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Inland, coastal, marine waters

Use of freshwater resources in Europe 2002–2012

Supplementary document to the European Environment Agency's core set indicator 018

ETC/ICM Technical Report 1/2016

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Contents

List of Acronyms

BAT	Best available techniques
BREF	BAT reference document
CIS	Common Implementation Strategy
CSI	Core Set of Indicators (EEA's indicators system)
CTY	Country (spatial scale)
DG ENV	Directorate-General for Environment (European Commission department)
ECRINS	European Catchments and Rivers Network System
EEA	European Environment Agency
E-PRTR	European Pollutant Release and Transfer Register
ETC/ICM	European Topic Centre on Inland, Coastal and Marine waters
EU	European Union
FD	Floods Directive
FEC	Functional Elementary Catchment (ECRINS spatial reference scale)
FRBD	Functional River Basin District (ECRINS spatial reference scale)
IRWS	International Recommendations for Water Statistics
ISIC	International Standard Industrial Classification
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)
Nopolu	Water accounts application developed by Naldeo
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-CF	System of Environmental Economic Accounting – Central Framework
SEEA-W	System of Environmental Economic Accounting – Water
SoE	State of Environment dataflow
TWG	Technical working group
UMZ	Urban Morphological Zones
UWWTP	Urban waste water treatment plant
WA	Water Accounts
WAT	EEA's water indicators
WEI(+)	Water Exploitation Index (plus)
WFD	Water Framework Directive
WG	Working Group
WRAP	Waste and Resources Action Programme (http://www.wrap.org.uk/)

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The first version of the report was circulated to the EEA Member Countries on 6th of March 2015[1] with the purpose of updating the EEA indicator on the Use of Freshwater Resources (CSI 018/WAT01). Furthermore, the results have been presented to and discussed with the members of the CIS WG WA in Brussels in March 2015 and WG Water Statistics in Luxembourg, in April 2015.

Following the WG Water Statistics Meeting held by Eurostat, the report had been revised and the second version was made available by Eurostat to the National Statistical Offices[2]. Since then, EEA has received written comments from Estonian and Maltese Statistical and Environmental organizations including individual expert comments from Jürgen Förster (Eurostat) and Rudy Vannevel (Belgium).

The third version of the report was revised based on new results as well as on comments received. It has gone through EIONET consultation till February 2016 and comments were received from two member countries (Austria and United Kingdom), Eurelectric and from individual water accounts expert (Carlos Benítez Sanz, INTECSA-INARSA, S.A.) from Spain.

[1] European Water Assets Accounts and updating the use of freshwater resources indicator (CSI018)

[2] Eurostat's Working Group on Water Statistics (23-24 April 2015)

Summary

Use of freshwater resources (CSI 018 alternatively Water Exploitation Index plus, WEI+) is one of the core indicators implemented by EEA for identifying water stress prone areas and the water use pressures over the renewable water resources. This indicator is regularly updated by means of data deliveries under the SoE data flows from the EEA member countries and cooperation countries together with several data sets obtained from cooperation partners i.e. DG ENV, Eurostat and the European Commission Joint Research Centre (JRC). The latest update of the CSI 018 was in 2010 comparing country scale of multi-annual average of water exploitation index for the 1990s and 2007. The current update of CSI 018 has developed a baseline as a building block to the previous EEA works (European Environment Agency, 2012a, 2012b, 2013) covering almost all functional river basin districts – FRBDs (namely without political boundaries of the countries) and sub-basins (SB) of EEA member countries for the years 2002–2012 on monthly resolution.

This report is a supplementary document to the CSI 018 indicator sheet. It should be regarded as a documentation on all the results along with the databases and tools in a way to inform about the methodology used for updating of CSI 018.

The report has been organized into five main chapters. The first chapter is about the conceptual issues while the second chapter outlines data related topics. The third and fourth chapters are mainly discussing the results of water stress and pressures over the water resources. The last chapter provides information on the future directions. In addition to these main chapters, two annexes have been introduced for detailed clarifications on data integration and updates.

Renewable water resources, which is the denominator of the Water Exploitation Index plus, can be calculated with two different formulas endorsed by the Water Directors in 2012. The first formula is containing climatic and hydrological parameters which are mainly applicable for pristine areas, while the second formula is searching for relations between human intervention and output from the hydrological territory. The report introduces the results of formula 2 as it is adopted of a non-existence of pristine sub-basins (SBs) or functional river basin districts (FRBDs). Meanwhile, the results of formula 1 have also been produced only for the comparison purposes between those two formulas.

These are the following interpretations of the obtained results:

Assessment of WEI+ at ECRINS sub-basin (SB) scale on monthly/seasonal resolutions revealed that the freshwater systems are under pressure especially in the Mediterranean region due to high irrigation water abstraction in summer months, while the rest of Europe experiences lower water stress by other economic sectors, such as water collection treatment and supply, energy and industries. In addition to the Mediterranean region, particularly those sub-basins having a high population density illustrate also prone conditions to the water stress.

From the environmental perspective, high water abstractions overlap with low renewal of water resources particularly in summer months, which create partly additional stress over the freshwater resources.

As water availability is a regional phenomenon, spatial aggregation of the parameters involved with water stress (e.g. from sub-basin to country scale) is prone to hide the real conditions in the respective less aggregated areas. In this sense, the report also verifies the findings in the previous studies on regionalized WEI. Sectorial share of water abstraction and use is very crucial information for the policy makers and stakeholders in assessing water resources efficiency and implementing the measures to tackle environmental concerns including the role of water resources as part of our total natural capital.

The surface and ground water abstractions share across Europe is 65% and 35% respectively. Rivers are meeting around 46% of the total water demand followed by the groundwater resources (35%). Water abstraction is doubled during the 3rd quarter compared to 1st quarter of a year. Reservoirs play a significant role in meeting the water demand during the summer months. Water abstractions from the reservoirs are 300 % higher in summer than the winter months.

In Europe, almost 70% of water is used by agriculture, forestry and fishing (36 %), water collection, treatment and supply (32 %), followed by electricity[3], gas and steam and air conditioning supply (17%). Water used for hydropower production is regarded as non-consumptive in-situ use and the current water accounts database does not have such kind of information available yet. Abstracting water for electricity production purposes alters the hydrological regime in the water assets (especially in rivers and lakes), by increasing also the water temperature during the cooling process.

Water use by agriculture, forestry and fishing. Almost 36% of total water in average is used for agricultural activities across Europe. The Mediterranean biogeographical region consumes solely almost 75% of this volume of water. This rate reaches up to 94% in winter and 70% in summer seasons as the total share of agricultural activities across the biogeographical regions change. The Mediterranean region is followed by Continental (14%) and Atlantic (5%) biogeographical regions.

Water use in irrigation shows also great seasonal variations. Around 94% of total water use for irrigation is abstracted during spring (33%) and summer (61%). Despite 22% decrease occurred in water abstraction for agriculture since 1990s, still agriculture is the highest water consumer.

Abstraction for water collection, treatment and supply. According to the NACE classification water collection, treatment and supply represents the volume of water used for public water supply. Public water supply is the second largest sector (32%) after agriculture. Public water supply illustrates water stressed conditions driven mainly by population density and economic activities.

The Atlantic (31%) and Continental (30%) biogeographic regions use almost 60% of total water collection treatment and supply in Europe. The Mediterranean region is the third region (26%) following those regions. There is more or less a steady condition in terms of water use by public water supply throughout the year with a slight increase (3%) in summer compared to winter. The consumption of water collection, treatment and supply sector presented a 5% decrease as general trend through the period of analysis.

An average European citizen uses 36 m^3 of water from the renewable freshwater resources within a year. This corresponds to approximately 98 litre of water per-capita/day. This volume excludes recycled, reused and desalinated water.

The highest water use per capita for the water collection treatment and supply sector is estimated for the Mediterranean biogeographical region with 133 litre/capita/day. Alpine (123 litre/capita/day) and Atlantic (120 litre/capita/day) are following while 72 litre/day and 34 litre/day are estimated for the Continental and Pannonian biogeographical regions respectively.

Water use per-capita fluctuates little throughout the year with a slight increase in summer and a decrease in winter.

The annual net water use per capita is estimated at about 114 m^3/year which corresponds to approximately 310 litres net water consumption per capita/day across Europe. This amount of water is

[3] ISIC Rev.4:This section includes the operation of electric and gas utilities, which generate, control and distribute electric power or gas. Also included is the provision of steam and air-conditioning supply. This section excludes the operation of water and sewerage utilities. This section also excludes the (typically long-distance) transport of gas through pipelines."

used for all economic sectors, in hygiene and social activities. Thus, it doesn't mean the actual amount of water consumed by each person of the European inhabitants.

