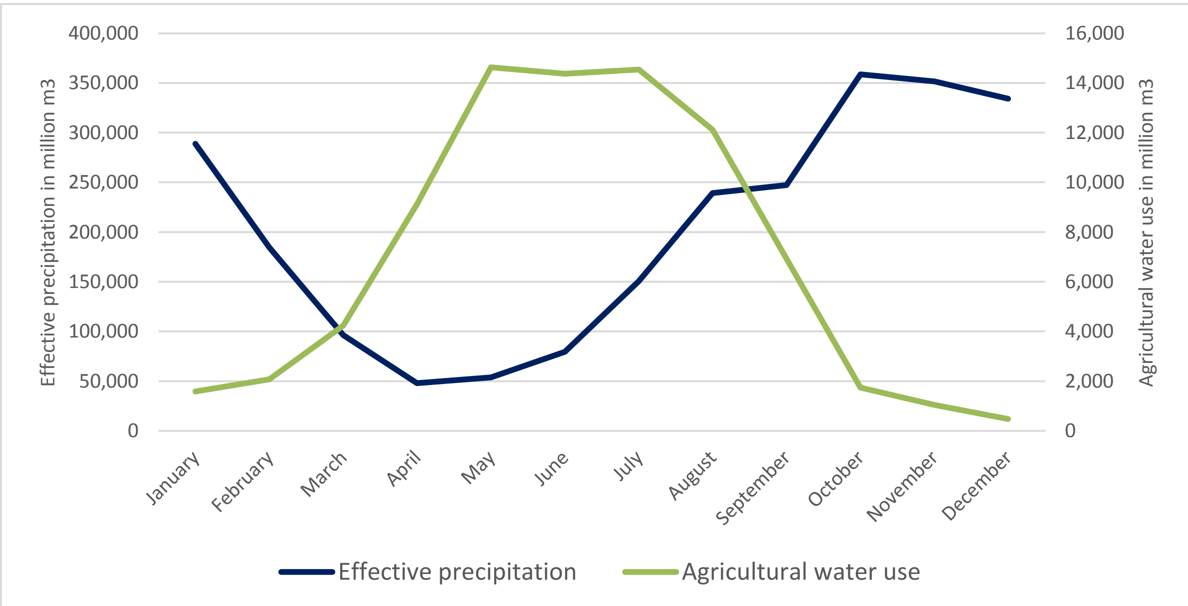
Figure 5.3 Irrigation water abstraction by source per region



Data source: Eurostat, 2016c
Note: Data availability concerning the latest year of reported data, varies per country. Latest data used is for Slovakia (2014).

On a seasonal scale, the peak seasons of agricultural water demand are spring and summer. Both seasons are characterized with lower water availability compared to winter and autumn. Higher water demand associated with lower water availability particularly in summer months creates more pressure on water resources (Figure 5.4).

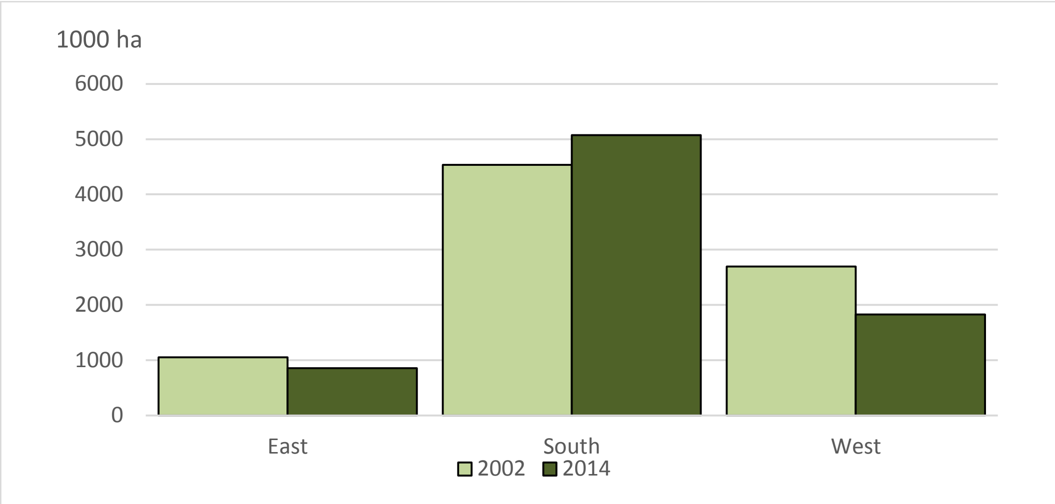
Figure 5.4 Monthly effective precipitation compared with water irrigation (multi-annual average 2002–2014)



Wherever surface water is not sufficiently available e.g. within southern countries, groundwater resources together with reservoirs are densely used to meet water demand. In some cases, these high pressures result with a number of environmental impacts such as over exploitation of groundwater resources, salt water intrusion into groundwater aquifers, for instance in Cyprus.

Since 2002 the total amount of irrigated areas in Europe have decreased by around 6%, while utilized crop areas have increased by 4% for the same period of time (Figure 5.5). However, the total irrigated area in southern Europe has increased by 12% for the same time period, which is associated with an increase in the utilized crop areas.

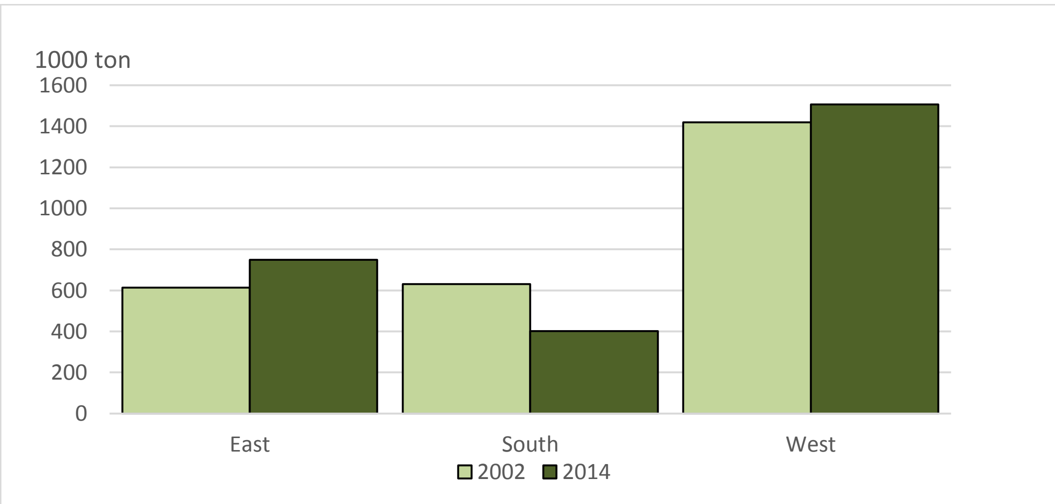
Figure 5.5 Change in irrigated area in Europe (2002–2014)



Data source: Eurostat, 2016d

Total harvested agricultural production, compared with the 2002 level, increased by 22% in Eastern Europe and by 6% in Western Europe in 2014. However, despite a 12% increase in the irrigated area in southern Europe, harvested agricultural production has been decreased by 36% from 2002 to 2014 (Figure 5.6).

Figure 5.6 Change in total harvested agricultural production in Europe (2002–2014)

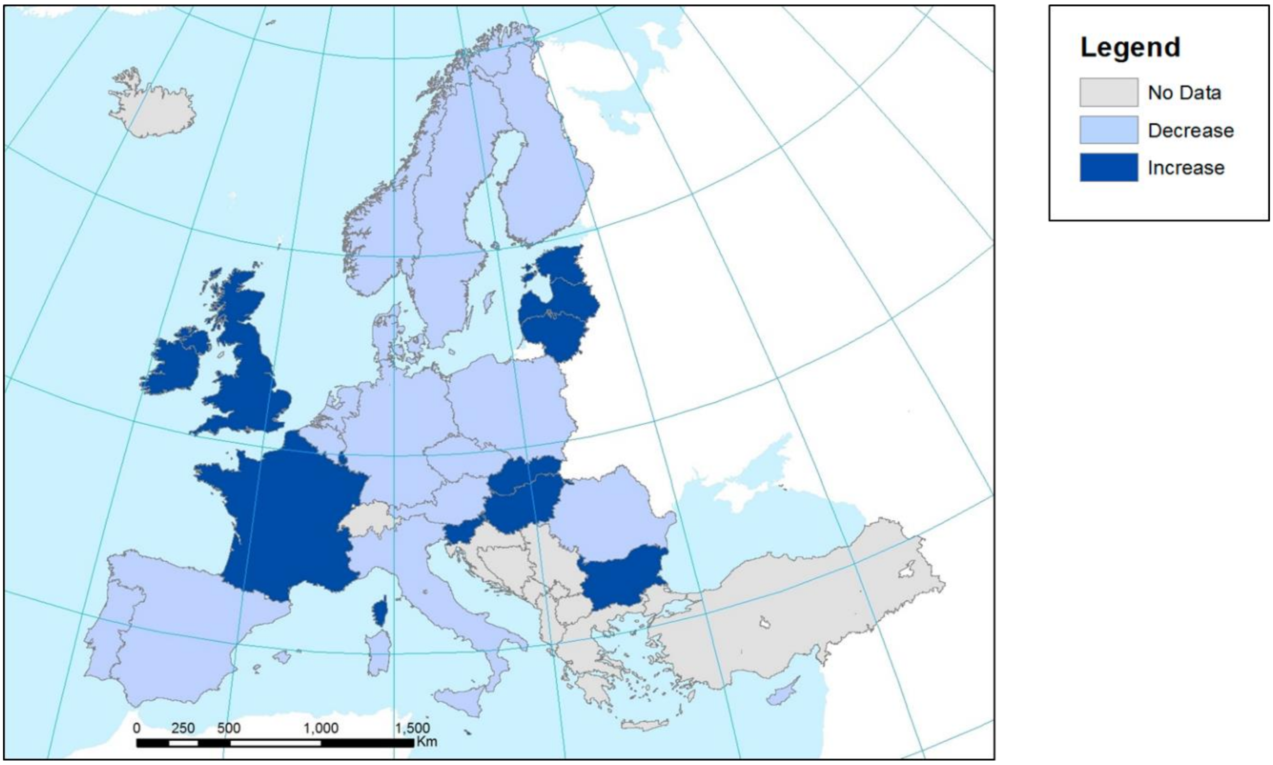


Data source: Eurostat, 2016d

As for the regional pattern of changes (percentage) in utilized crop areas and irrigated areas per country, increases have been observed within the irrigated area particularly in Latvia (528.9%) followed by

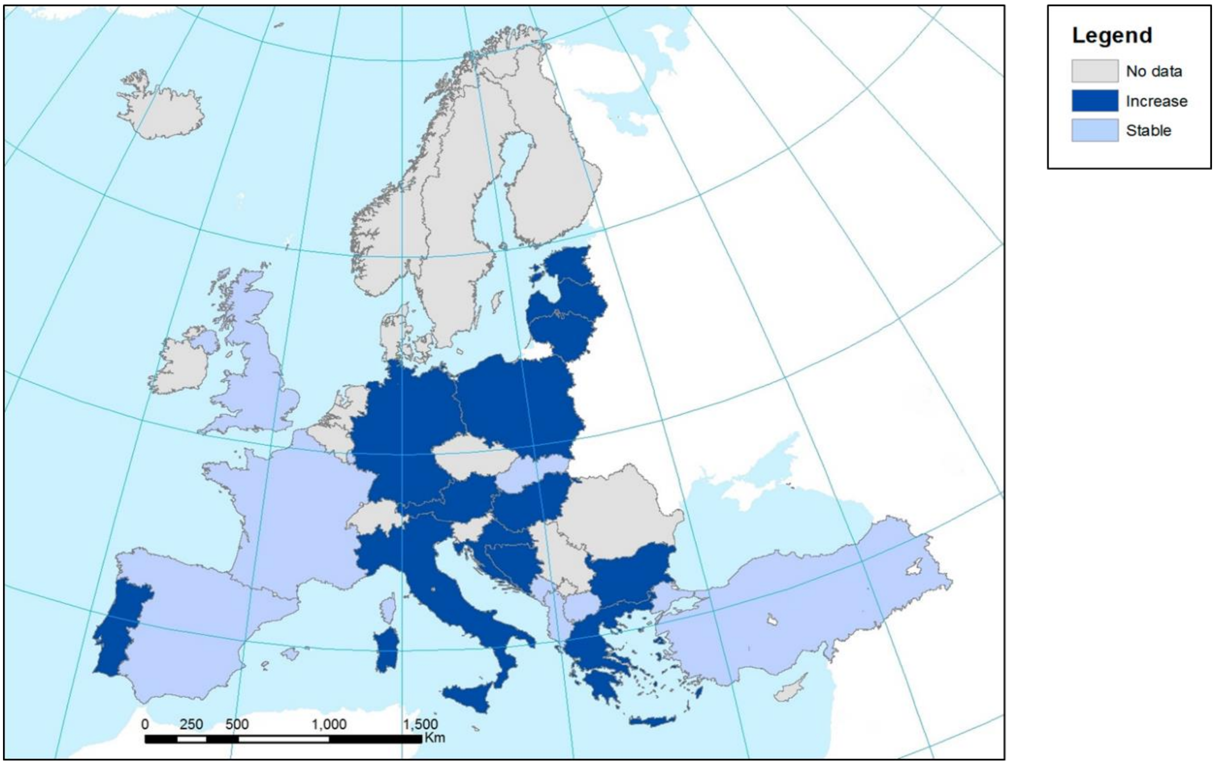
Lithuania (186.9%), Portugal (82.7%), Austria (31%), Italy (17.3%), Germany (4.9%) and Bulgaria (4.5%), (Map 5.1 and Map 5.2).

Map 5.1 Changes (%) in utilized crop area between 2002 and 2014



Data source: Eurostat, 2016h

Map 5.2 Changes (%) in irrigated area between 2002 and 2014



Data source: Eurostat, 2016h

The above mentioned countries except Bulgaria mainly abstract groundwater resources in irrigation practices. Therefore, increasing changes/use in irrigated areas in those countries would also increase pressures on groundwater resources in the coming years.

There is no sufficient data available to develop scenarios for illustrating different conditions of water use and agriculture. The time series of water accounts used in this analyses covers only thirteen years (2002–2014). However, longer time series are needed to derive more robust outputs for future developments in water (quantity) accounting. Nevertheless, even though a no change scenario for the crop area and the irrigated area would be adopted for the coming years[17], the climatic analyses generally results with three major conclusions which may have a negative impact on renewable water resources in Europe particularly in a water irrigation context;

- Due to climate change impacts irrigation water requirement would be increased by up to 20% compared to today's level, particularly in southern Europe (EEA, 2014b).
- Decreasing trend in precipitation in southern of Europe associated with rising temperature has already affected soil-moisture content in the Mediterranean (EEA, 2015e).
- Thermal growing season has already lengthened by 11.4 days on average from 1992 to 2008. This has resulted in an expansion of the growing season northward (EEA 2012a) as well as shortening crop growth phases (EEA 2012b).

All these forecasts indicate that it is still early for deriving a conclusion of a decoupling between the irrigated area, irrigation water and total crop production in many parts of Europe.