Water use for the service industry. The service industries sector is registered in Section I under the NACE economic activities classification by Eurostat. The share of water use for the service sector is estimated approximately at 11% in Europe. Due to a high number of visitors in tourism activities across Europe, water use by tourism has a significant impact on the general overview of water use by the service sector. Around 85% of total water use by the service sector is occurring in the Atlantic (38%), Continental (29%) and in the Mediterranean (19 %) regions.

Seasonal water use (multi annual average) by the service sector indicates winter share as the highest proportion of water (28%) compared to summer (23%) while the rest amounts of water are distributed in the other two seasons. Apart from this general overview, tourism particularly in the Mediterranean islands has a greater impact on water use than the service sector. The average number of tourists received in the Mediterranean islands is almost 17 times more tourists than their local residents. Almost 27% of total water use by the service sector is consumed in the summer months in the Mediterranean islands followed by 26% in winter.

Water abstraction for energy production. Water abstraction for electricity production (hydropower or cooling) is not considered as consumptive use of water resources, as most of the water volumes are returning back to the environment. Approximately 17% of total freshwater water abstraction is Europe is accounted for electricity production. Almost 65% of total water abstraction for electricity production is used in the Continental region followed by Atlantic (15%) and Mediterranean (13%). Winter months record the highest water abstraction rate (28%) for electricity production compared while in summer this rate decreases to 21%.

Water is not only abstracted from the freshwater resources for producing the electricity. Coastal and transitional water resources are also used for cooling purposes. Around 25% of total water abstraction for electricity production is made from brackish and salt water.

Water use for mining, quarrying, manufacturing and construction. Total water use by mining, quarrying, manufacturing and construction counts for 4% of total freshwater use in Europe. Continental region consumes 35% of water used for mining and quarrying. This region is followed by the Mediterranean (28%), Boreal (17%) and Atlantic (14%) biogeographical regions. Seasonal conditions in water use by these sectors are showing quite steady trends between summer and winter.

Change in water abstraction. For comparability reasons, a check has been made with annual freshwater abstractions on country scale from Eurostat data[4]. There is a tendency of decrease in water abstraction for some economic sectors across Europe since the 1990s. Based on the current available datasets, the industry sector has improved resource efficiency and registered the most significant decrease (28 %) in water abstractions since the 1990s. This sector is followed by Agriculture where a 17 % decrease occurred since the 1990s; still agriculture is the highest water demanding sector.

A significant increase in water abstraction for agriculture has been observed in Turkey between the 1990s and 2013. During that time, the water abstraction for agriculture increased around 140 % in Turkey. Water abstraction for electricity has been decreased by 14 % since 1990s and indicate more or less constant trend as of 2000s in West Europe.

Little improvement has been obtained in water abstraction for public supply. Only 5 % decrease happened since 1990s. Significant decrease in public water supply occur in the eastern and western

[4] Annual freshwater abstraction by source and sector, [env_wat_abs] dataset; Last update: 08-10-2015

part of Europe, while public water supply has increased in the south, West Balkans and Turkey. This might be related to the improvements in the water supply network.

During 2002–2012 the number of tourists has increased around 30% across Europe. Water use for the service sector has steadily increased (7%) between 2002 and 2008. However during the last 3 years (2010–2012) a decrease (1.5%) is observed in water use for the service sector.

The results obtained by this study should be treated as an estimation of the regional statuses and not as a replacement of the more detailed information provided by the local authorities/institutions. The main target of having the WEI+ at the European scale is to provide information on state of the art and trend at the European scale in the context of water scarcity and pressures.

Last but not least, it also has to be mentioned that the Water Exploitation Index plus depends on data quality and availability. Future developments towards a robust common knowledgebase can only be possible if spatial and temporal coverage of water quantity data would be further improved.

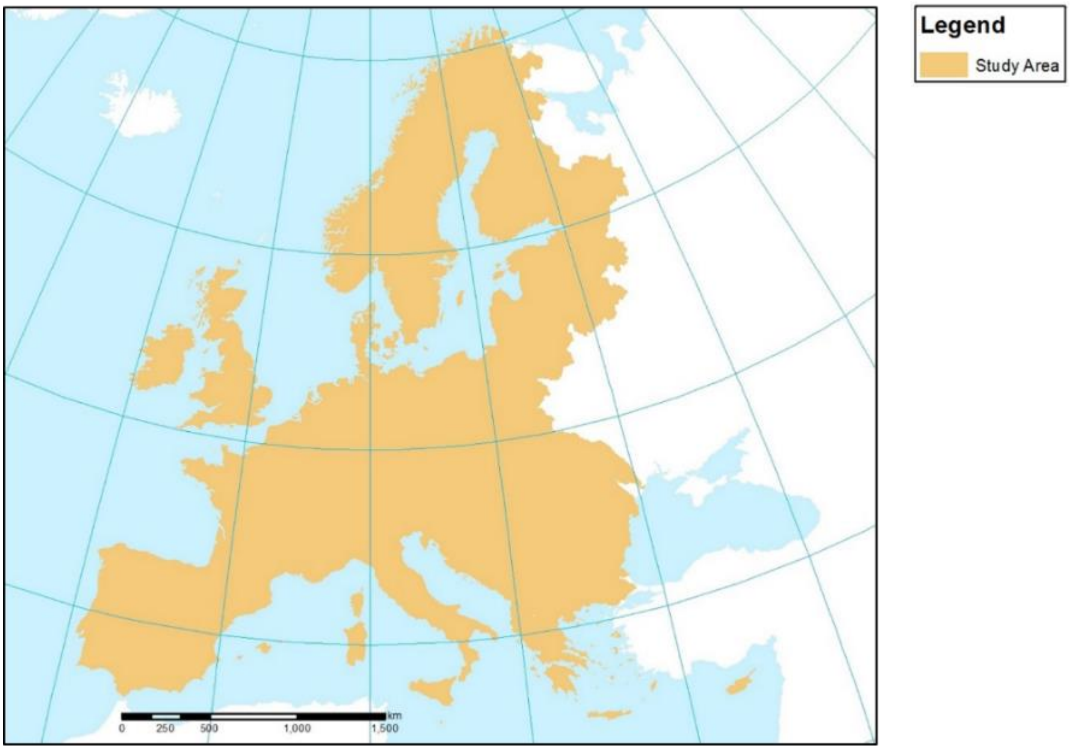
1 Introduction

The purpose of producing the information on the use of freshwater resources is to provide a European overview on water scarcity and drought conditions. Therefore, the outcomes of this report should be regarded as an approximation to the ground truth by using the best available data provided by the EEA member and cooperating countries under the SoE data flows including the data provisions from the cooperating partners i.e. the European Commission, Eurostat and the EC Joint Research Centre. The report does not aim at producing the information with such scope and content on water scarcity and drought conditions that can directly be translated into the implementation at the local scale.

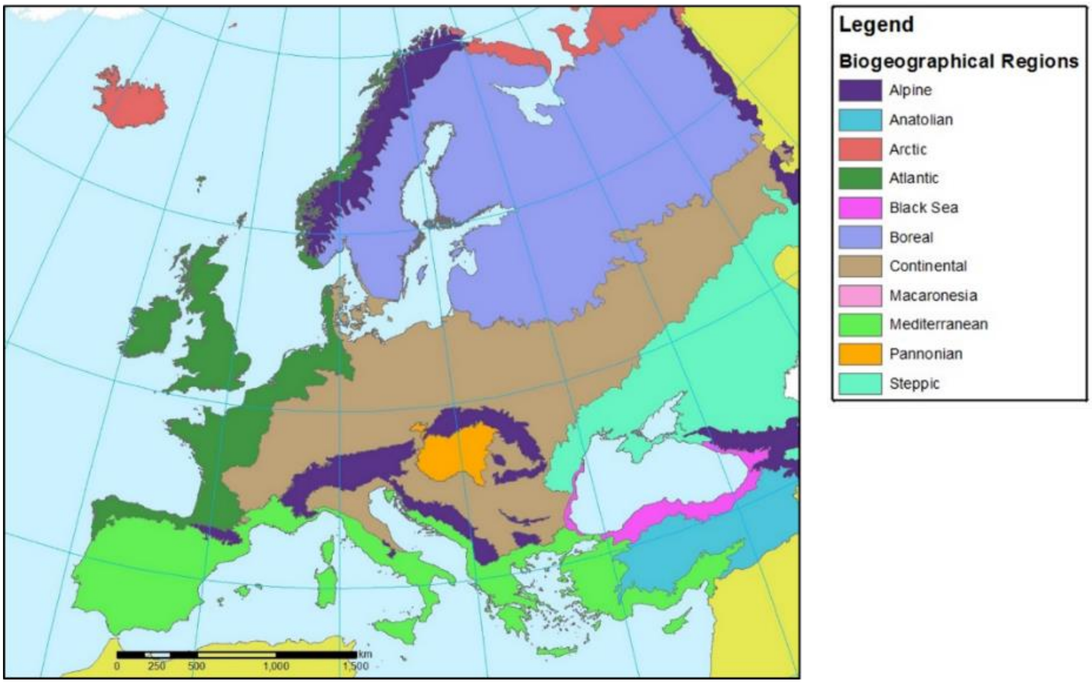
This Technical Report is a supplementary document to the indicator sheet of CSI 018. The purpose of this report is to provide detailed information on all data sources, methods and procedures implemented in the computation of the Water Exploitation Index plus. This document is providing the transparency and traceability between source data and the final production of updating CSI 018.

The study area of this report is based on the ECRINS sub-basins areas extent as shown in the Map 1.1, across seven biogeographical regions across Europe: Alpine, Atlantic, Boreal, Continental, Mediterranean, Pannonian and Steppic (Map 1.2).

Map 1.1 Areal extent of the study area



Map 1.2 Biogeographical regions across Europe



Source: Biogeographical regions, EEA, version 2012

1.1 Updating the Use of Freshwater Resources Indicator (CSI 018)

The use of freshwater resources (CSI 018/WAT01)[5] is one of the EEA core indicators illustrating the level of pressure that human activity exerts on the natural water resources of a particular territory as well as helping to identify those prone to suffer problems of water stress. That is also known as Water Exploitation Index plus (WEI+). The latest update of CSI 018 was done in 2010 ([6]) providing the information on water exploitation index at country level on multi-annual average. The new update aims to provide a consistent baseline among the EEA member countries for the years 2002–2012.

> During the 2010–2012 CIS WFD&FD Working Programme a working group was set up by the Commission with an updated mandate on water scarcity and droughts, requesting to deliver a set of common indicators for both water scarcity (influenced by human activity) and drought (natural). The CIS WG developed a Technical Working Group (TWG) in order to produce a proposal on implementing the WEI. The TWG has proposed two different formulas for estimating the Renewable Water Resources. That proposal was endorsed by the Water Directors in 2012.

The previous works of the EEA since 2008 (Kossida M. et al., 2009, EEA 2012a, EEA 2012b, EEA ETC/ICM 3/2012, ETC/ICM 2013) as well as the outcomes of the CIS WG Water Scarcity and Drought have strongly recommended that the WEI+ should be developed at finer scales than at

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[5] There are two different terms used interchangeably for assessing the pressures of water consumption; the use of freshwater resources (CSI 018) and the water exploitation index (WEI+)). Both of them are completely addressing identical phenomena. In this report, the WEI+ has been adopted to be used in order to ensure the consistency between WFD reporting guidance and the EEA CSI 018 indicator update.

[6] Use of freshwater resources, CSI018 Indicator Assessment

country level and on seasonal or monthly time resolution in order to better represent the problem of water scarcity. The new EEA Water Exploitation Index plus calculation has been formed according to these recommendations and provides the results at the sub-basin scale on monthly resolution with aggregation to the functional river basin on seasonal or annual resolution. With that structure and content, the new WEI is known as the “Regionalized Water Exploitation Index plus” or WEI+.

1.2 Overview on the conceptual understanding of renewable water resources and water consumption

1.2.1 Regionalized Water Exploitation Index (WEI+)

Traditionally the WEI has been defined as the annual total water abstraction, as a percentage over long-term annual average of freshwater resources. It has been calculated so far mainly on a national basis ([7]).

The previous definition of the Water Exploitation Index was the following:

> The Water Exploitation Index (WEI) is the mean annual total abstraction of freshwater divided by the mean annual total renewable freshwater resource at country level, expressed in percentage terms.

$$\boldsymbol{WEI} = \frac{\boldsymbol{Abstractions}}{\boldsymbol{Renewable\ Water\ Resources}} \qquad (1)$$

The coming years revealed that the implementation of the Water Exploitation Index at lower hydrological scales (i.e. catchment, sub-unit or river basin) with monthly or seasonal resolution, can better illustrate water scarcity as well as other pressures from the exchanges of water between natural and anthropogenic (economic) agents (European Environment Agency, 2012a). The previous experiences implicitly suggest that the WEI+ should be dimensionless so that it can easily be adjusted to the different spatial and temporal scales. Therefore, the following modification with the WEI+ definition is proposed:

> Water Exploitation Index (WEI+) is total water use (abstraction minus returns), from surface and groundwater systems, as a percentage over the renewable freshwater resources in a given territory and time scale.

$$\boldsymbol{WEI+} = \frac{(\boldsymbol{Abstractions} - \boldsymbol{Returns})}{\boldsymbol{Renewable\ Water\ Resources}} \qquad (2)$$

[7] Update on Water Scarcity and Droughts indicator development

Calculation of the Water Exploitation Index plus

For the calculation of the denominator “Renewable Water Resources (RWR)” two alternative approaches have been proposed by the CIS WG Water Scarcity and Drought in order to suit more cases subject to different data availability. The hydrological balance equation, as applied in pristine basins unaffected by human interventions, has been used as a starting point (ETC/ICM, 2013)[8]:

$$\mathbf{ExIn + (P - ETa) - \Delta S = Q_{nat}}$$

Where:
ExIn is the External Inflow
P is the Precipitation
ETa is the Actual Evapotranspiration
ΔS is the Change in Storage
Q_{nat} is the Natural Outflow

Both sides of the above equation may be identified with “Renewable Water Resources”, and thus the two alternative approaches for calculating RWR are:

Option 1. $RWR = ExIn + P - ETa - \Delta S$

Option 2. $RWR = Q_{nat}$

Consequently, when applied in basins with human alterations, the observed outflow does not in fact equal RWR. For option 2, a flow re-naturalization is thus necessary. This correction can be made by restoring the consumption (abstractions – returns) and flow alteration linked with management, which may be approached by adding the variation in artificial storage:

Option 1. $\mathbf{RWR = ExIn + P - ETa - \Delta S_{nat}}$

Option 2. $\mathbf{RWR = Outflow + (Abstraction - Return) - \Delta S_{art}}$

It has been identified by the CIS TWG that both approaches present certain limitations. There are practical difficulties in incorporating the variation of natural storage (ΔS_{nat}) in option 1. In case this is neglected, the (P-ETa) at the monthly scale can render negative values. The calculation of the ΔS_{nat} most often requires hydrological modelling and is not a parameter to be obtained for measurements as such. With regards to option 2, the outflow should consider both surface and groundwater. In case of systems that are not groundwater dominated, one could assume that the surface outflow (i.e. streamflow at the outlet), which in fact includes base flow, is representative enough. Yet, it is to be emphasized that in the case of non-pristine sites, where water abstraction is influencing the system, the observed streamflow does not represent the RWR. The necessary in these cases “naturalization” of the streamflow is a challenging process, especially in complex water systems on a monthly basis. In case that a part of the water stored in the artificial reservoirs comes from a transfer (as opposed to generated within the territory of reference) or from a desalination plant, then the ΔS_{art} needs to be carefully considered and corrected for the effect of these alternative water resources (i.e. water transfers, desalination). Water uses analysis in this study excludes sea water due to lack of information whether the water is used for cooling or desalination purposes.

[8] This chapter has been mainly quoted from the ETC Internal Report on the water accounts work and the data flows, 2013

The EEA Water Exploitation Index plus calculation involves only freshwater resources in estimating the renewable water resources, but excludes water transfers among the river basins and also desalinated water from the sea.

Water use can be calculated by extracting returns from the water abstractions (Abstractions-Returns). Despite quite straight forward definition, there would be a time lag between water abstractions and returns on a monthly scale that may cause returns that would be greater than abstractions.

The current study arbitrary adopts that a one month time length is sufficiently enough to close the time lag between water abstractions and return regardless the spatial scale of the analysis.