5.2 Water collection, treatment and supply

In many cases, water abstraction from surface or groundwater resources has to be treated (e.g. filtration and removal of sediments from the water etc.) before being supplied to houses and industries. After the use of water by households or industries, the water is returned either directly back to the environment without treatment or treated by urban waste water treatment plants before being discharged back into the environment. While the first part of water processing and distribution is known as water treatment and supply, the second part is very much linked with waste water management.

Water is supplied either by public institutions such as municipalities or by individuals (self-supply) in the case there is no public water supply service provided. In many cases, the services of water collection, treatment and supply are provided by private companies. For instance, almost 100% of water supply in the United Kingdom is provided by private companies while in the Netherlands all water is supplied by public bodies. In France 71% and in Germany 33% of water is supplied by private companies (McMahon, 2013). Population ratio connected to the public water supply system[18] varies between 80 and 100% in many European countries. However, three countries provide public water supply below 80%; Lithuania (76%), Romania (62%) and Bosnia and Herzegovina (56%).

The water collection, treatment and supply sector in practice is for water being supplied to households and also to other business and industrial entrepreneurs located within settlement areas. However, water supply to households would cover a major portion of the water collection, treatment and supply sector. Water is used by households mainly for drinking, cooking, daily hygiene, recreational activities etc. The hierarchy of water requirements by household activities is shown in Figure 5.7.

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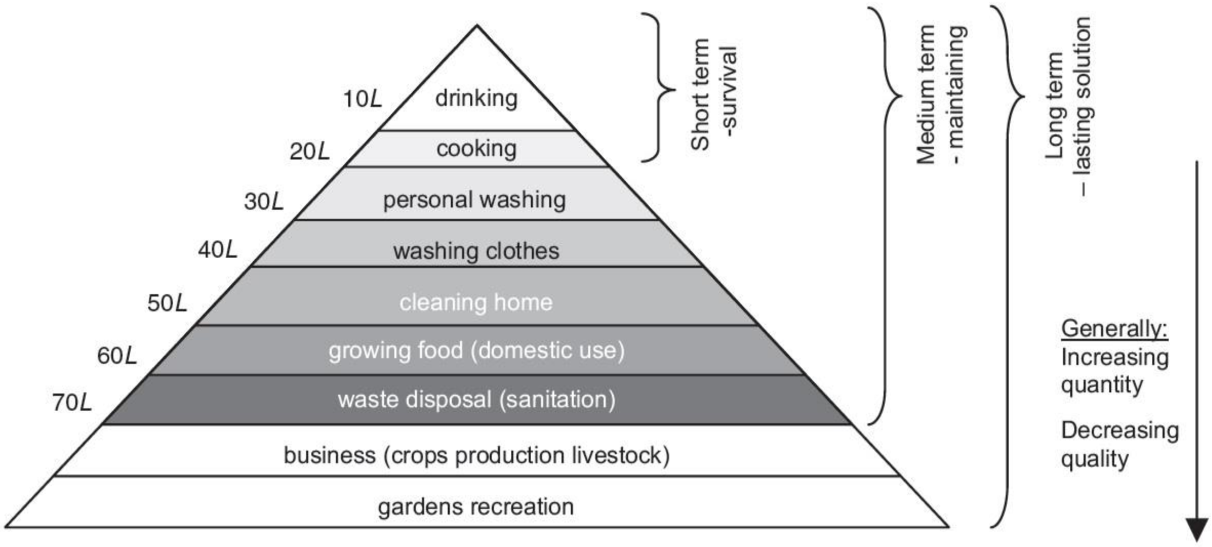
[17] No change in the agricultural area is not an objective or realistic scenario. A recent EEA publication (EEA 2013) indicates that agricultural zones are disappearing in favor of the development of artificial surfaces. Relative contribution of arable land and permanent crops to urban and other artificial areas are estimated at 45.7%.
[18] Data source; Population connected to public water supply.

Figure 5.7 Hierarchy of water demand for household's activities



Source: Reed, 2005

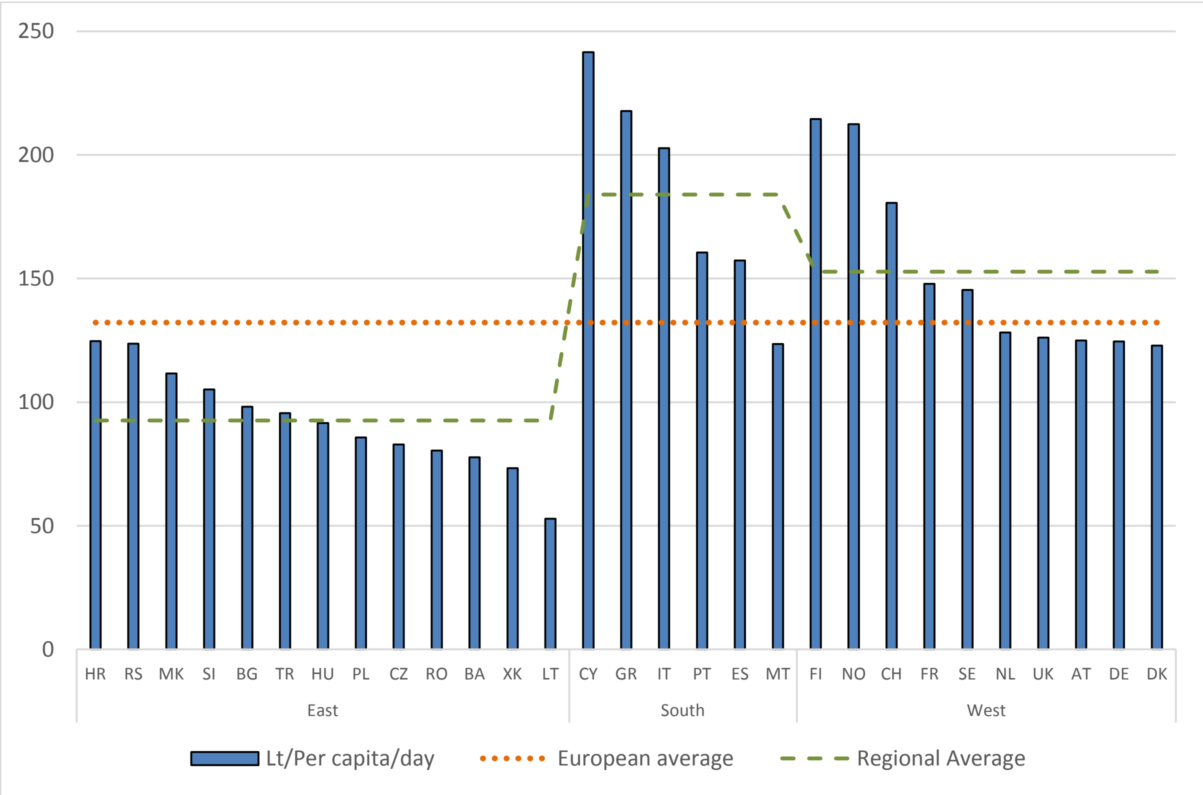
Based on the hierarchical water requirement schema, it can be concluded that two major drivers are controlling water demand for households; population growth and water use per capita or in other terms, water use efficiency at the individual level. While the first driver is creating pressures on water resources, the second is very much linked with resource efficiency.

World Health Organization (Reed, 2005) suggests about 20 litres of water to be provided per capita per day, should be assured to take care of basic hygiene needs and basic food hygiene. Laundry/bathing might require higher amounts unless carried out at source (WHO, 2016). There are also many other suggestions on basic water requirements for household activities. For instance, (Gleick, 1996) has estimated around 50 lt/person/day should be the basic water requirement. According to Gleick, 5 lt is required for the minimum amount of drinking water, 5 lt and 20 lt for basic requirement concerning sanitation and 10 lt for food preparation ([19]).

The European average on water supply per capita is around 124 lt/person/day (Figure 5.8). However, this average value greatly changes from one country to another. Iceland provides the highest water supply per capita with 529 lt followed by Finland (214 lt/person/day) and Norway (212 lt) both of which can be counted as water abundant countries. Cyprus (241 lt/person) and Greece (217 lt/person), Switzerland (180 lt), Portugal (160 lt), Spain, France and Sweden (130 lt) are those countries slightly above the European average.

[19] Flushing toilets may require up to 70L per person/day

Figure 5.8 Water supply for households per capita in Europe



Data source: Eurostat, 2016o, 2016k

Looking into the regional pattern in terms of water supply per capita on an annual scale, show that the highest volume of water is supplied to southern Europe, compared to population hosted, while the lowest water supply per capita occurs in Eastern Europe (Table 5.2). Climate conditions and tourism would play a significant role in this overview in relation with southern Europe.

Table 5.2 Regional total water supply compared with the population distribution among European regions

Region	Population (%)	Water supply (%)
East	31.3	21.9
South	21.4	30.1
West	47.3	48.0

Data source: Eurostat, 2016o, 2016k

5.2.1 Pressures of tourism on water abstraction

Water abstraction for tourists

Europe receives high numbers of tourists on a global scale every year. Annually, around 900 million nights spent abroad occur in many tourist destinations across Europe, which are contributing substantially to Europe's economy. While this sector is crucially important for the economy, it involves demanding activities on natural resource in which water is one of the major assets. From an environmental accounting point of view, major tourism related activities such as hotels and restaurants are counted as part of the service sector, within the economic sectors classification. However, tourism in the context of water is a cross-cutting sector relating to service and water collection treatment and supply activities. A tourist uses water for personal reasons such as drinking, taking a shower, cooking etc. from water collection, treatment and supply but, also for recreational activities such as swimming, golf and other similar activities which all fall under the service sector ([20]). Hence, water abstraction for tourism should explore the pressure of tourism on water collection, treatment and supply as well as the service sector.

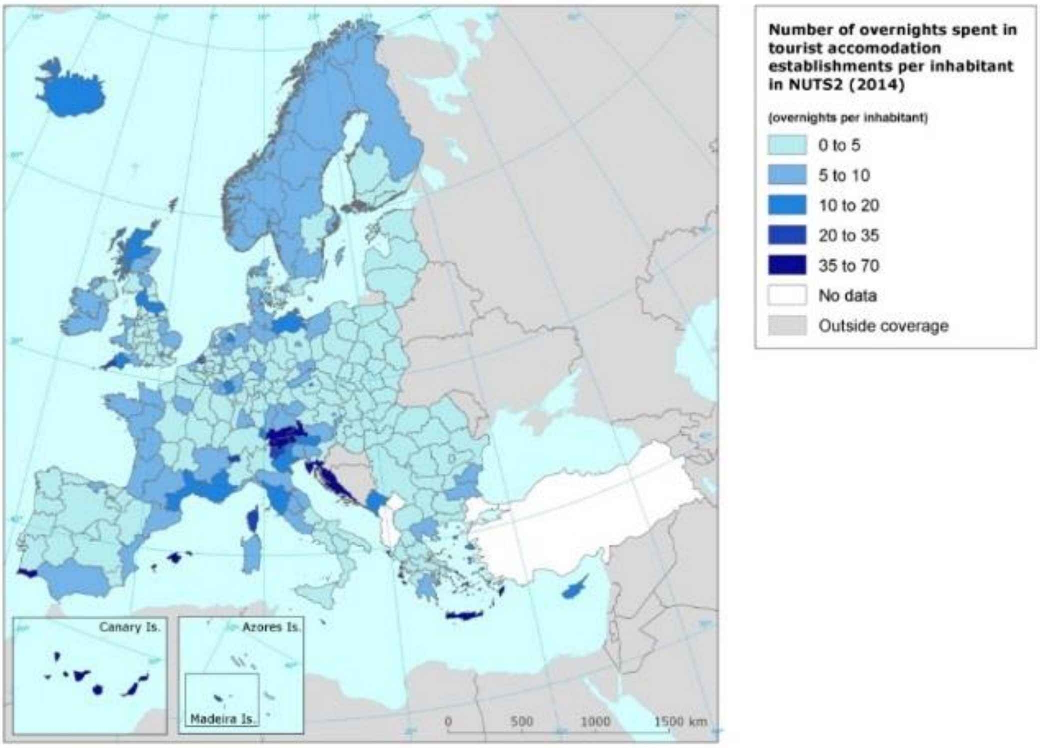
The service sector alone uses 9% of the total water used in Europe ([21]) compared to agriculture (59% in summer months). As this figure illustrates the European scale of conditions, thus it might be misleading in respect to particular local circumstances in terms of water scarcity. Tourists are not evenly distributed across Europe. Tourist statistics are collected based on the number of tourist nights spent in a location due to the temporal nature of accommodation. By following attractive places and "good weather", almost 75% of total nights spent are located in few locations across Europe. For instance, the Canary Islands received the highest number of overnight stays in tourist accommodation in 2014. The second most popular destination was the Italian region of Veneto and third the French capital region of Île de France. The regions with inbound tourists, were generally regions with major cities e.g. in the United Kingdom (London), Alpine regions (Tirol) or coastal regions (e.g. Crete). Every year Cyprus, Malta and Croatia receive a number of tourists equal to 5–7% of their total population.

As population is one of the drivers of water use, the contribution of tourists into the local residence can be taken as a portion of water abstraction by households. Comparing the number of tourists coming to a certain area with the local residents on a monthly scale revealed that small Mediterranean islands and the Alpine region are under the heavy pressure of tourist intensity. Tourism intensity is 5–9 times more during the summer months in many Mediterranean islands from Greece, Croatia and Spain (Map 4.3). Similarly, selecting tourist density (number of tourists per km^2) those areas that receive more than one million nights spent per year more or less point out to the same locations (Map 4.4) as hot spots in Europe.

[20] Hotels and restaurants which are mainly attached to the tourism sector are counted within the service sector. However, the service sector, along with hotels and restaurants, contains water abstraction and use by a broad range of economic activities such as repair of motor vehicles, education, social work, private households, transport, storage and communication etc. (OECD 2016). Thus, it is not possible to distinguish the share of hotels and restaurants within sectorial water use, if there is no such specific data collection for those particular activities. Even though such data would be available, again, knowing the share of tourists in that would not be easy to harvest. On the other hand, tourists – in many cases use the same water supply infrastructure developed for meeting water demand of local residents. Therefore, it is not easy to separate the tourism pressure over the water collection, treatment and supply sector which is generally supplying water to the residential areas.