1.2.2 Pressure analysis and UN SEEA – Water accounting framework

While the Water Exploitation Index plus is an indicator for analysing the water scarcity and drought conditions, further supplementary information is needed for better illustrating pressures of water consumption by economic sectors. Water accounts is a way of organizing economic and hydrological information, enabling a consistent analysis of the contribution of water to the economy and of the impact of the economy on water resources (United Nations, 2012b). Thus, the Water Exploitation Index plus and Water Accounts are strongly interlinked and can be regarded as two building blocks of information which are helping in a better understanding of the water exchange between environment and economy.

The current study is following the UN SEEA Water Accounting Framework for assessing the water asset accounts and covering physical supply and use tables of the Flow accounts. Physical supply and use tables provide information for the pressure analysis.

The United Nations System of Environmental-Economic Accounting for Water (United Nations, 2012b) is about estimating natural water assets and depletion in them due to human interventions for different purposes i.e. water consumption modifying the System of National Accounts (European Commission, International Monetary Fund, Organisation for Economic Co-operation and Development, United Nations and World Bank, 2009). Within this framework the water account is understood as a balance calculation of water resources within a specific area (e.g. catchment, sub-basins, river basin district) ([9]). The UN SEEA-W has been prepared by the UN Statistical Division (UNSD) in collaboration with the London Group ([10]) on the Environmental Accounting and the SEEA-W 2012 builds on the results already achieved during the preparation of SEEA–2003 (European Commission, International Monetary Fund, Organisation for Economic Co-operation and Development, United Nations and World Bank, 2003). Several guidance international standards satellite documents such as SEEA–CF (European Commission, FAO, IMF, OECD, United Nations and World Bank, 2014a), SEEA–EEA European Commission, FAO, IMF, OECD, United Nations and World Bank, 2014b) and IRWS (United Nations, 2012a) complete the set of the concepts and provide all the necessary information to be assessed by policy makers and stakeholders as well as the experts in evaluating effectiveness of water protection policies under implementation. The UN SEEA-Water

[9] EEA Note "Water Accounts: summary of the results so far"

[10] London Group on Environmental Accounting

Framework has three main components to be filled in (Table 1.1); flow accounts, assets accounts and valuation of non-market flows (monetary accounts).

Table 1.1 The SEEA-Water framework

1. Flow accounts	(a) Physical supply and use tables
	(b) Emission accounts
	(c) Hybrid and economic accounts
2. Asset accounts	(a) Produced assets
	(b) Water resources
	(c) Quality accounts
3. Valuation of non-market flows	

Note: Green cells indicate the developed SEEA-W components in this study

The components of the UN SEEA-W covered in this study represent all water assets in the territory of reference for surface water, groundwater, soil water and natural flows among them including water exchange within the whole economy and its components (within the administrative and hydrological boundaries of accounting) at catchment scale further aggregated to sub-basin, river basin and country scales.

Due to the further needs in developing a conceptual framework for quality, emission and hybrid accounting together with the economic valuation of the water assets, these components could not be included into the current study ([11]).

1.2.3 Thresholds for the Water Exploitation Index

Having agreed thresholds of water exploitation index (WEI) is quite important for delineating non-stress and stress areas. Raskin et al. (1997) suggests above 20 % of WEI indicating water scarcity and higher than 40% for severe water scarcity. These thresholds are commonly used in scientific studies (Alcamo et al, 2000). Besides, Smakhtin, et al., (2005) suggest 60 % withdrawal from the annual total runoff would cause environmental water stress. Despite no formally agreed thresholds are available for assessing the water stress 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 the mapping purposes.

By definition WEI+ is the ratio of water use over the renewable water resources. Using certain thresholds for identifying the level of stress from water consumption will be very helpful in better illustrating the water scarcity and drought conditions in a given territory. For this purpose the CIS

[11] Nopolu application has been used in the current water asset accounts computation. Nopolu was developed by Pöyry, later changed by Naldeo, following the UN SEEA Water Framework. The application contains a number of specific algorithms for computing different components of the UN SEEA Water. In the current calculation the new version of the Nopolu has been used with some significant modifications done by Naldeo and EEA.

TWG Water Scarcity and Drought ([12]) has proposed the environmental flow concept to be implemented. Furthermore, the Commission has set up two Working Groups in accordance with 2013–2015 CIS WFD-FD program which have ended up with producing guidance documents on the application of water balances for supporting the implementation of the WFD technical implementation on water accounts (European Commission, 2015b) and Ecological flows in the implementation of the Water Framework Directive (European Commission, 2015a) in River Basins or Catchment scales. Several pilot studies were funded as grant initiatives under DG Environment i.e. in Spain (Guadiana, Guadalquivir, Tagus, Duero, and Segura RBDs), Italy (Arno RBD) and Greece (Pinios RBD) to assess physical and economical accounts ([13]). But a harmonized and comparable method of calculation for environmental flow could not be achieved so far.

Agreed warning thresholds of the Water Exploitation Index are quite important for correctly interpreting the European WEI results. Raskin et al (1997) suggests above 20% of WEI indicating water scarcity and higher than 40% for severe water scarcity. These thresholds are commonly used in scientific studies (Alcamo et al, 2000). Besides, Smakhtin, et al., (2005) suggest 60% withdrawal from the annual total runoff would cause environmental water stress.

> In this report 5% intervals are used for the mapping purposes and greater than 40% is adopted as the highest interval in the WEI+ maps.

Another concern is related to the question of which formula has the capacity to better estimate the water stress. This concern is highly linked with the quality of data on one hand and to the degree of human intervention with natural hydrological cycle on the other. As proposed by the CIS WG TWG on Water Scarcity and Droughts in 2012, Formula 1 is generally convenient to be implemented in “pristine” areas where there is no or a very sparse degree of human involvement. While it is proposed, formula 2 is to be applied in those hydrological units where water abstraction alters the run-off regime.

> In this study it is adopted that there is no whole sub-basin presenting “pristine” natural conditions in Europe. Therefore, Water Exploitation Index is assessed based on the formula 2 results.

[12] Update on Water Scarcity and Droughts indicator development

[13] Water balances and water resources management targets

2 Data and uncertainties

2.1 EEA Water Accounts Production Database

Exploring the routes of water between environment and economy requires various heterogenic environmental and economic data sets to be involved and integrated. The EEA Water Accounts Database is a warehouse of data harvested from SoE and other data sources enabling quantification of the European scale of WEI+ and Water Asset Accounts.

> Detailed clarifications on data processing for the renewable water resources can be found in Annex – I; and for the water use component in Annex – II.

In practice, the Water Exploitation Index plus is exploring input/output relationship in a given hydrological territory. In hydrological terms, inputs refer to external inflows from upstream territories (either surface or groundwater) and to precipitation. Output from the hydrological entity is possible after volumes of water used either by the environment (actual evapotranspiration, outflow to downstream territories/to the sea) or by economic activities.

For estimating the climatic variables in renewable water resources; climatic data were obtained from the EEA Climatic Database developed based on ENSEMBLES Observation Dataset (E-OBS) (Haylock et al., 2008). E-OBS data are further processed to disaggregate the climatic parameters to the catchment scale (see clarifications on the climatic parameters at Kurnik et al., 2014). The current climatic data available in the EEA Water Accounts Production Database consists of precipitation, actual evapotranspiration, surface stream flow, soil water and temperature for the years 2002–2013. SoE water quantity climatic data has been used for validating the E-OBS data before running the computation for the renewable water resources.

As for the estimation of external inflow and outflow, the main source is the SoE water quantity streamflow data reported by the EEA member countries. This database doesn't have full spatial and temporal coverage for all of Europe yet. Previously, an ad-hoc streamflow data compilation had been carried out by Pöyry under the contract with the DG ENV in 2012 ([14]). This data has been kept. Furthermore, in order to fill the gaps in spatial and temporal coverage, JRC LISFLOOD data has been integrated into the Water Accounts Production Database ([15]). By means of the JRC LISFLOOD data the current EEA Water Accounts Production Database has enabled to cover all EEA countries for the years 2002–2012 at catchment scale.

The second input/output relation is the subject between water abstraction and return. Water is abstracted for different purposes to meet the demand of societal and economic needs and is returned back to the environment after its use. SoE Water Quantity Database hosts information about water abstraction, but with insufficient temporal and spatial coverage. Therefore, some proxies and modelling had been developed by Pöyry in the previous European Water Assets Accounts

[14] Service Contract to contribute to the building of Water and Ecosystem accounts at EU level, Final Report 1, Reference system and Ressouces datasets

[15] LISFLOOD data is providing information on stream flow at 5 km grid covering all of Europe with daily resolution. Thanks to the JRC provision of the stream flow data to EEA, this data has been integrated into the EEA WADP and used for gap filling. See further clarifications on the stream flow database structure and methodology implemented in integrating LISFLOOD data in Annex-I of this report.

implemented by the DG ENV ([16]). The model has been maintained in the new calculation of the WEI+ with the updating water use time series via inserting SoE and Eurostat data.