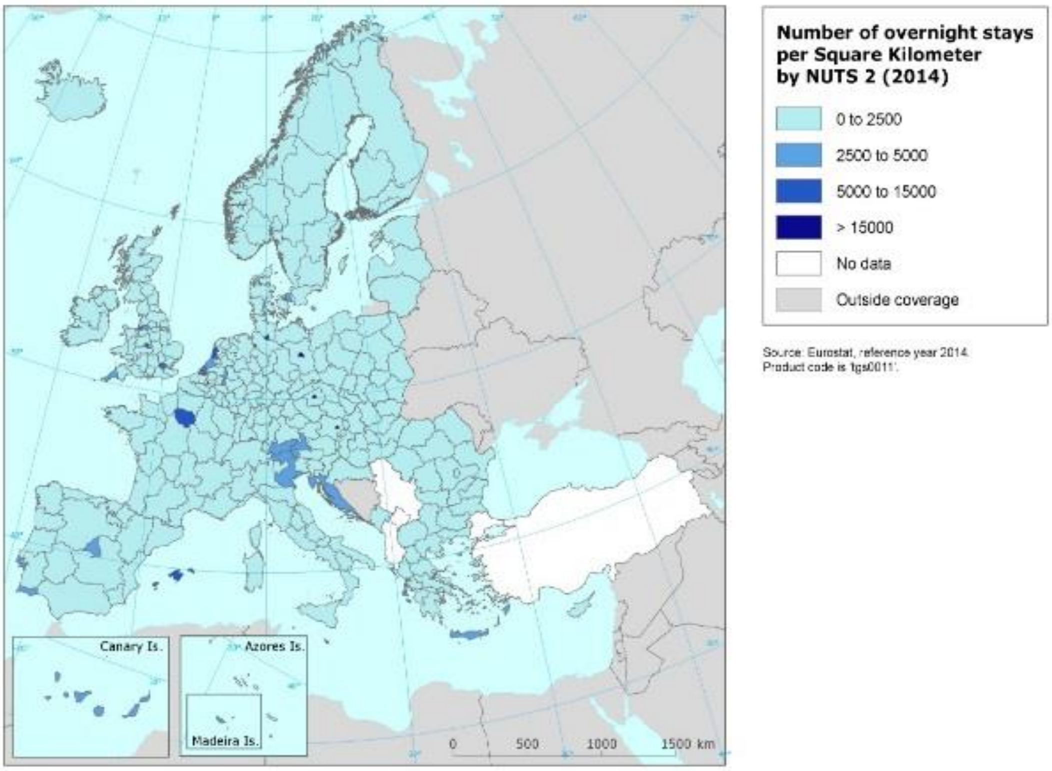
[21] CSI 018 Indicator Assessment

Map 5.3 Number of overnights spent in tourist accommodation establishments per inhabitant in NUTS2 (2014)



Source: EEA, 2017

Map 5.4 Number of overnight stays per square kilometre by NUTS2 (2014)

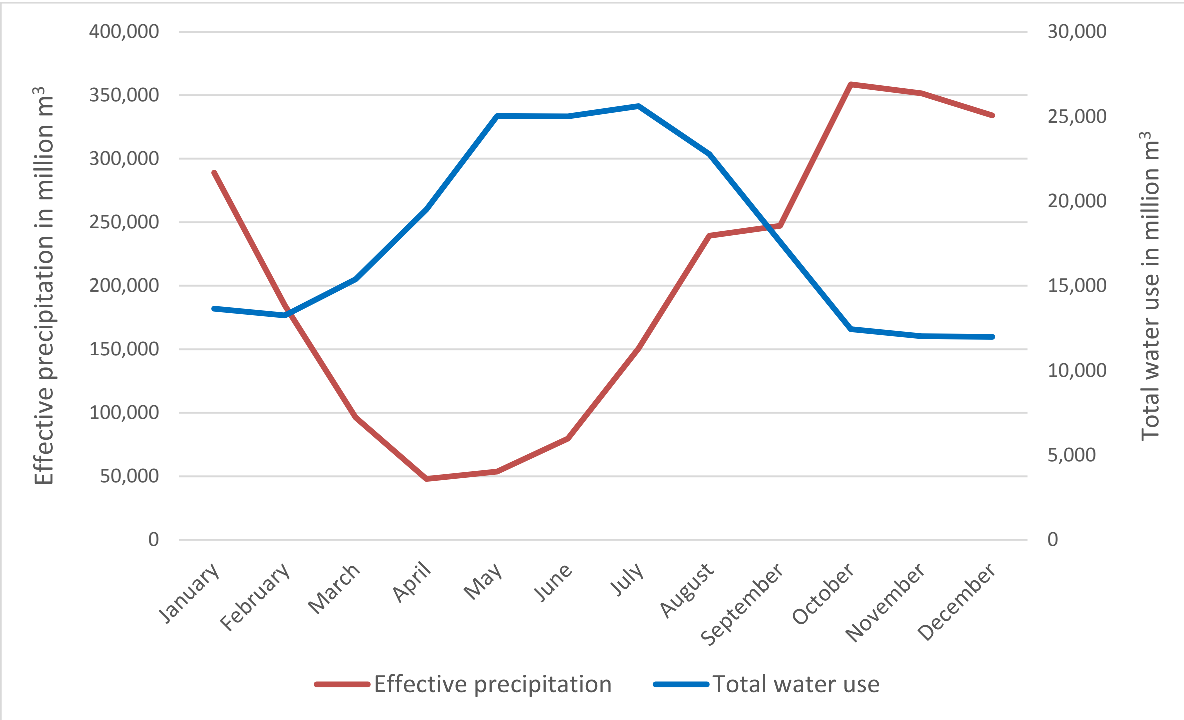


Source: EEA, 2017

Seasonality is also a very important aspect of tourism movements across Europe which condenses water use by tourists in certain months e.g. July or August. For instance, coastal areas and islands of the Mediterranean region are mostly concentrating their number of tourists in summer months mainly from northern and eastern parts of Europe while mountain areas such as the Alps, Scandinavian mountainous areas and the Carpathians receive millions of tourists during summer and winter.

Around 60% of tourists visit Europe during the summer, while the rest (40%) visit in the winter. Receiving around 560 million nights spent during a few summer months associated with this intense activity and low water availability at that time of year in a few particular locations is creating pressures on local water resources (Figure 5.9).

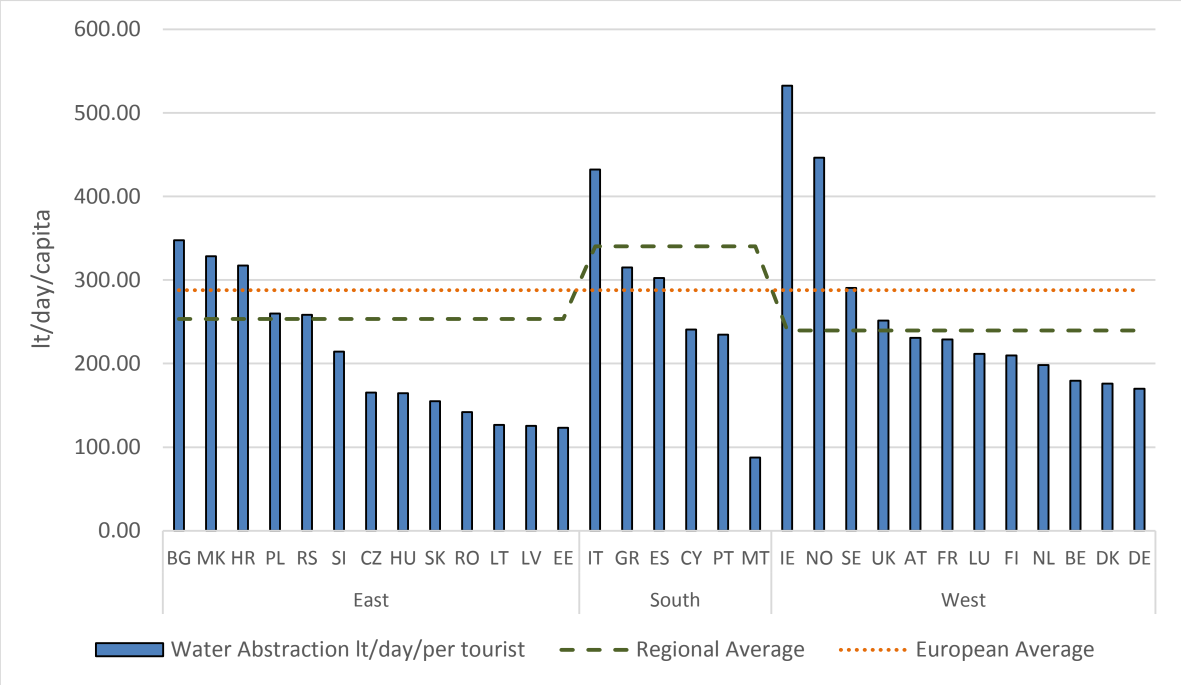
Figure 5.9 Effective precipitation versus water use by service sector and water collection treatment and supply sector in Europe (2002–2014)



Unfortunately, no data are available for assessing *"actual water use"* by individual tourists. However, using water abstraction for water collection, treatment and supply as proxy including water abstraction for the service sector as additional information, a rough quantification indicates that on average 287 lt/day/capita water is abstracted for each tourist in Europe. The highest water abstraction per tourist is abstracted in southern Europe (340 lt/day/per capita) followed by Eastern Europe (253 lt/day/capita). The most efficient water abstraction occurs in Western Europe with 240 lt/day/capita.

On a country scale (Figure 5.10), the highest water abstraction is in Ireland (532 lt/day/capita) followed by Norway (446 lt/day/capita) and Italy (432 lt/day/capita). The relatively lower water abstraction per capita is in Malta (87.5 lt/day/capita) followed by Estonia (123 lt/day/capita).

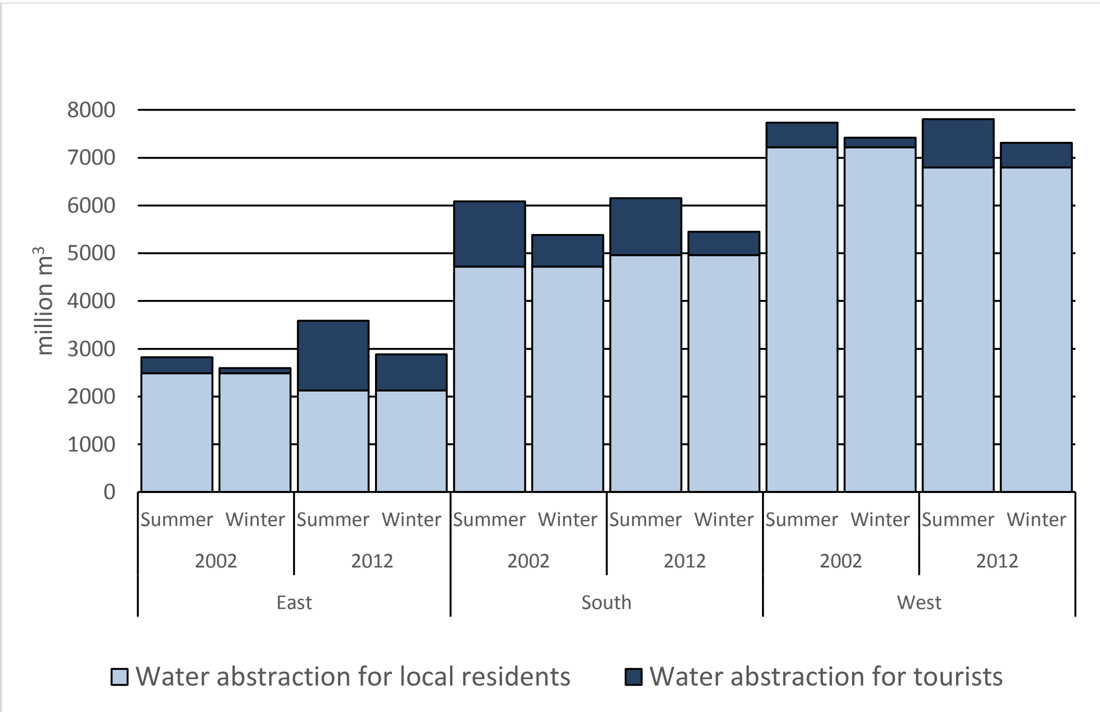
Figure 5.10 Water abstraction for tourists in Europe (lt/day/capita)



Data source: Eurostat, 2016c, 2016i

Between 2002 and 2012, water abstraction for local residents across Europe has decreased by around 3.8%. But, water abstraction for tourists has increased by 78% for the same period of time. Additionally, increases have been occurred in winter tourism particularly in Eastern Europe (Figure 5.12). Almost five times more water is abstracted in Eastern Europe compared to the level in 2002. Similarly, in Western Europe water abstraction for tourism has increased by around 150%. On the contrary, in Eastern and Western Europe, water abstraction for tourism in southern Europe has provided a decreasing trend (26% in winter and 13% in summer) (Figure 5.12).

Figure 5.11 Change in annual water abstraction for local residents and tourists in Europe (2002–2012)



Data source: Eurostat, 2016c, 2016i

Resource efficiency measures could be taken particularly in Eastern Europe for the water and tourism nexus. The number of tourists has increased by around 58% in Eastern Europe during 2002–2012. Despite that, water abstraction has increased almost four times more compared to the 2002 level (Table 5.3). Similarly, in Western Europe despite tourism having increased by 21.5 %, water abstraction for tourism has more than doubled.

Table 5.3 Change in water abstraction and number of tourists (2002–2012)

Region	Change in tourist night spent %	Change in water abstraction for tourism %
East	57.9	397.8
South	15.3	–17.1
West	21.5	112.9

Data source: Eurostat, 2016c, 2016i

Eventually, there is a decoupling observed between the number of tourists and water abstraction in southern Europe, while southern Europe still has the highest water abstraction per tourist.

The tourism peak areas require additional investments in developing water supply and treatment systems to tackle with high water demands for tourism. For instance, the population of the Balearic Islands (Spain) was around 1,115,000 (in 2014). These groups of islands receive approximately 2.5 times more tourists compared to the number of local residents.

The Spanish government has made investments in constructing urban waste water treatment plants with a capacity of around one million population equivalents despite the fact that the total urban population of the islands is around 190,000. Similarly, Adriatic coastal areas of Croatia (Jadranska/Hrvatska region) have around 320,000 (total population -urban and rural- is about 1,400,000). The installed capacity of the urban waste water treatment plant for this region is over 1.5 million population equivalent (EEA, 2012g). In addition to that, in many cases, meeting such high water demand for tourism require additional water supply measures to be taken such as inter-basin water transfer, desalination of sea water or over exploitation of local resources particularly groundwater resources which result with irreversible environmental impacts. Taking into account that seasonality is a characteristic shared by several of the world’s leading tourist destinations (i.e., Canary Islands, French coasts, etc.), and those major efforts are being made by local governments to reduce it, an analysis of its potential effects on water consumption is fundamental.

Water abstraction for golf courses

Text box 5.1: Balearic Islands: Mallorca

Source: Deyà Tortella, and Tirado, 2011

The Balearic Islands form an archipelago in the western Mediterranean Sea, off the east coast of the Iberian Peninsula. The archipelago is composed of four main islands (Mallorca, Minorca, Ibiza and Formentera), as well as a number of practically uninhabited smaller islands. The archipelago covers a total area of about 5,000 km^2, with more than 1.1 million residents (in 2014). The island of Mallorca is not only the archipelago's largest (3,600 km^2), and the most heavily populated island (78.7% of the archipelago's total population), but it also receives the most tourism, accounting for 75.3% of all tourists and 70.2% of all accommodation rooms in the Balearic Islands.

As a result, Mallorca has the highest water consumption level (82.5% of the Balearic's total water use).

Raw water use and water sources per sector and island (Hm^3/year).[a]

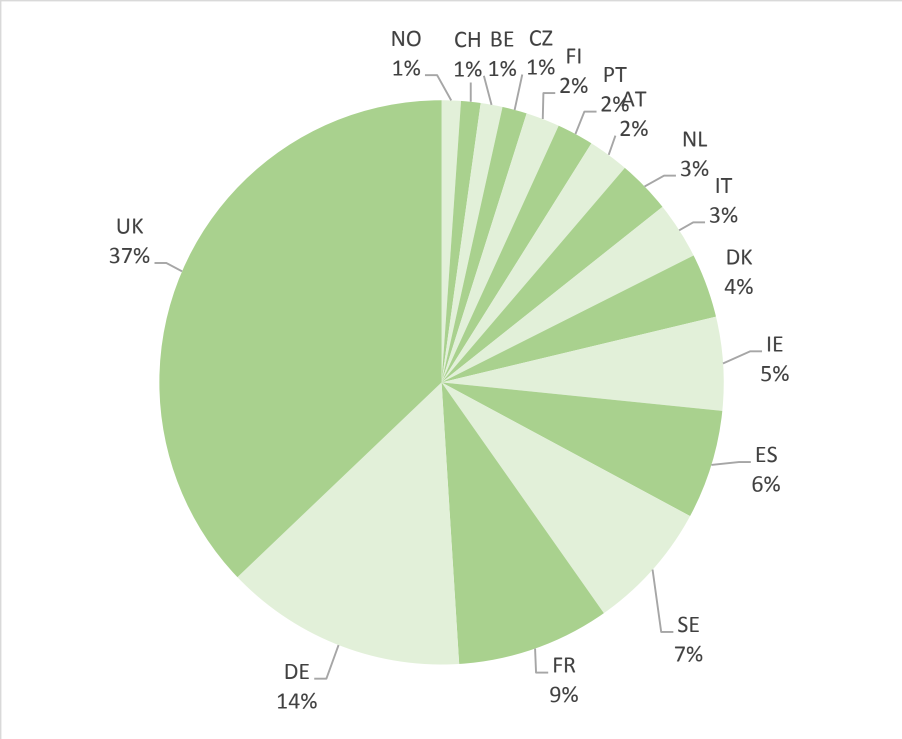
		Mallorca	Minorca	Ibiza	Formentera	Balearic Islands	Consumption Share(%)
Public Consumption	Underground	79.3	12.9	7.9	0	100.1	
	Water Reservoirs	7.2	0	0	0	7.2	
	Desalinization	20.2	0	4.7	0.5	25.4	
	Total	106.7	12.9	12.6	0.5	132.7	*47.3*
Agro-Gardening[b]	Underground	19.3	1.8	3.3	0.5	24.9	
	Total	19.3	1.8	3.3	0.5	24.9	*9*
Industry	Underground	0.8	0.1	0.1	0	1	
	Total	0.8	0.1	0.1	0	1	*0.3*
Irrigation and livestock	Underground	81.2	5.6	10.1	0.1	97	
	Wastewater Treated	16.9	1	0.1	0.1	18.1	
	Total	98.1	6.6	10.2	0.2	115.1	*41*
Golf irrigation	Underground	0.3	0	0	0	0.3	
	Wastewater Treated	4.3	0.2	0.2	0	4.7	
	Total	4.6	0.2	0.2	0	5	*1.8*
Others[c]	Wastewater Treated	1.8	0	0	0	1.8	*0.6*
Total		*231.3*	*21.6*	*26.4*	*1.2*	*280.5*	*100*
Island Share (%)		*82.3*	*7.7*	*9.4*	*0.4*	*100*	

[a] Elaborated from data of the draft Hydrological Plan of the Balearic Islands (GIB, 2008).
[b] Public consumption not connected to the public water network.
[c] Public gardens/parks irrigation.

Golf courses serve as recreational facilities to attract tourists. Over decades, water abstraction and use for golf courses have been one of the longest lasting discussions within public circles. Currently, there are around 8,000 golf facilities in Europe. In addition to that, golf tourism has increased in popularity and the number of golf courses has grown rapidly in recent years. The average area of golf facilities is approximately 40 ha. However, the size is site depending and showing great variation from 10 m^2 to 700 ha. The United Kingdom hosts 35 % of all golf courses (by area) in Europe ([22]) followed by Germany (13%), France (8%), Sweden (7%), Spain (6%) and Ireland (5%). These six countries possess ¾ of all of the golf facilities in Europe (Figure 5.13).

[22] European Topic Centre ULS has extracted the data on golf courses from OpenStreet Map Data Extracts combined with NUTS Administrative units / Statistical units

Figure 5.12 Golf courses by area in Europe



Source: EEA, 2017

According to the report from Randa (Randa.org) golf facilities around the world have expanded, including in Europe. In the coming years, Europe will have around 160 new golf facilities. Between 1985 and 2010, around 3,000 new golf courses have been established in the USA and the EU with much of this development in areas with limited water resources (Gössling et al, 2012). Future development of new courses is anticipated to be strongest in China, the Middle-East, South East Asia, South Africa and Eastern Europe; many of which are expected to face water shortages in the decades ahead (Arnell, 2004; Bates et al., 2008). All these developments show that golf courses are increasingly becoming popular around the world. However, this increased popularity has major impacts not only on water quantity but also pollution generation (e.g. use of pesticides) and land occupation. If resource efficiency would not be improved, golf courses would cause the increase of water scarcity conditions on a local scale in some parts of Europe, particularly in the Mediterranean in the coming years.

There is no specific data collection on a European scale for water irrigation of golf courses. Thus, the assessment of water abstraction or water use by golf courses requires the use of some proxies. However, it is already known that golf courses require high volumes of water every day particularly in the active season. Water use by golf courses varies considerably, depending on soils, climate and golf course size (Baillon & Ceron, 1991; Ceron & Kovacs, 1993). For instance, a standard golf course may have an annual consumption of 80,000 m^3 to 100,000 m^3 in the North of France and 150,000 m^3 to 200,000 m^3 in Southern France. Much higher values can be found in dry and warm climates. For instance, van der Meulen and Salman (1996) report that an 18-hole golf course in a Mediterranean sand dune system is sprinkled with 0.5 to 1 million m^3 of fresh water per year.

Text box 5.2: Golf course irrigation needs

Golf course maintenance may deplete fresh water resources. In recent years golf tourism has increased in popularity and the number of golf courses has grown rapidly. Golf courses require an enormous amount of water every day and, as with other causes of excessive extraction of water, this can result in water scarcity. If the water comes from wells, over pumping can cause saline intrusion into groundwater. Golf resorts are more and more often situated in or near protected areas or areas where resources are limited, exacerbating their impacts.

In the hot, dry, tourist-filled summer months, even greater quantities of water are used to clean the streets, feed the gardens and fill the pools, in order to maintain the area as an attractive tourist destination. On top of this, the huge swell in the local population over this period places even greater stress on the level of domestic water-use.

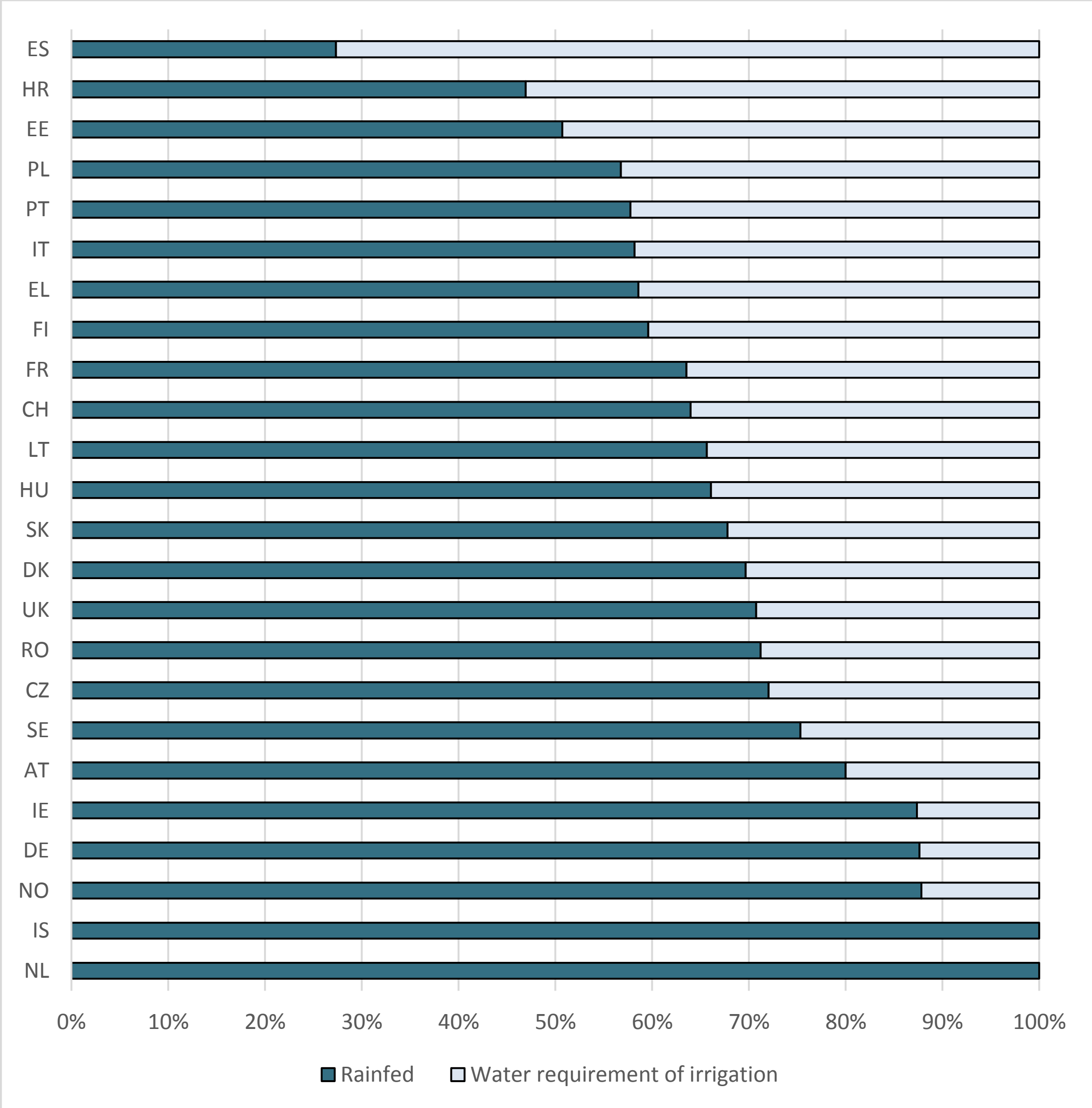
In water-stressed locations, golf courses have to compete for the water resources with rising domestic demands and existing uses, which are predominantly agricultural (EEA, 2009). For this reason and because golf course irrigation is perceived to provoke significant additional abstraction and, thus, major impacts on the environment and other abstractors, golf course developments have often been the subject of controversy, especially in countries where water resources are under stress (Markwick, 2000; Rodríguez et al.,2007).

In order to reduce water consumption associated to golf courses, some more recent research has been carried out to ensure self-sufficiency. In the case of golf courses associated to residential developments, to estimate the number of dwelling units needed to ensure self-sufficiency of the golf course in irrigation, i.e., that it can meet its irrigation needs entirely with the effluent of the associated dwellings (Ortuno et al., 2015). In fact, the transfer of water from agriculture to golf is widely criticized and a highly contentious political issue (Rodríguez et al., 2011). Spain provides a good example of the competition for water resources that exists between agriculture and golf course facilities. The average irrigation of golf courses in the Alicante province and the Region of Murcia is approximately 7,800 m^3/ha (Ortuno et al., 2014). This figure reflects an acceptable adjustment between the theoretical irrigation needs and the actual consumption, which shows the high efficiency in control and irrigation systems.

These results are consistent with those obtained in other studies, which estimated that the average annual water consumption of a golf course in Spain, excluding the Canary Islands, was 8200 m^3/ha (Rodríguez et al., 2007) and approximately 7,653 m^3/ha for Almeria, Murcia and Valencia (Sanz, 2005).

Mediterranean countries e.g. Spain, Croatia, Portugal, Italy etc. due to a high water deficit during the summer months are faced with increased water demand for irrigating golf courses (Figure 5.14). In Spain, for instance, only 27% of the total water requirement can be met from rain, while the remaining 75% of the water requirement should be abstracted either from groundwater or surface water resources. Despite the ratio for water irrigation requirements being low in the UK, it is estimated that 60% of the actual total water abstraction for maintaining golf courses is used only in the UK.

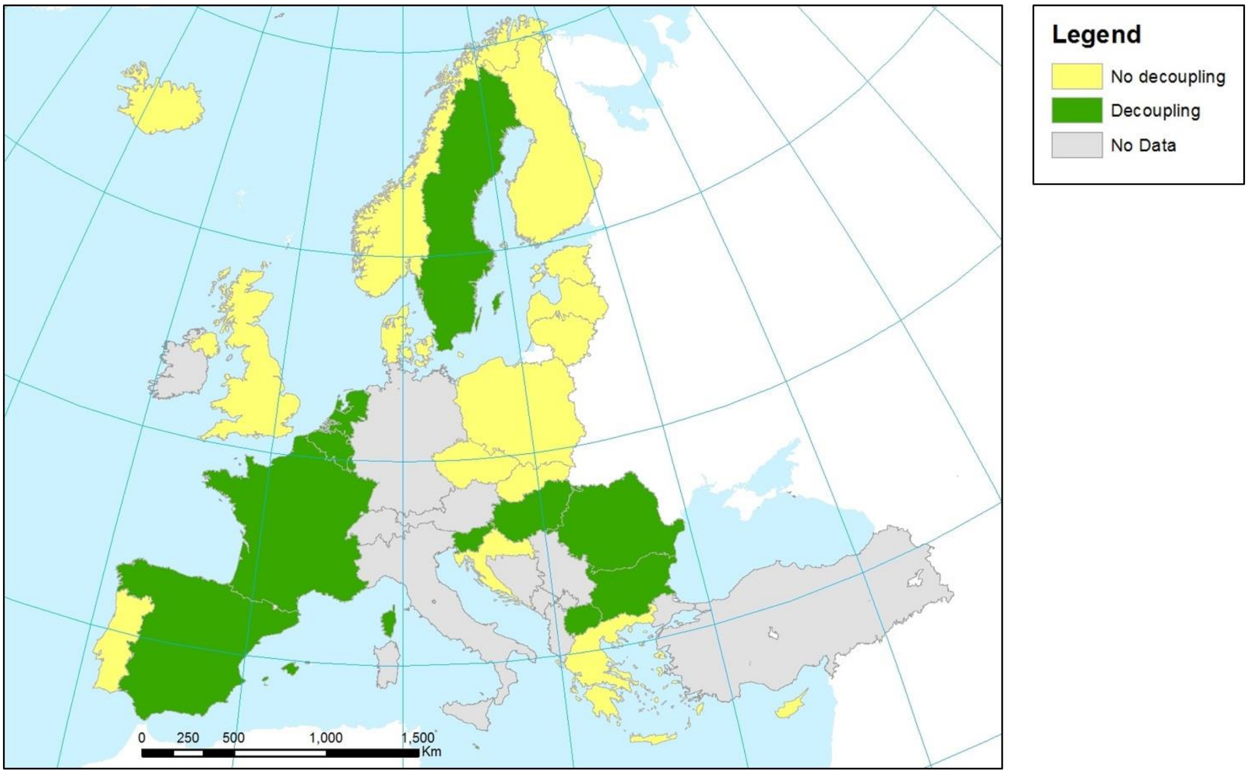
Figure 5.13 Ratio of theoretical irrigation need for golf courses in Europe (estimated based on Blaney-Criddle method)



However, the relation between water demands and available water resources are a controversial subject matter that has been linked to the residential expansion (De Stefano, 2004; Hernández, 2013). Based on the current developments with constructing new golf courses and the maintenance of the existing ones in Europe, water demand for the irrigation of golf courses should be expected to increase in the coming years.