To compile water use information across Europe, Pöyry had used in 2012 the Landscan 2010 ([17]) for the distribution of population across Europe, Urban Morphological Zone (EEA dataset ,2014) for distinguishing urban and rural population and Urban Waste Water Treatment Plants (UWWTP) database (EEA, reported data 2015a) for estimating the proportional distribution of population connected to Urban Waste Water Treatment Plants. Landscan and UMZ have not been updated in this study as there is no significant changes in both databases. However, UWWTP database has been updated via the new data deliveries under that reporting cycle.

For water abstraction by industry, The European Pollutant Release and Transfer Register (E-PRTR) database (EEA, reported data 2015b) was used for distribution of industrial installations ([18]). E-PRTR database has been updated in the new computation. Water use coefficient per industrial installation had been obtained from BREF ([19]) without information on production level at the instalment scale. Cooling water database has been developed by the European Commission General Directorate of Environment in 2014 ([20]).

As for water return, this information is mainly harvested from the UWWTP database. The population equivalent capacity of each UWWTP is taken into consideration while estimating the water abstraction and return. It is assumed that all urban population is connected to UWWTPs while the remained capacity of the UWWTP installations are used for the rural population ([17]).

Water use by agriculture had been harvested from the JRC database on water requirements per crop (Gunter Wiedt et al., 2008) by Pöyry under the contract with the DG-ENV in 2012. No further update has been done in the database except the coefficient per crop type has been expanded until 2012 based on the results of the previous period of time.

All components of the water abstraction and return are validated at sub-unit or river basin district or country scale with the data reported by member countries to the SoE Water Quantity database or to Eurostat where available.

The spatial reference data is the European Catchments and Rivers Network System (Ecrins). Ecrins is a seamless spatial data set produced by the EEA containing necessary spatial information on catchments and drainage networks (EEA, 2012). Ecrins makes possible further aggregations between different hydrological administrative units i.e. catchment, sub-basin, river basin, NUTS2 and country scale.

2.2 Data and methodology uncertainties

> Due to insufficient data availability, opening and closing stock of the reservoirs can’t be quantified. Instead, change in reservoirs is provided.

[16] Service Contract to contribute to the building of Water and Ecosystem accounts at EU level, Final Report 2, Uses & Supply

[17] LandScan™

[18] See for further clarifications on the water use data modelling in Annex –II of this Report.

[19] Reference documents under the IPPC Directive and the IED

[20] This database is treated as confidential

The complete calculation of renewable water resources can only be done when actual total volume of water stored in lakes and reservoirs together with the information on external inflow and outflow would be available. The current SoE Water Quantity Database hosts information for these parameters only for 147 entities from 10 EEA member countries, despite Ecrins has 70 000 lakes and reservoirs while the WFD reporting in 2010 provides information on the existence of 372 000 entities across Europe but without storage information. The possibility for involving the change in storage into the calculation is only possible to include relative changes of storage as possible water demand. But this approach is a very rough approximation and creates uncertainty around the actual volume of water abstraction from the reservoirs.

Water abstraction and returns calculation is a hybrid calculation of reported data together with the modelling.

Due to the complex nature of relationships between environment and economy, the water abstraction and return calculation is highly demanding on data. Data required for a complete analysis of water abstraction and return are not available for all European regions. Therefore, population, industrial plants and their installation capacities as well as crop water demand for irrigation are used as the main proxies in calculating the water abstraction by economic sectors further compared with the renewable water resources. This algorithm had been already developed within the Nopolu by the Naldeo for the DG ENV contract.

The same algorithm has been used in the new calculation as well. For the variation of the water use on monthly scale, tourism data ([21]) and production in industry ([22]) have been additionally used in the new calculation. Further validation of the water abstraction and return have been made with SoE and Eurostat data at sub-basin or river basin scales where reported data is available.

Double counting of water consumption by tourism

Dealing with the impact of tourism over the water consumption certainly causes double counting due the lack of information on the origin of the travel. On the other hand, the impact of tourism on local water resources is quite important to know particularly in those areas prone to water scarcity and drought i.e. in small Mediterranean islands and in some popular tourist destinations of Europe.

Double counting aspect of tourism in WEI has been partially counterweighted in the current study by the assumption, that tourism water consumption equals the respective residents' consumption. However, scientific literatures suggest that one tourist generally uses 2–3 times more water per capita/day compared to the local inhabitants (Essex et al. 2004; Gössling et al., 2012).

Water Exploitation Index plus results are not always positive values. Because of the limitations in WEI+ formulas, sometimes the monthly scale of WEI+ can render negative values.

Water Exploitation Index plus calculation sometimes can render negative results as some months provide water return greater than water abstraction due to the time lag between water abstraction and return or insufficient data quality. Similar situations would also be encountered particularly in

[21] Eurostat tourism (tour) dataset

[22] Eurostat Production in industry (sts_inpr_m) dataset

summer months when actual evapotranspiration would be greater than precipitation. In both cases, the WEI+ results would be negative. For proper interpretation with this type of result the following approaches were adopted;

Return greater than abstraction

For a month where the volume of returned water is greater than water abstraction, from the water assets accounts point of view, it means that there is no net water consumption from the environment. On the contrary, the residual water returning back to the environment can be calculated as surplus. In order to avoid from effect of "0" value in the division "1 m^3" of water is adopted as the positive difference between water abstraction and return.

Actual evapotranspiration greater than precipitation

During the summer months in many locations particularly in the Mediterranean region actual evapotranspiration could be greater than precipitation. As there is no clear conceptual solution for the deficit between ETa and P in both proposed renewable water resources formulas, this deficit is met from the water storage i.e. from reservoirs. This causes the water balance in reservoirs to be always negative until the next period where P would be greater than ETa. This situation is certainly related to the lack of data on reference volume of water in reservoirs and lakes. On the other hand, this type of negative WEI+ value points out the pressure over the renewable water resources. Therefore, it is adopted that such negative WEI+ values have to be converted into the positive.

In order to avoid such cases to the extent possible, seasonal Water Exploitation Index assessments have been conducted at river basin district scale despite the upper scale of WEI assessment in spatial and temporal terms, may hinder the appropriate analysis of water scarcity and drought conditions.

Both nominator and denominator are negative

As mentioned earlier, sometimes water consumption and renewable water resource components of the WEI+ formula would be negative for the same time period. In such cases, even water is returned back to the environment more than water abstracted, still there is significant pressures over the renewable water resources due to less available water in the environment. Therefore, whenever negative values would be on the both sides of the WEI formula, the result is also converted into the positive.

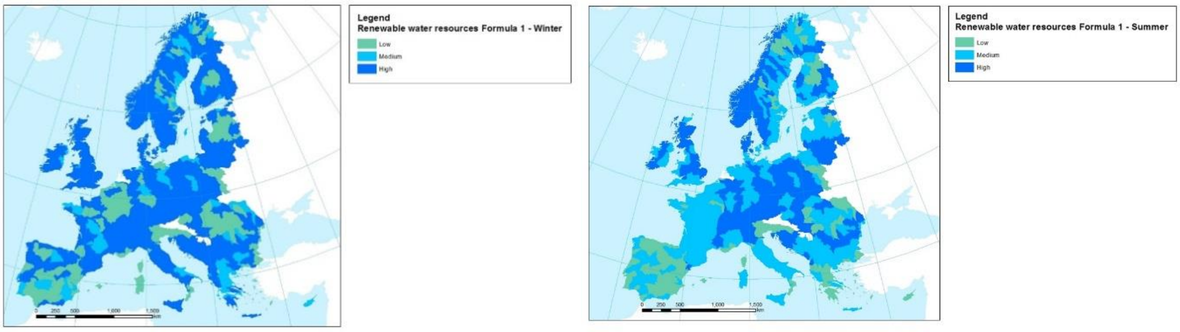
3 Water availability and consumption

3.1 Renewable water resources of Europe

Europe ([23]) receives approximately 3.7 x 10^6 hm^3 of water from precipitation on an annual scale (average for the years 2002–2012). More than half of that amount (55%) returns back to the atmosphere by actual evapotranspiration. Renewable water resources (estimated according to Formula 1) significantly varies among the regions[24] and seasons (Map 3.1) across Europe. Mostly mountainous areas and lowlands of the western part of Europe and Baltic region have comparatively higher renewable water resources compared to the Mediterranean region. Seasonal variations indicate lower water availability during the winter particularly in those areas receiving precipitation, while in summer high water availability can be observed in the Alpines and Atlantic. The Mediterranean region experiences a significant low level of water availability during summer and winter months.