Improving efficiency in total water abstraction and decoupling water abstraction from the number of tourists are crucial implementations in reducing the environmental impacts of tourism. For instance, in Spain, France and Malta (Map 5.5), despite total water abstraction for tourism having been increasing over time, eventually decoupling relatively between water used from the number of tourists received has been initiated for almost 10 years ago. Similarly, in Bulgaria for example, despite the number of tourists has been increasing over the years, due to the decreases in the total population of Bulgaria, it doesn't have any significant impacts on water abstraction. Romania, Slovenia, Hungary and Sweden are also among those countries having relatively decoupled the number of tourists from water abstraction per capita.

Map 5.5 Relative decoupling in water abstraction by tourism



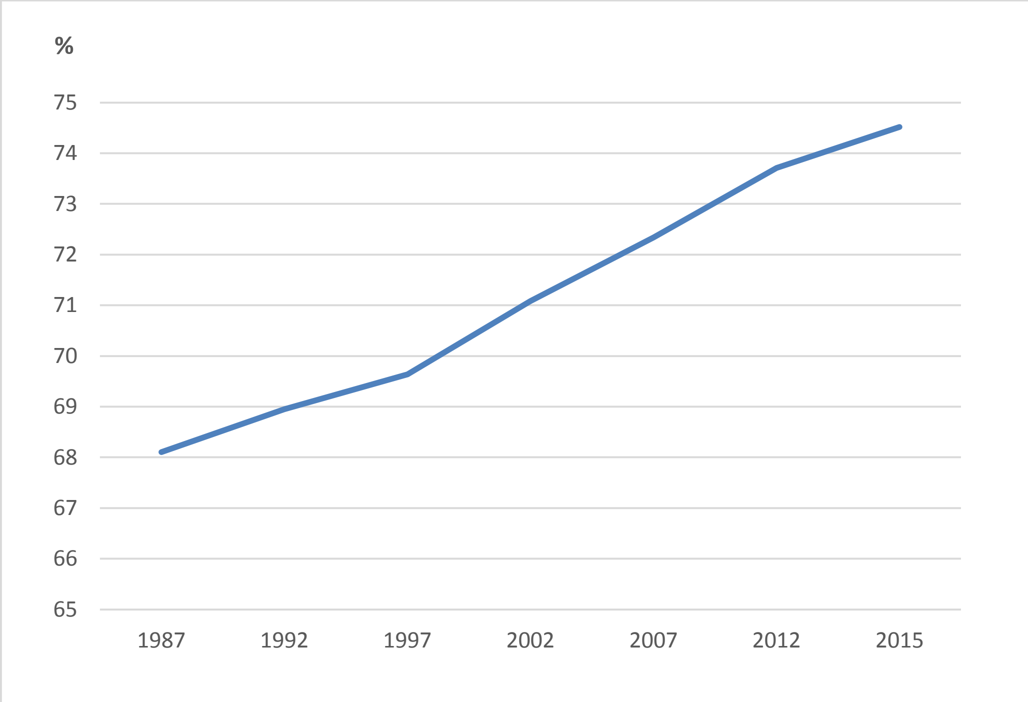
However, still many other countries could not achieve decoupling of water abstraction from the number of tourists received such as Greece, Cyprus and Croatia. Similarly, Iceland and Denmark including Norway are within the group of countries having made some progress towards decoupling.

5.2.2 Environmental impact of households on freshwater resources

Water abstraction, supply and use for household activities are mainly driven by population. The population pressure would cause over exploitation from freshwater resources. In addition to population growth, rapid urbanization becomes a fact in Europe increasing the population and population density in urban areas. For instance, the European population has increased by around 117 million (24%) over the last three decades (1987–2015)[23]. During the same period the urban population has increased by around 120 million (Figure 5.14).

[23] AQUASTAT

Figure 5.14 Change in urban population ratio in Europe (1987–2015)



Data source: FAO, 2016

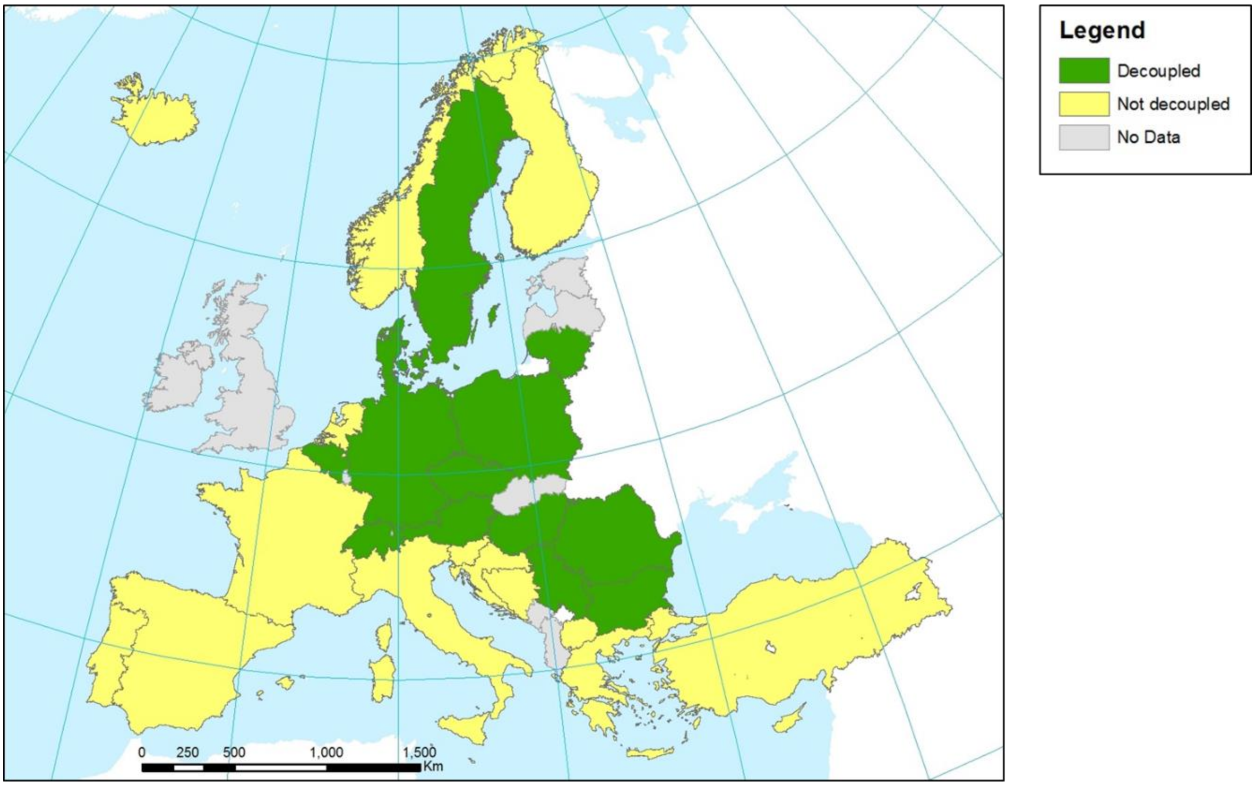
Rapid urbanization has also caused land uptake by urban areas from other land cover types particularly from agricultural areas and forests. It is assessed that the annual land uptake by urban areas between 2000 and 2006 in Europe was 108,000 ha/year (EEA, 2013a).

Due to the high mobility across Europe in recent years, as explained in the above chapters, tourism is also becoming a driving force in the increasing amount of water use by households. For example, the number of tourists travelling across Europe has increased by around 35% between 2002 and 2014.

A short assessment of water supply[24] to household activities based on the latest available data from countries around Europe has shown that thirteen countries could achieve relative decoupling between population growth and water supply (Map 5.6). For instance, Germany, Austria, Denmark, Poland, Sweden, Switzerland, Belgium, Czech Republic, Lithuania, Bulgaria and Romania have decoupled the water supply from their population growth. Despite the population decrease in both Romania and Bulgaria during the last few years, relative decoupling of the water supply from the population has also been achieved due to improvements in infrastructure of the water supply network.

[24] Data availability for water abstraction compared to water supply has better spatial and temporal coverage in Europe. However, comparing water abstraction with water supply would provide quite important information on leakage as function of resource efficiency in water resources management.

Map 5.6 Relative decoupling between water supply and population change in Europe



Data source: Eurostat, 2016o, 2016k

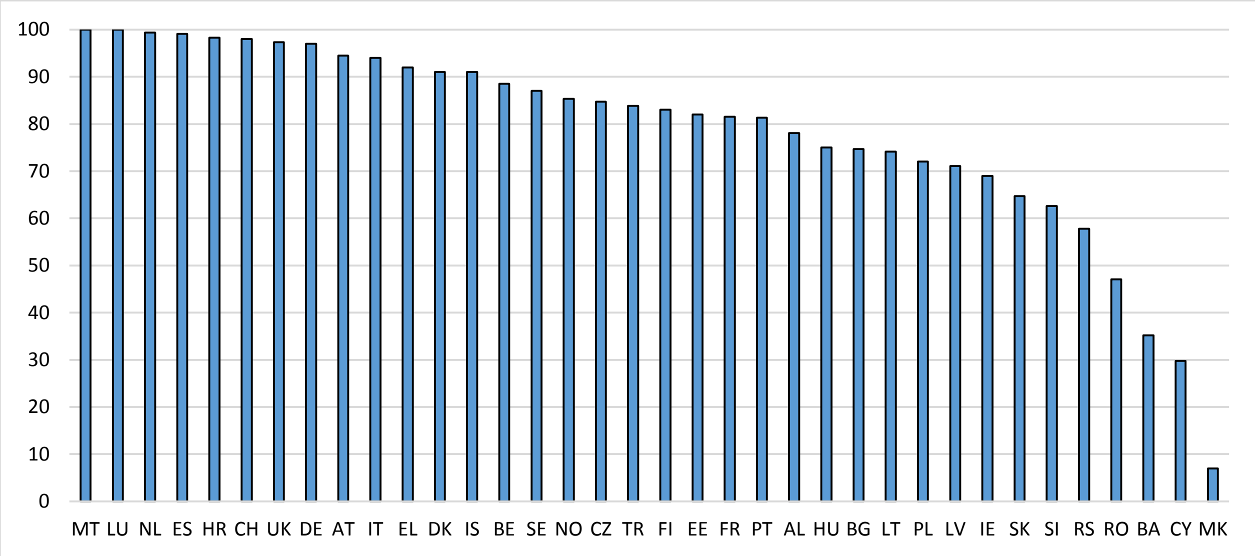
On the other hand, in those countries mainly located in southern Europe and other countries including Iceland, Norway, Finland and Turkey, no decoupling has been identified between population growth and the public water supply.

Water is returned back to the environment after its use by households. The returned water is discharged back into the environment either treated or untreated. Waste water treatment plants play a significant role in the reduction of environmental impacts of water use by households. Wastewater treatment in all parts of Europe has improved during the last 15–20 years. The percentage of the population connected to wastewater treatment in Southern, South-Eastern and Eastern Europe has increased over the last ten years. The latest figures of the population connected to wastewater treatment systems in southern countries are comparable to the values of Central and Northern countries, whereas the values of Eastern and South-Eastern Europe are still relatively low compared to Central and Northern Europe (EEA, 2013c).

Around 21% of population in average (2005–2014) is still not connected directly to urban waste water treatment plants in Europe (Figure 5.15)[25]. Although there are countries (e.g. Poland, Iceland, and Lithuania) which currently have independent waste water collection systems, via tanks transferred by means of tracks.

[25] Population connected to wastewater treatment plants the ratio of the population connected to water supply has been multiplied with the population of the respective country (Eurostat data) and compared with the population connected to UWWTP.

Figure 5.15 Population connected directly to urban waste water treatment plants

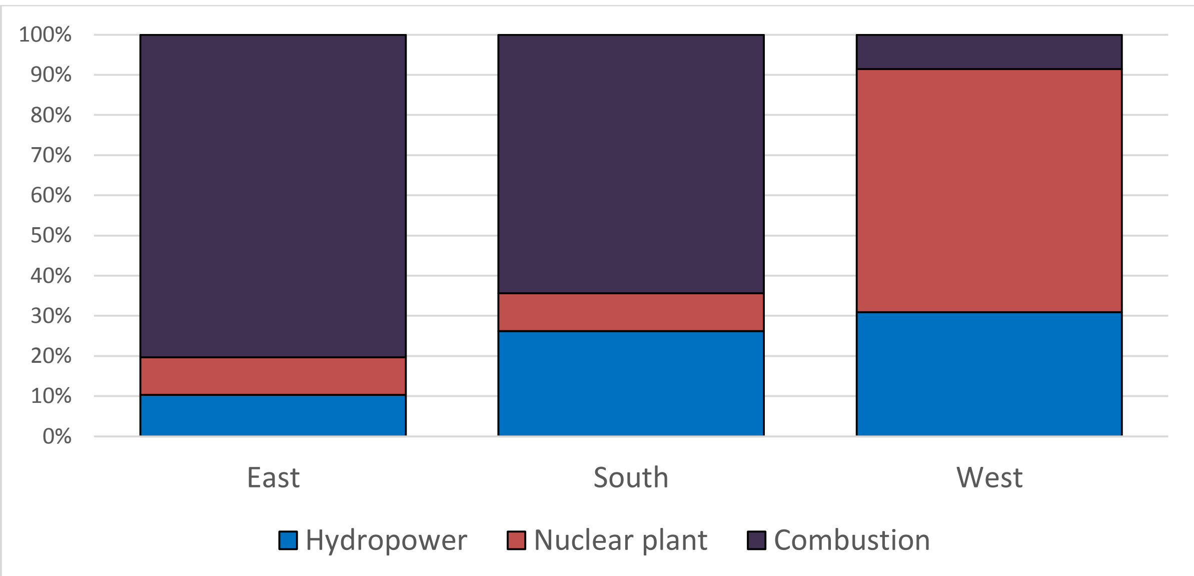


Data source: Eurostat, 2016j

5.3 Water abstraction for power generation

Water is used in the production of electricity by hydropower and it is used for cooling purposes by nuclear power stations and combustion plants. Therefore, there is a direct link between water abstraction and electricity generation. The regional pattern of electricity production by source substantially varies across Europe. Around 13% of all electricity in 2014 is produced by hydropower in the EU-28 (representing over 40% of all renewable electricity), while nuclear power plants produce 27% and fossil fuel combustion plants have a combined share of 40% of the total electricity production. In Western Europe around 60% of total electricity production is met by nuclear power plants while, in Eastern and Southern Europe combustion plants are used by 80% and 65% respectively. The share for hydropower is 30% and 25% within the total production of electricity in Western and Southern Europe (Figure 5.16).

Figure 5.16 Gross electricity production by source



Data source: Eurostat, 2016n

In general, hydropower is regarded as non-consumptive in a water use context. Indeed, water is returned back to the environment after being used in electricity production by hydropower. However, it has to be noted that this process is not impact-free on the environment and freshwater ecosystems. Water abstraction for hydropower deteriorates the natural water cycle in rivers and lakes (Text box 5.3).