> The Mediterranean region experiences less renewable water resources throughout the year compared to other biogeographical regions of Europe.

Map 3.1 Renewable water resources seasonal (winter & summer) *distribution across Europe calculated by formula 1*



The length of time series is not sufficiently long enough for a trend analysis in terms of changes in the renewable water resources in the European biogeographical regions.

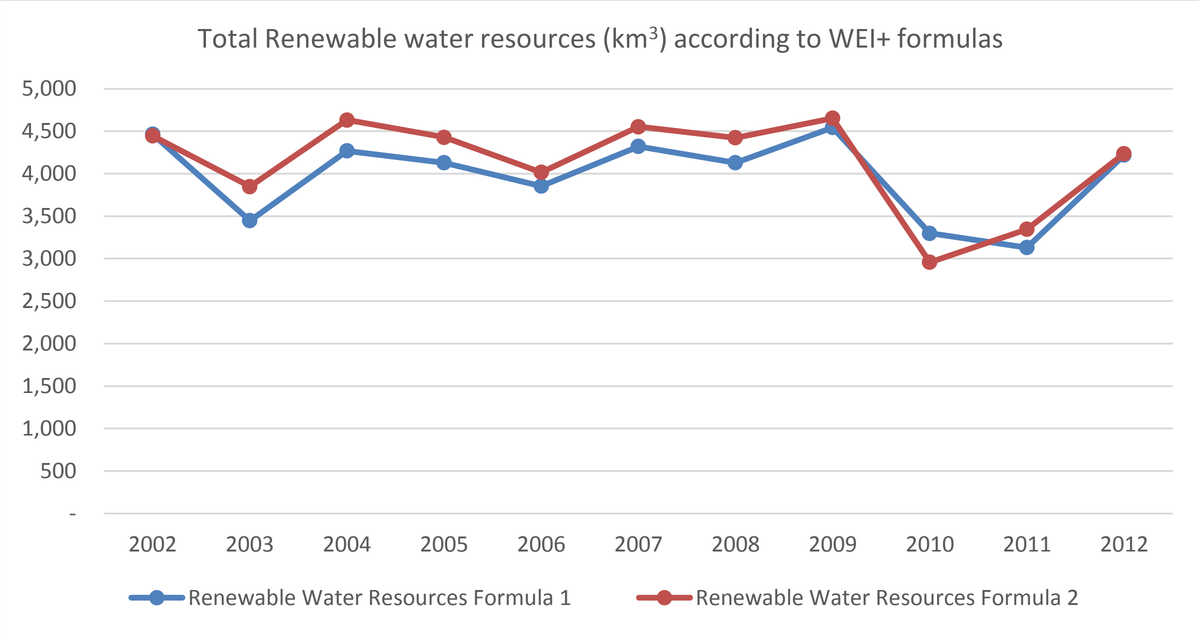
> Renewable water resources are fluctuating over the years.

However, fluctuations from one year to another are observed depending on the calculation formula used (Figure 3.1) revealing to the possible extent the importance of pristine/human intervened status of the hydrological entities examined.

[23] Spatial coverage of this study are the EEA member countries including cooperating countries of the West Balkans excluding Turkey and Iceland due to the lack of available data.

[24] Biogeographical region is used in this indicator as one of the assessment scales. Delineation of the biogeographical regions are taken from the official delineations used in the Habitats Directive (92/43/EEC) and for the EMERALD Network set up under the Convention on the Conservation of European Wildlife and Natural Habitats (Bern Convention).

Figure 3.1 Total renewable water resources across EU

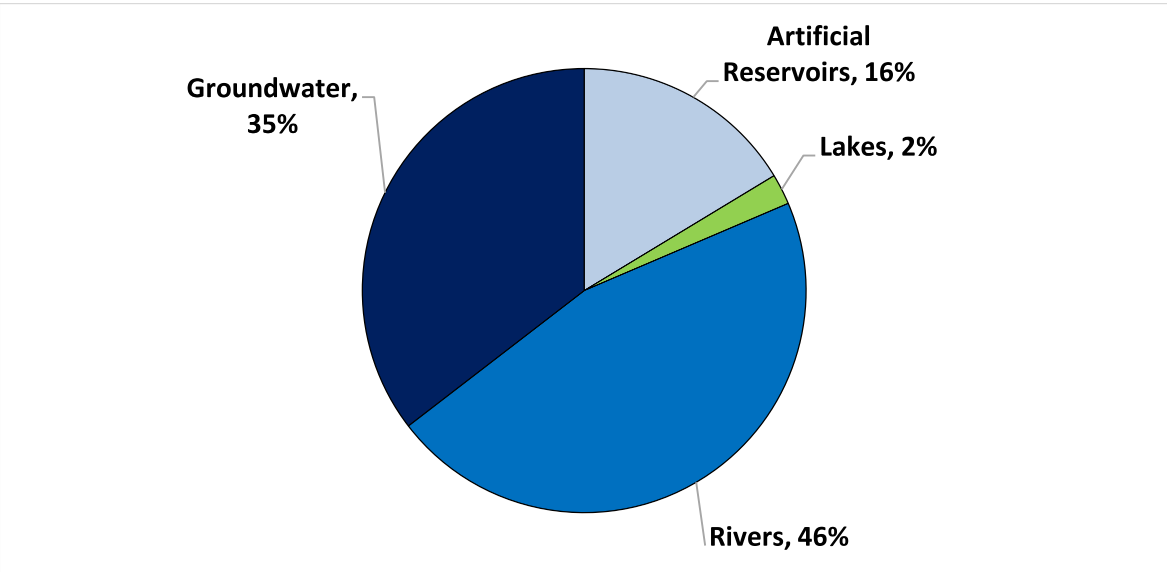


3.2 Water use in Europe

> Surface water meets around 65% of total water abstraction needs, while groundwater proportionally covers 35% of the European demand on freshwater resources.

The main source of meeting the water demand in Europe is surface waters. Among the surface water resources, rivers are receiving the main pressure by covering around 46% of total water abstraction. Rivers and ground water are the main resources where almost 80% of total water abstraction occurs every year (Figure 3.2).

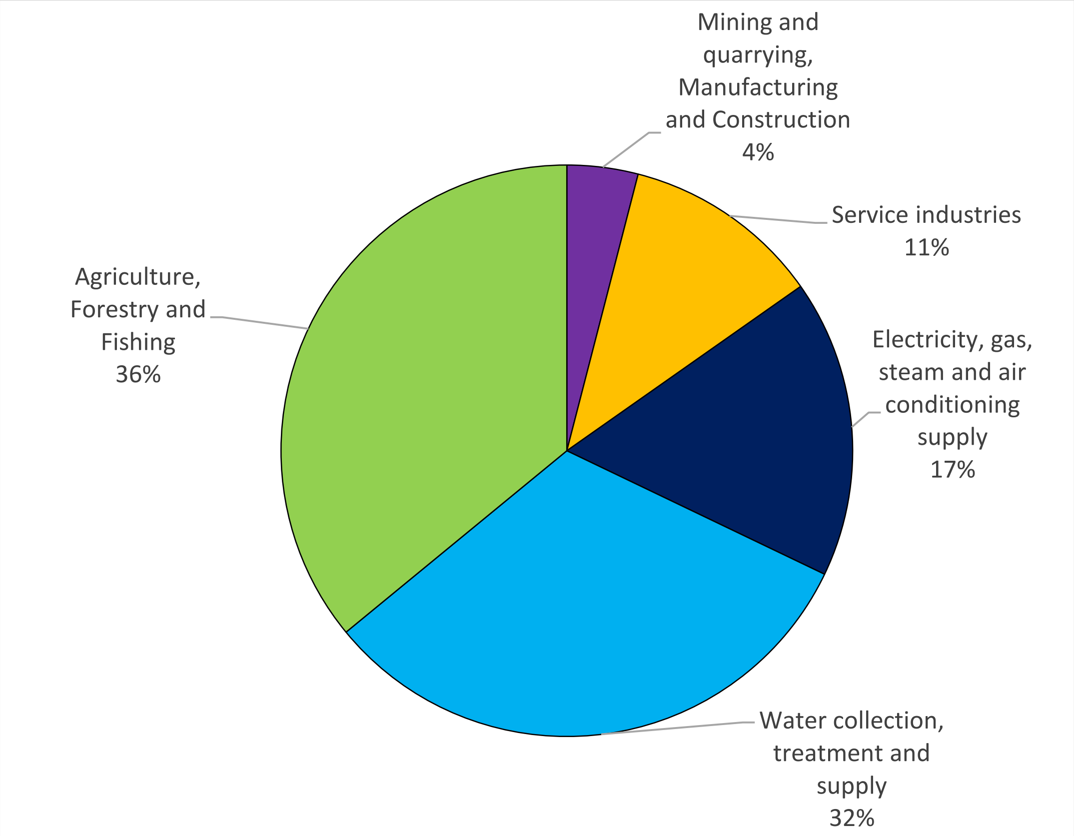
Figure 3.2 Water abstraction by sources (multi-annual average for 2002–2012)



Around $6x10^4$ hm^3 of water is annually used in Europe for different purposes from renewable water resources. Despite almost 109 000 hm^3 of water is abstracted every year, a big portion of this water is returned back to the environment mainly from electricity, gas, steam and air conditioning supply sector.

Three main sectors are using approximately 85% of total water abstraction in Europe; Agriculture, water supply and electricity (Figure 3.3).

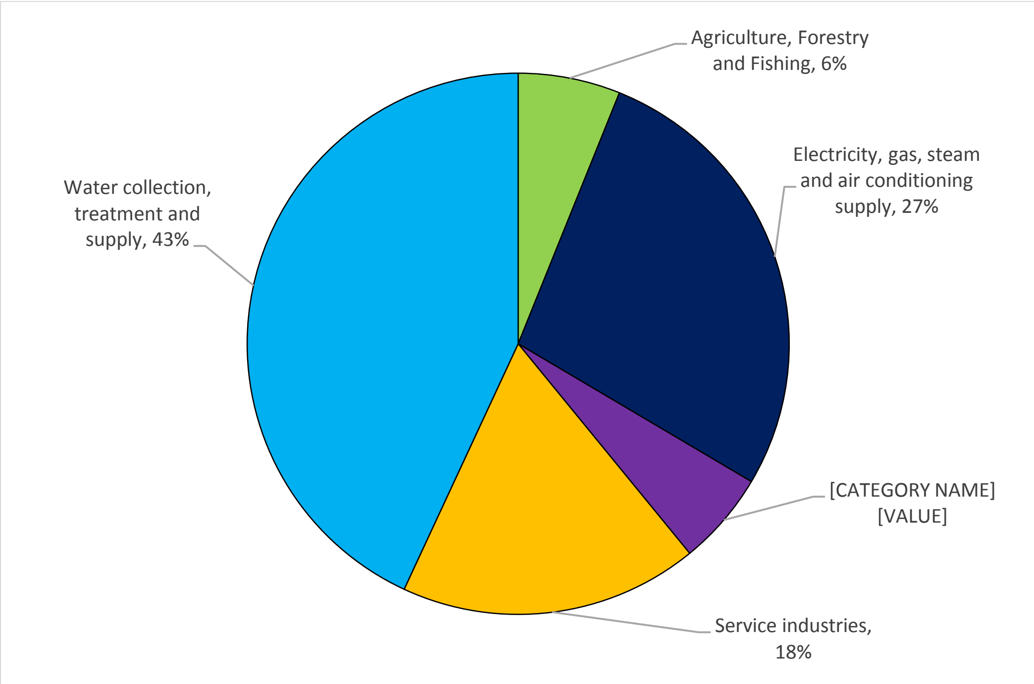
Figure 3.3 Water use by economic sectors (multi-annual average for 2002–2012)

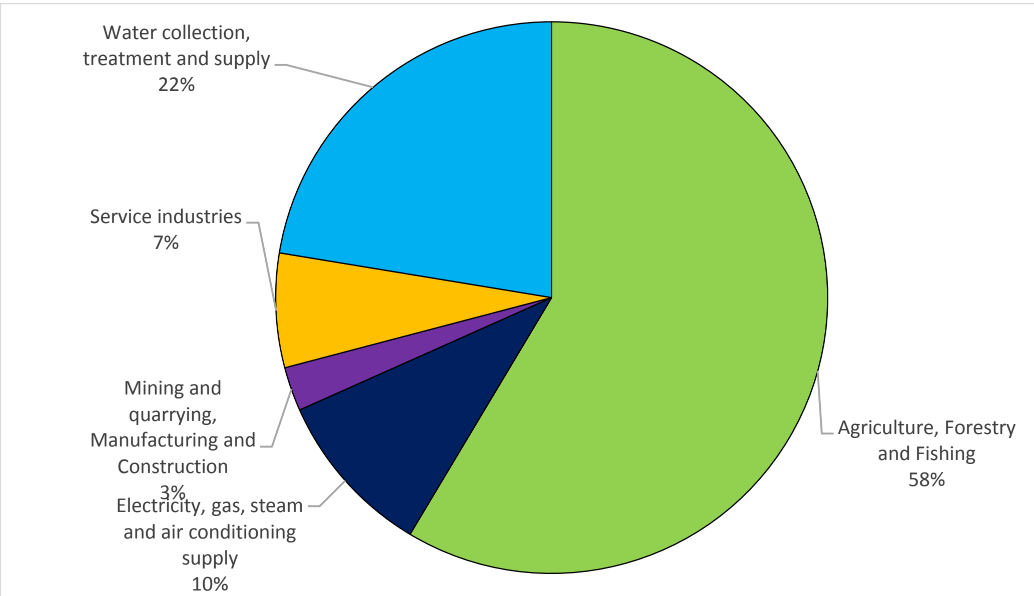


Water abstraction in summer is almost two times more compared to winter.

Seasonal water use presents significant differences between summer and winter. In winter almost half of the total water abstraction is used by water collection, treatment and supply whilst the electricity sector uses almost 10% of the water in summer months (Figure 3.4).

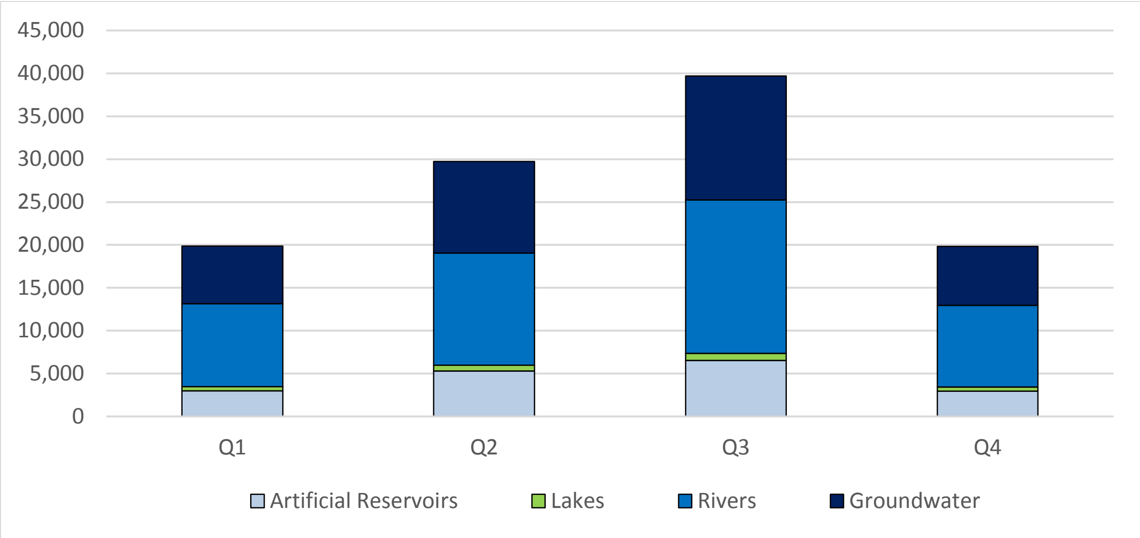
Figure 3.4 Seasonal water use per economic sector for winter (above) and summer months (below)





In summer months, agriculture, forestry and fishing uses almost 60% of total water abstraction in Europe. Seasonal assessment of water abstraction by source indicates that water is abstracted more in summer compared to winter. The pressure of abstraction over the water resources is fluctuating for rivers and groundwater resources throughout the year. Water is stored in reservoirs mainly during the winter months and used in summer (Figure 3.5).