Text box 5.3 Environmental impacts of hydropower in Scotland

Source: SEPA 2007

Large-scale hydropower schemes covering hundreds of square kilometres were created in Scotland in the late 19th and early 20th centuries. Many of these schemes divert water across catchments to dams which hold the water until energy generation is required. There are 23 major schemes in Scotland supplied by catchments covering over 8,373 km^2 of mainland Scotland. A further 74 small-scale hydropower plants (installed capacity <2 MW) are owned by private companies and individuals, and there is some potential for further development of such schemes. These small-scale schemes may remove water from a river, pass it through a turbine and return it back to the same river.

Although hydropower is an important source of renewable energy (and important in controlling carbon dioxide emissions), it causes major impacts on rivers in Scotland. Valuable improvements in the water environment could be achieved by moving existing schemes towards modern good practice without significantly affecting the amount of energy generated.

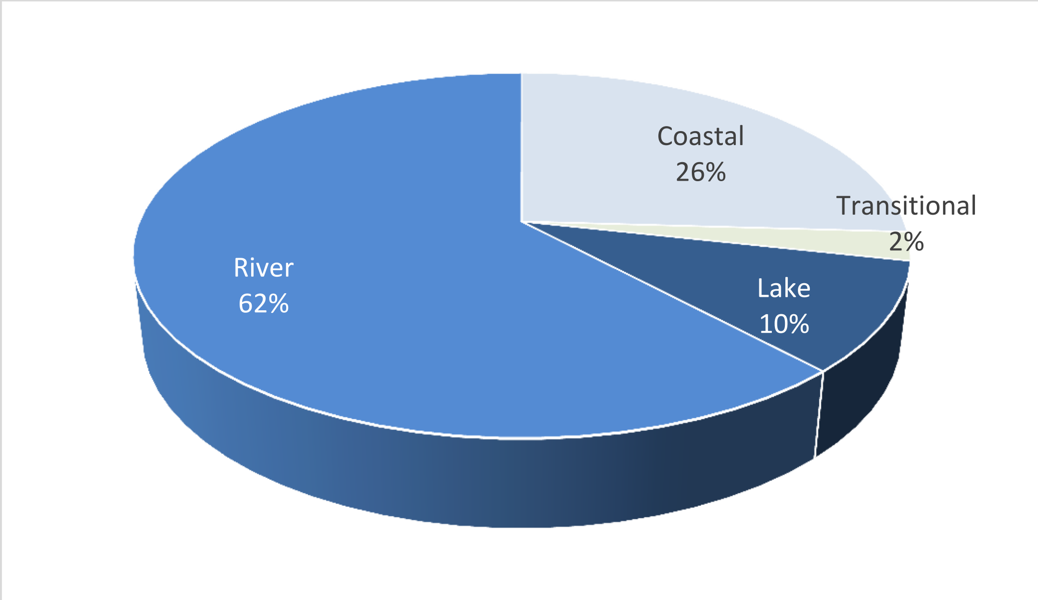
Main impacts

- Low flows in rivers which may be virtually dry except during periods of heavy rain.
- Highly variable flows below generating stations, resulting in bare banks and potential stranding of fish.
- Highly variable water levels in reservoirs leading to regular drying out of the shoreline, preventing the growth of plants and spawning of fish.
- Barriers to fish migration caused by dams and death of fish entering turbines.
- Interruption of flow of sediment downstream of dams depletes gravels needed by salmon and trout to spawn.
- Impacts upon the morphology of rivers and lochs caused by changes in flow and sediment transport.

Europe still depends heavily on fossil fuels and nuclear power in electricity generation (EEA, 2015c) with their significant demands of water abstraction. Water is used by different types of power plants e.g. nuclear power plants, gas or solid-fuel based combustion plants, for cooling purposes during the electricity generating process. On an annual scale, around 600 km^3 ([26]) of water is abstracted in Europe for the cooling of power plants. The water consumption factor due to the evaporation that takes place during cooling processes varies by power plant between 0.2m^3/MWh and 129m^3/MWh. In general, about 1.5% of total abstracted water is consumed via evapotranspiration. However, this ratio can reach up to 100% depending on the cooling system and fuel type of the individual installations. Rivers and lakes meet 74% of the total water abstraction for cooling in electricity production, while 24% of water is abstracted from coastal and transitional water on an annual scale (Figure 5.17). Water abstraction from groundwater for cooling seems very negligible, only around 0.03% of the total water abstraction for cooling purposes is used on an annual scale.

[26] According to the EC database, total water abstraction for cooling electricity is 180,000 hm^3; however this value is estimated based on “ValueHigh” which is defined as maximum water abstraction (electricity cooling provides results of water abstraction).

Figure 5.17 Water abstraction for cooling in producing electricity by power plants in Europe

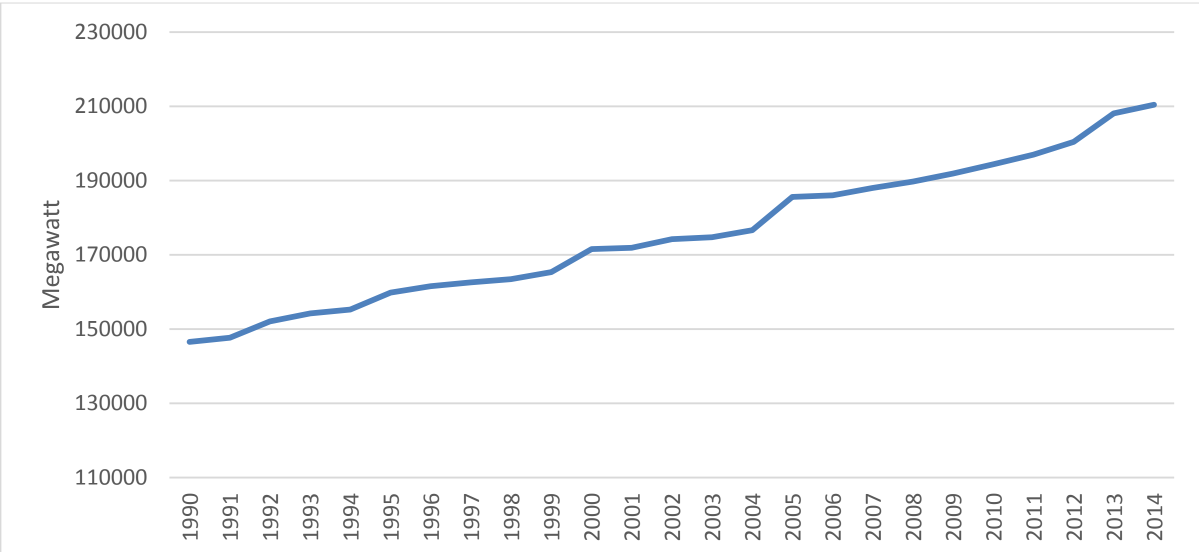


Data source: European Commission 2014[27]

The cooling process also increases water temperature, which is in turn a significant deterioration in the physical condition of water and has a number of consequences particularly on freshwater biodiversity. However, it should also be mentioned that all water that is used for cooling in power generation is not abstracted from just freshwater resources. Brackish (transitional waters) and sea water is also used in the cooling process, depending on the location of the power plant.

Electricity production and the share of electricity generated from renewable sources is growing rapidly in Europe (EEA 2016). In parallel with this trend, capacity for electricity production by hydropower has increased by 39% between 1990 and 2014 (Figure 5.18).

Figure 5.18 Development with hydro-electrical capacity in Europe (1990–2014)

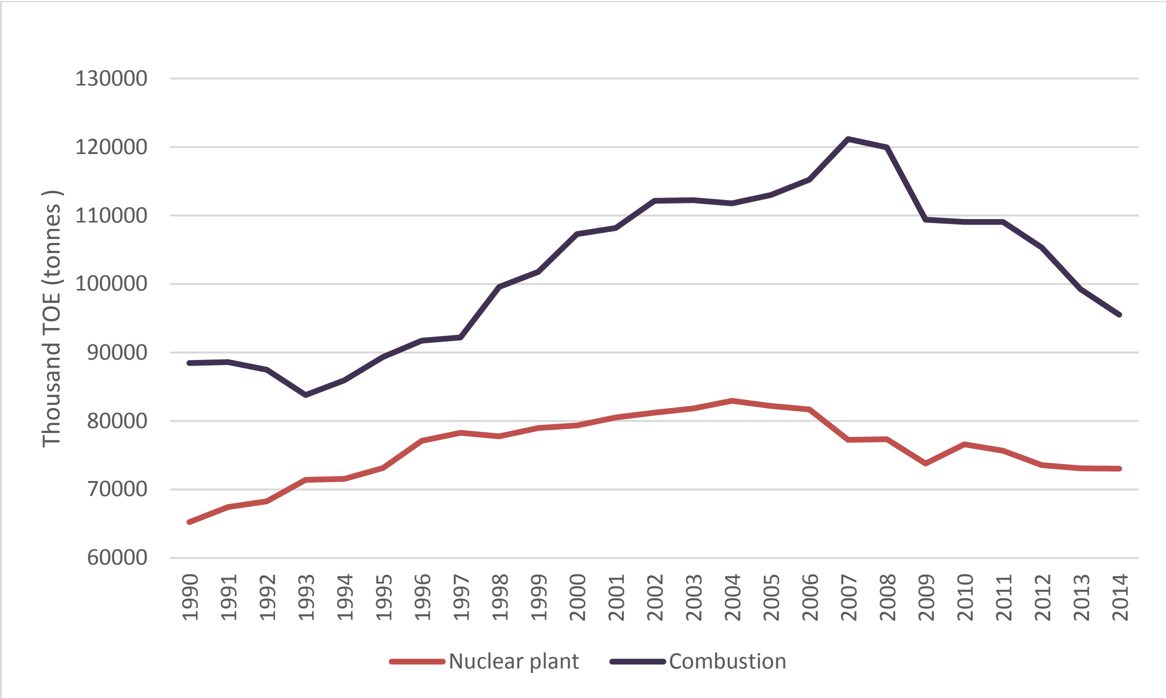


Data source: Eurostat, 2016f

[27] That is ad hoc data compilation by the European Commission and hosted by the EEA

Over the last decade, the share of nuclear electricity in gross national electricity generation has decreased in some European countries. Despite that, gross electricity generation by nuclear power plants has increased by 10% between 1990 and 2014 across the EU-28 (EEA 2015a), (Figure 5.19), which in turn may have increased the demand of water for cooling.

Figure 5.19 Trends in electricity production by nuclear power plants and combustion plants (1990–2014)

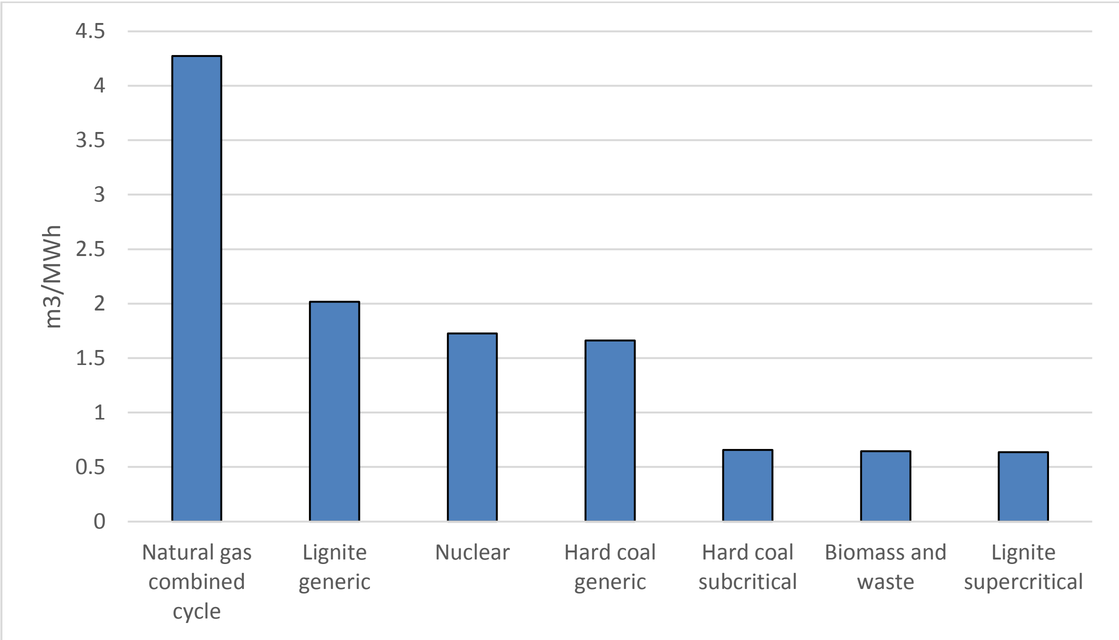


Data source: Eurostat, 2016n

Water use for electricity production accounts for 16.9% of all water use in Europe. As a positive development, the share of renewable energy sources in energy production is increasing in Europe and the average carbon emission intensity of electricity production is getting lower (EEA 2015). However, with the electricity generating sector still being dominated by fossil fuels and nuclear sources, a high water demand for cooling remains and it creates pressures on freshwater resources, notably on rivers and lakes. Despite water use for electricity production purposes being relatively lower compared to agricultural and household activities, resource efficiency measures should be taken into account once the environmental impacts of water abstraction for electricity production is concerned. The water consumption factor[28] of a power plant is a very important indicator in assessing how efficiently water is being used by a respective plant. The range of water consumption factor by fuel type and by plant type is presented with a high variation (Figure 5.20). Based on the available data for Europe it can be concluded that the highest water consumption factor is presented with 4.2m/MWh by those power plants operating with a natural gas combined cycle, followed by lignite generic. Nuclear power plants present an average water consumption factor of 1.72, after natural gas and lignite power plants.

[28] Water consumption is defined as the difference between water uptake (abstraction) for cooling and discharge (return) from the cooling. Water consumption factor is the volume of water required in producing one MWh of electricity.

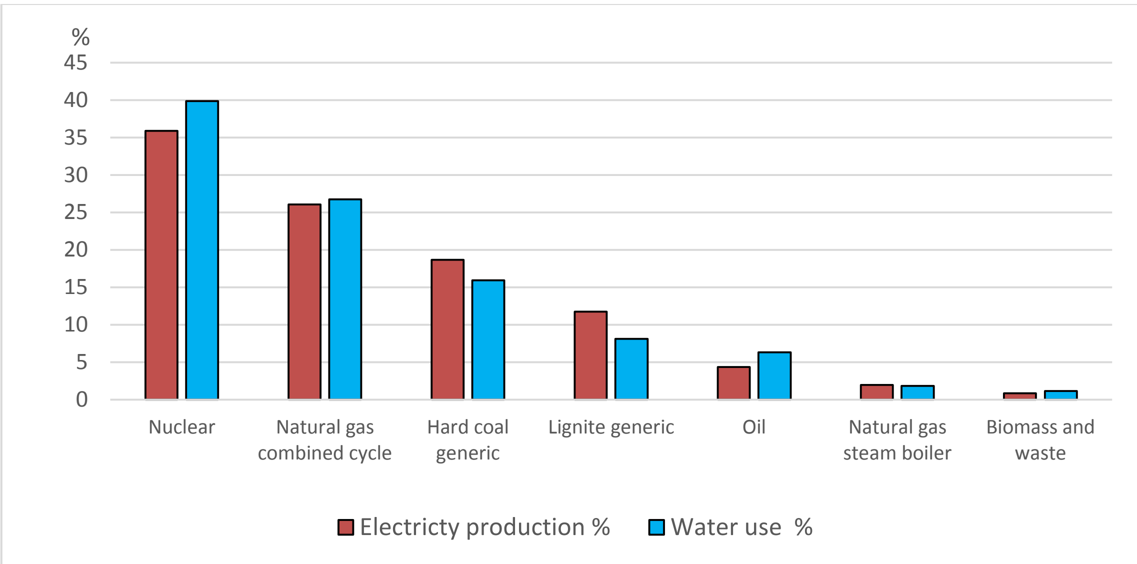
Figure 5.20 Water consumption factor by fuel type of power plants



Data source: European Commission, 2014[29]

A short comparison of water abstraction against electricity production by fuel type in general shows that nuclear power plants produce around 27% of the gross electricity in Europe and abstracts 40% of the total water resources for cooling purposes in the electricity sector (Figure 5.21)[30]. Similarly, natural gas and oil based power plants also use more water per unit of electricity generated, compared to other sectors.

Figure 5.21 Water abstraction versus electricity production by fuel type of power plants in Europe



Data source: European Commission, 2014

[29] That is ad hoc data compilation by the European Commission and hosted by the EEA

[30] Data source for this assessment was compiled by the DG ENV in 2014. However, Eurostat also collects data on electricity production by production type. Due to slight inconsistencies between these two datasets, the ratio of electricity production by type in this report provides some inconsistencies despite there being no significant difference as presented in the European overview.

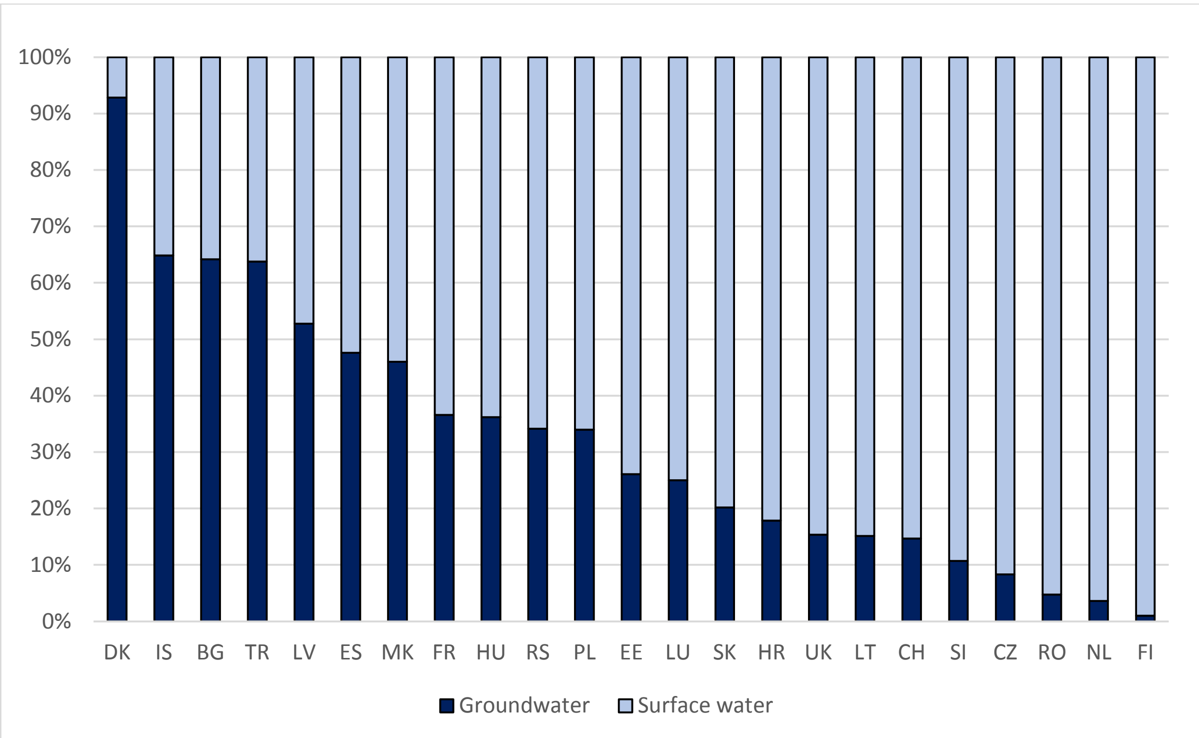
Water abstraction for cooling has decreased by around 11% between the early 1990s and 2010s. However, this decrease has occurred due to the reduction of water abstraction for cooling particularly in Western Europe. As Western Europe is a major water user for cooling, any proportional change in water abstraction for cooling has an impact on the whole European overview. Between the 1990s and 2010s, water abstraction for cooling in Western Europe has decreased by around 16% which corresponds to about 10,000 hm^3 of water per year. On the other hand, water abstraction for cooling in southern Europe has increased by 10% (corresponding to around 580 hm^3 of water) and 6.5 % in Eastern Europe (about 1.095 hm^3 of water).

5.4 Manufacturing industries

Manufacturing industries use water either as a raw material e.g. in the food industry or during production process. Industrial water use includes water used for such purposes as fabricating, processing, washing, diluting, cooling, or transporting a product; incorporating water into a product; or for sanitation needs within the manufacturing facility. Some industries that use large amounts of water produce such commodities as food, paper, chemicals, refined petroleum, or primary metals (USGS, 2000).

On an annual scale, around 56km^3 of water is abstracted for manufacturing industries in Europe. About 34% of this volume is abstracted for processing, fabricating, diluting including construction purposes while 66% of the water goes for cooling in the manufacturing industry. Manufacturing industries are supplying the water mainly by themselves. About 96% of the total water supply for the manufacturing industries is self-supply. Water is mainly abstracted from surface water (82%) to meet the water demand for industrial activities. However, some countries such as Denmark (92%), Iceland (65%), Bulgaria (64%), Turkey (64%) and Latvia (53%) use more groundwater resources compared to surface water (Figure 5.22).

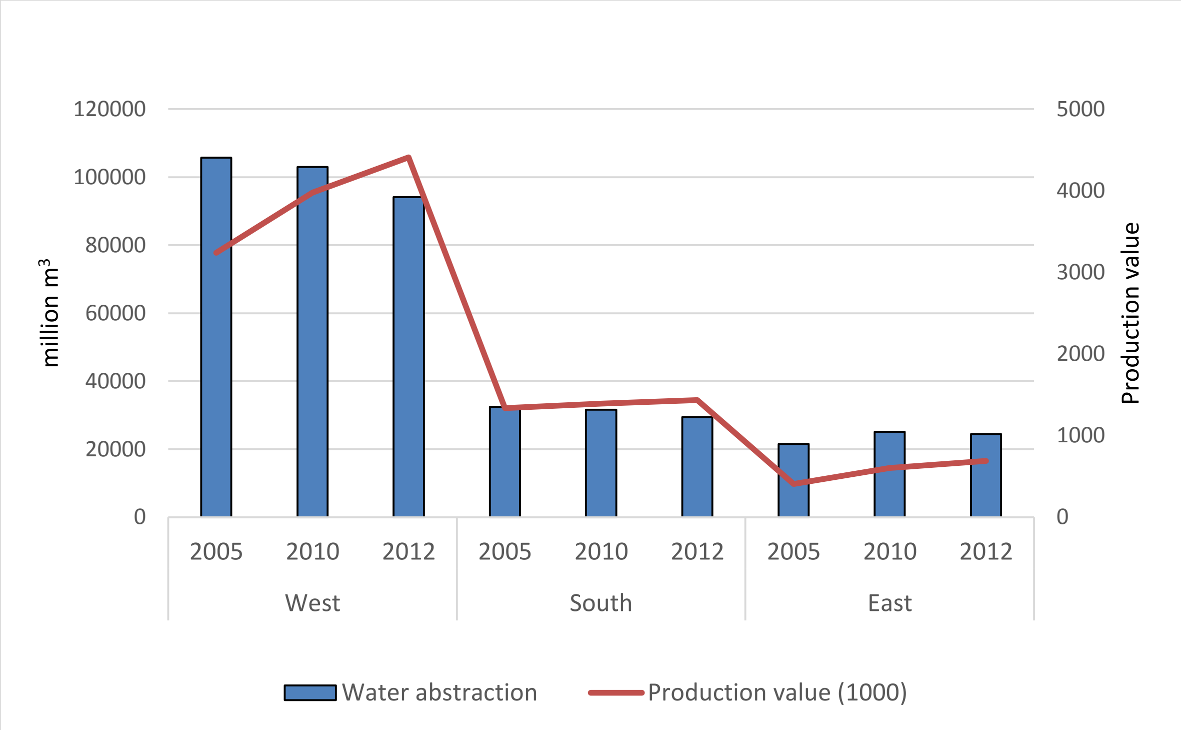
Figure 5.22 Water abstraction by source for manufacturing industry in Europe (2012)



Data source: Eurostat, 2016c

The trends in water abstraction by the manufacturing industry including for cooling between 2005 and 2012 has decreased by around 10% in Western Europe and by 9% in Southern Europe. It has been increased by around 14% in Eastern Europe for the same period of time. A regional comparison between water abstraction for the manufacturing industry and the production value of the manufacturing industry has shown that while in Western and Southern Europe a slight decoupling has been achieved. Thus, water abstraction for the manufacturing industry has been decreasing, while the production value has been increasing. However, in Eastern Europe, a linear regression can be observed between water abstraction and the production value over time (Figure 5.23).

Figure 5.23 Change in water abstraction by the manufacturing industry and production value (2005–2012)



Data source: Eurostat, 2016c, 2016b

Europe will eventually need to pay special attention to resource efficiency within water abstraction and water use for manufacturing industry particularly in Eastern Europe (Table 5.4).

Table 5.4 Percentage of total water abstraction versus total production value in the manufacturing industry across Europe (2012)

Region	Total water abstraction %	Total production value %
West	63.6	67.5
South	19.9	22.0
East	16.5	10.6

Data source: Eurostat, 2016c, 2016b

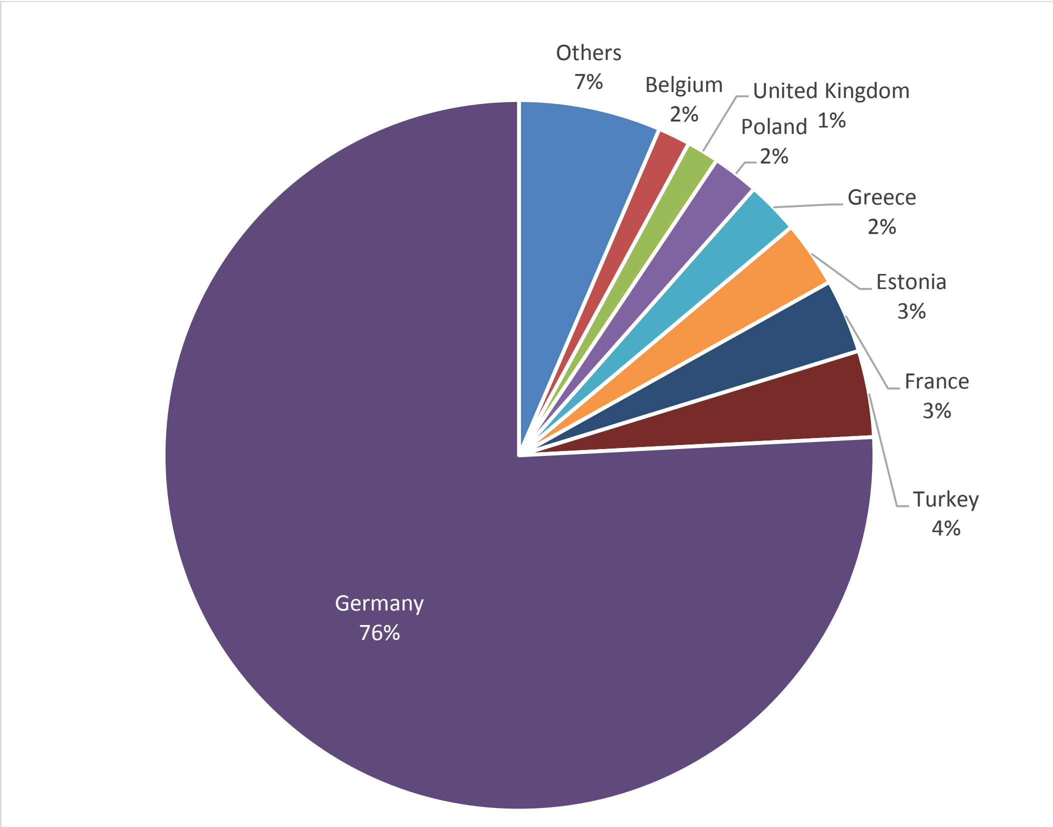
For instance, Eastern Europe shares around 17% of the total water abstraction for the manufacturing industries. However, the production value of the manufacturing industry made by this region accounts only for 11% of the total production of the value in Europe. This overview is emerging mainly due to poor water supply and distribution systems, if not all are dependent on industrial technologies.

5.5 Mining and quarrying

Generally water is used in the mining and quarrying sector for the extraction of naturally occurring minerals including coal, ores, petroleum, and natural gas which is known as mining water use (United Nations, 2012).

Water abstraction and use for mining and quarrying has a small share compared to other sectors in Europe. The annual volume of water abstracted for mining and quarrying is around 3km^3. Germany alone abstracts more than 75% of the total water abstraction for mining followed by Turkey (4%), France (3%), Estonia (3%) and Greece (2%), (Figure 5.24).

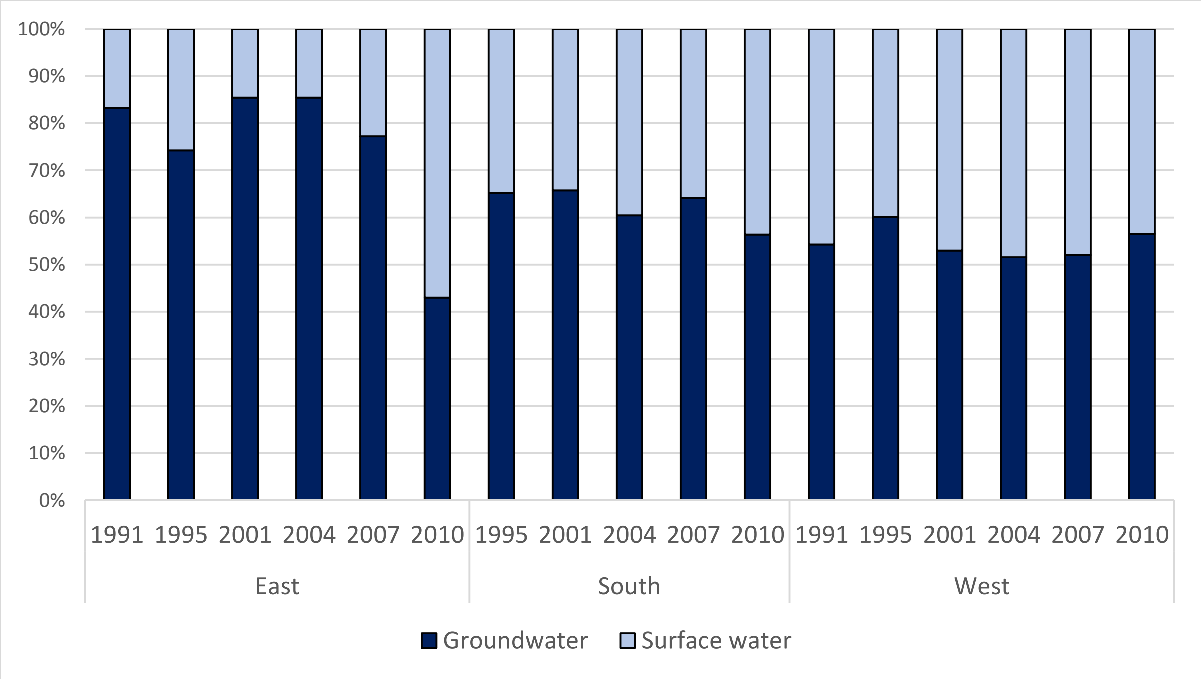
Figure 5.24 Water abstraction for mining and quarrying in Europe



Data source: Eurostat, 2016c

The source of water abstraction for mining and quarrying varies across Europe. In the early 1990s usually groundwater resources were dominantly used for abstracting the water. Over time the ratio of groundwater resources has been slightly declining from 60% down to 56%. However, during previous years (namely 2007–2010), water abstraction from groundwater resources had increased by 4% compared to the level found in 2007. But in general, on a regional scale, groundwater resources meet more than 50% of the water abstraction for mining and quarrying (Figure 5.25).

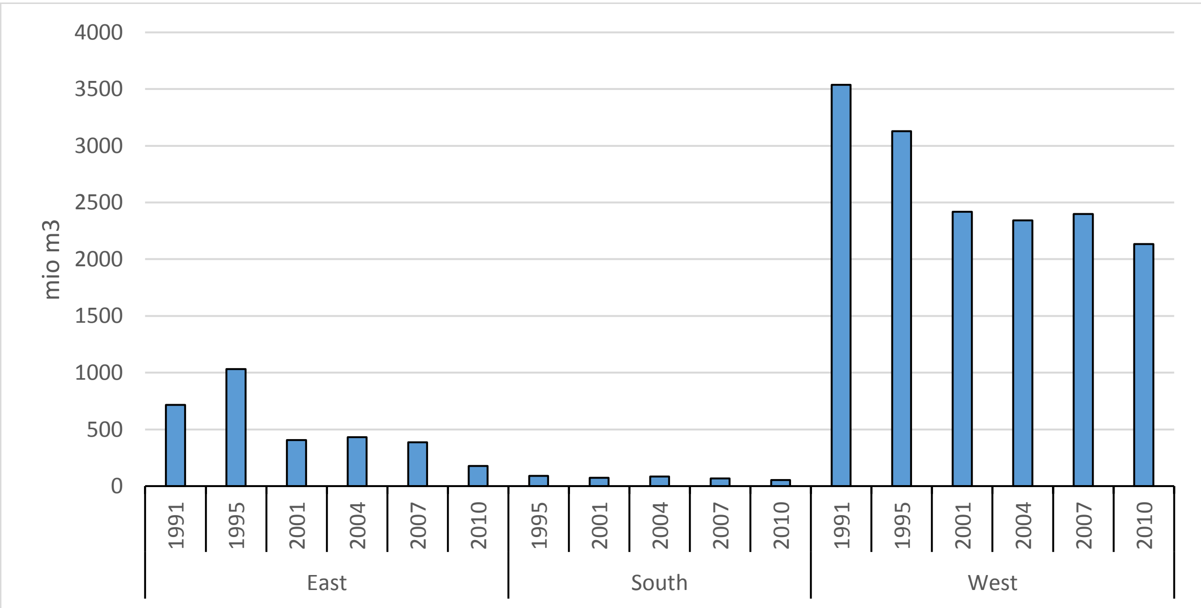
Figure 5.25 Water abstraction for mining and quarrying by source (1991–2010)



Data source: Eurostat, 2016c

On a European scale, water abstraction for mining and quarrying has declined by almost 45 % compared to the level found in 1991 (Figure 5.26). Declining particularly in Western Europe, which is very important as Western Europe is the major water user for mining and quarrying. For the same period of time water abstraction for mining and quarrying in Western Europe has decreased by around 40%. Eventually, this trend will continue.

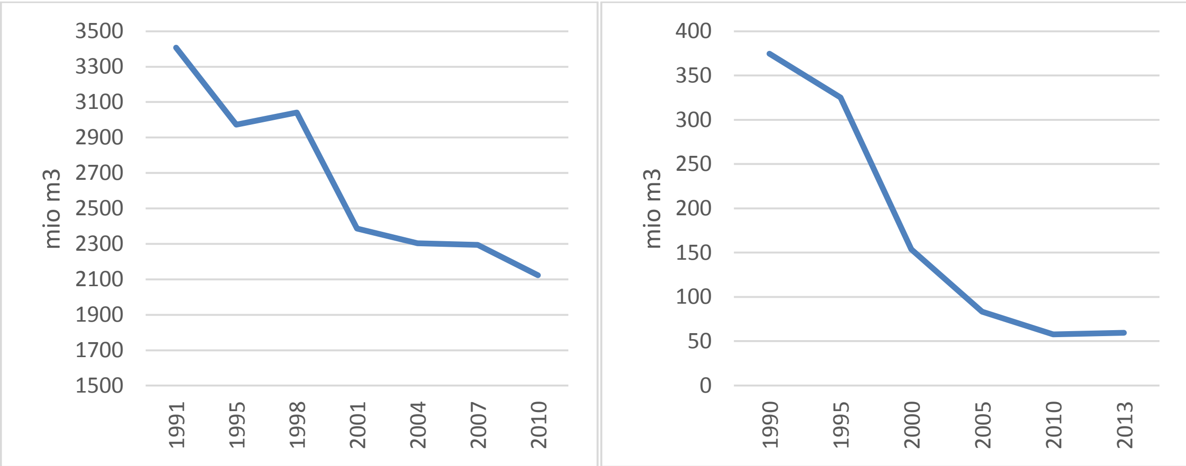
Figure 5.26 Regional change in water abstraction for mining and quarrying (1991–2010)



Data source: Eurostat, 2016c

For instance, two countries i.e. Germany and Poland that have been extensively abstracting water for mining and quarrying provide a similar trend in water abstraction with a substantial decrease shown during previous years which is more or less testifying the above conclusions (Figure 5.27).

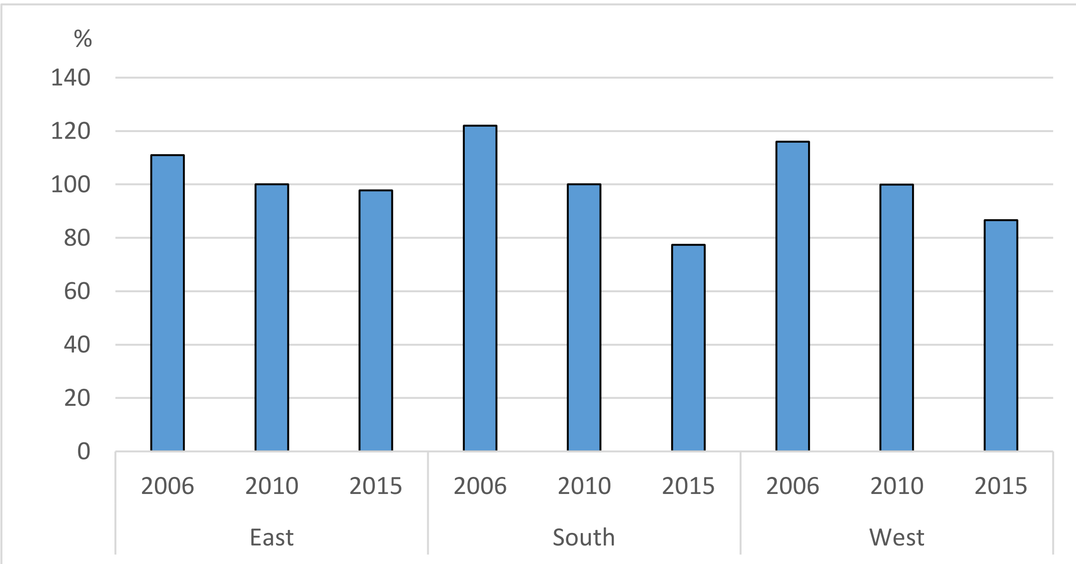
Figure 5.27 Trend in water abstraction for mining and quarrying in Germany (left) and Poland (right)



Data source: Eurostat, 2016c

Market conditions are one of the most important driving forces in the mining and quarrying sector, creating demand indirectly on water abstraction. Since 2006, there has been a substantial decline in the production of mining and quarrying across Europe (Figure 5.28).

Figure 5.28 Volume index of production in mining and quarrying in Europe

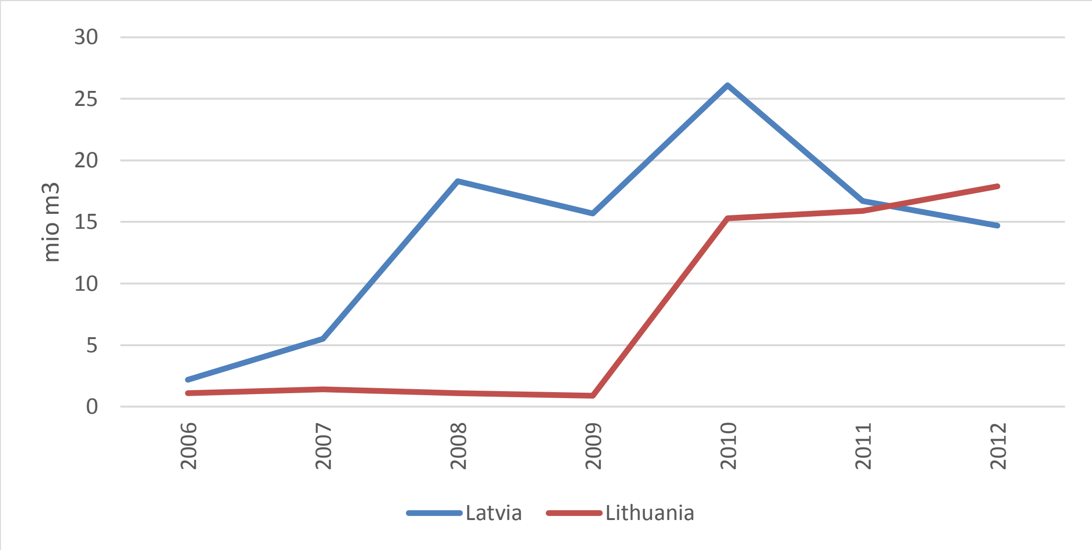


Data source: Eurostat, 2016l
Note: 2010 is used as the baseline year

By taking the year 2010 as a baseline, in southern and western parts of Europe mining production has been in decline by 45% and 30% respectively compared to the level of 2006. This can also be observed in the volume of abstracted water for mining. Since the early 1990s up to 2010 a decrease of around a ¼ of the water abstraction has been observed.

Despite this general trend, in a few countries the trend in water abstraction for mining and quarrying has been increasing over the last 6–7 years. For instance, in Latvia and Lithuania a substantial increase has been observed. However, that substantial increase with Lithuania looks more related to changing in the data collection. In Lithuania, beginning from 2010 the amount of "water returned without use" was being included in "water abstraction for mining and quarrying" and that is why the water volumes for the mining and quarrying sector has presented a substantial increase.

Figure 5.29 Water abstraction for mining and quarrying in Latvia and Lithuania



Data source: Eurostat[31]

5.5.1 Environmental impacts of water abstraction for mining and quarrying

In general, water is abstracted in mining activities for flotation (washing) processes and in the dewatering of mining areas. Both types of usage have a number of detrimental impacts on the environment. Dewatering mining areas would have serious impacts on lowering the groundwater level (Pusch and Hoffmann, 2000) (Text box 5.4). In addition, dewatering of old mine areas may also deteriorate water quality due to the loading of emissions with heavy metal contents to water (Robb, and Robinson, 1995). Therefore, knowing the source of water abstraction for mining as well as the point of discharge are very important pieces of information in assessing the environmental impacts of water abstraction for mining activities.

Text box 5.4 Lusatia region, Germany

Source: Pusch and Hoffmann, 2000

In the Lusatia region of north-eastern Germany, dewatering for mining activities has resulted in an 8km^3 deficit in the groundwater balance. In order to refill aquifers and empty lignite pits, water will be abstracted for several decades from the River Spree which drains this region. This affects the ecological integrity of a 230 km river section including the floodplain in several aspects. Ecological consequences are shown for fishes, the aquatic invertebrate fauna, the retention of suspended matter, and oxygen concentrations.

Since the unification of the two German states in 1990, lignite mining has been substantially reduced, and many lignite pits have been closed. Groundwater extraction declined to a third of former rates up to 1995, so much so that groundwater altitudes in the Lusatia region are currently slowly returning (Fyson, et al., 1998).

Minerals and metals, there are a large number of common impacts e.g. there are large volumes of waste, acid drainage can lead to water pollution (DG ENV, 2008).

[31] Annual freshwater abstraction by source and sector

Water pollution from the mining of some ores can be a severe pollution hazard. In certain mines where the ore has a high sulphide content, drainage from mine workings and waste heaps can become highly acidic (a pH of 3 or lower) and can contain high concentrations of dissolved heavy metals. This is caused by contact between the sulphide, oxygen and water and is called acid mine drainage (AMD) or sometimes acid rock drainage. Leaks, spills or seeps of acid solutions used in the extraction of metals from ores are additional potential sources of water pollution. AMD can be minimised by reducing the exposure of sulphides to oxygen or water (e.g. minimising disturbed areas and isolating sulphide-bearing wastes). In quarrying and production of bauxite ores and phosphate rock, the main water pollutant is suspended solids.

Thus, environmental impacts of water abstraction for mining and quarrying should be conducted in an integrated approach involving both water quality and water quantity.

6 Future work

The data used for the water scarcity assessment has quite a short time series for the trend assessment, enabling us to provide an overview whether we use less water over time. Similarly, resource efficiency assessment requires more sensible quantifications of renewable water resources, water abstraction and water use. That is not possible for the time being with the current data availability and also the time length of the data. Despite that, we can conclude that in general, water abstraction has decreased in Europe within the last decade. Similarly, water use efficiency is also increasing.

In the years to come, the EEA will have to expand towards modelled time series as much as possible, back to the previous decades particularly for the water use component. This will enable the EEA to carry out more robust trend analyses. On the other hand, without assessing changes in spatial extent of and conditions with freshwater resources, the assessment of environmental impacts of water use will always remain incomplete. Depending on resource availability, the EEA will also have to explore the possibility of including certain aspects of assessment as a periodic production in addition to the European water quantity accounts.

From a conceptual point of view, variations of the residence time of water in different water bodies e.g. in rivers, lakes, reservoirs and also in groundwater aquifers causes a number of conceptual issues in assessing renewable water resources and water use on coarse spatial and temporal scales. All these conceptual issues have to be properly addressed for future improvements, particularly in also supporting the UN SEEA for water.

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