Figure 3.5 Seasonal abstractions in hm³ by water sources (based on annual average values)

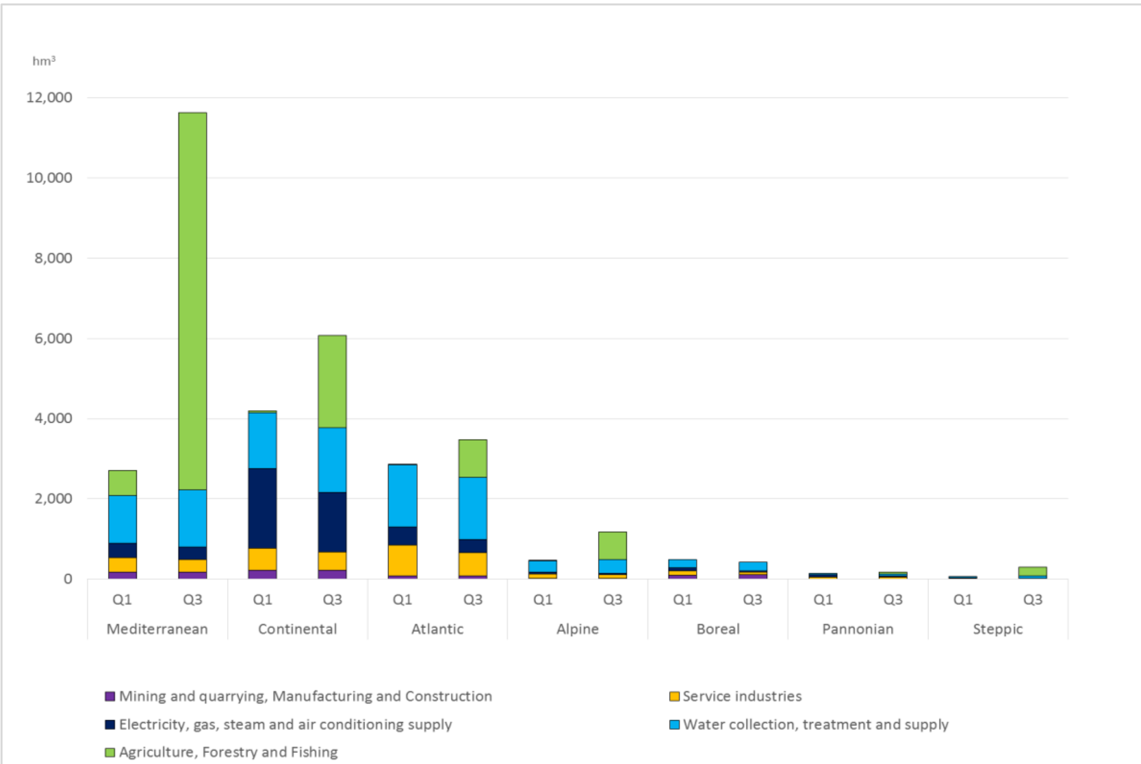


Note: Q1–Q4: Quarters (3 month intervals) of the calendar year

3.3 Pressures on the renewable water resources

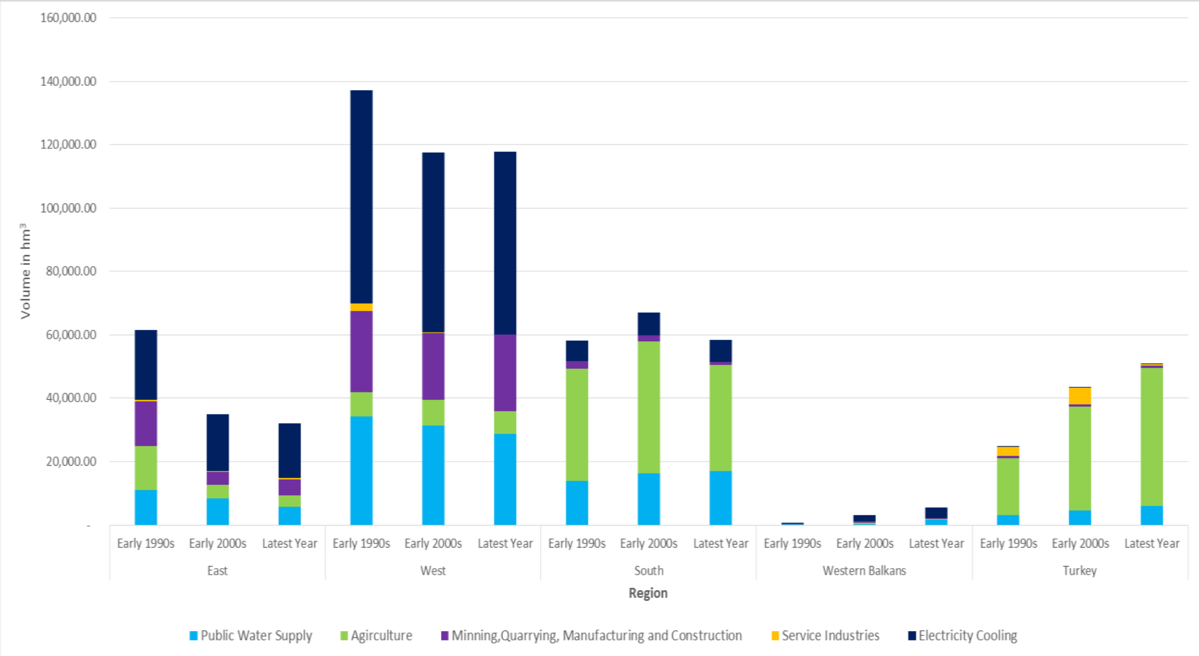
Water is abstracted from the environment for meeting social and economic needs. Following the trace of water cycling within the economy exposes information on the source of pressures on the water resources. Based on the ISIC (NACE) classification, analysis of water consumption per sector indicates that agriculture and water supply in Europe (Figure 3.6) are still remaining the main pressures on the water resources.

Figure 3.6 Seasonal water abstraction (comparison of Q1 and Q3) by economic sectors (multi-annual average 2002–2012)



The above assessment is mainly confirmed by the findings at the national scale based on the Eurostat data. A temporal comparison conducted for 1990s, 2000s and the latest year available (in most cases 2010–2013) in the Eurostat database for the water abstraction by sectors [env_wat_abs] points out a decrease in the Western parts of Europe while the Southern regions present mixed status with increased water abstractions for public water supply and electricity cooling sectors (Figure 3.7)[25].

Figure 3.7 Freshwater abstractions trend analysis based on annual country Eurostat data [env_wat_abs] dataset.



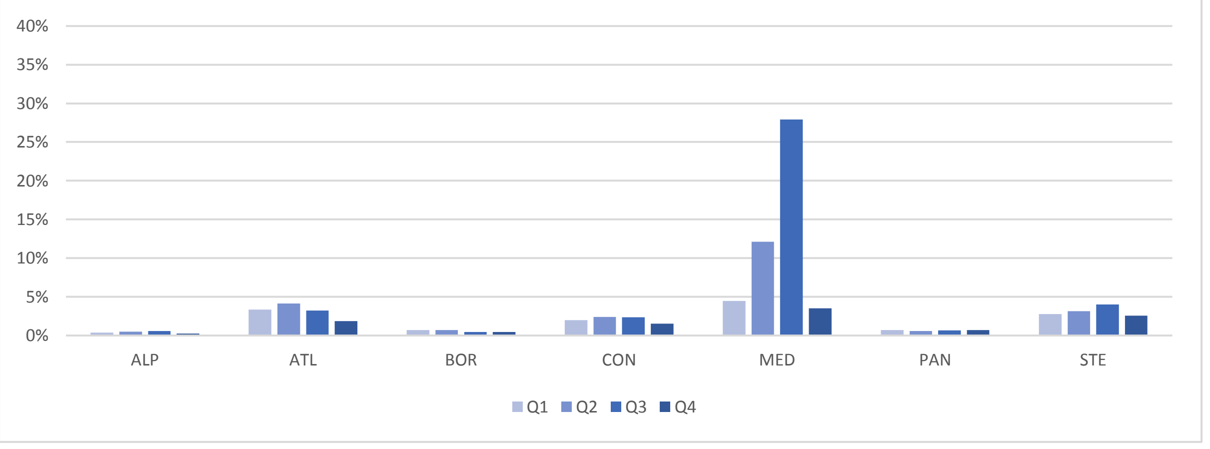
[25] Additionally, the Eurostat data were classified in regions (see Annex II table 7.7).

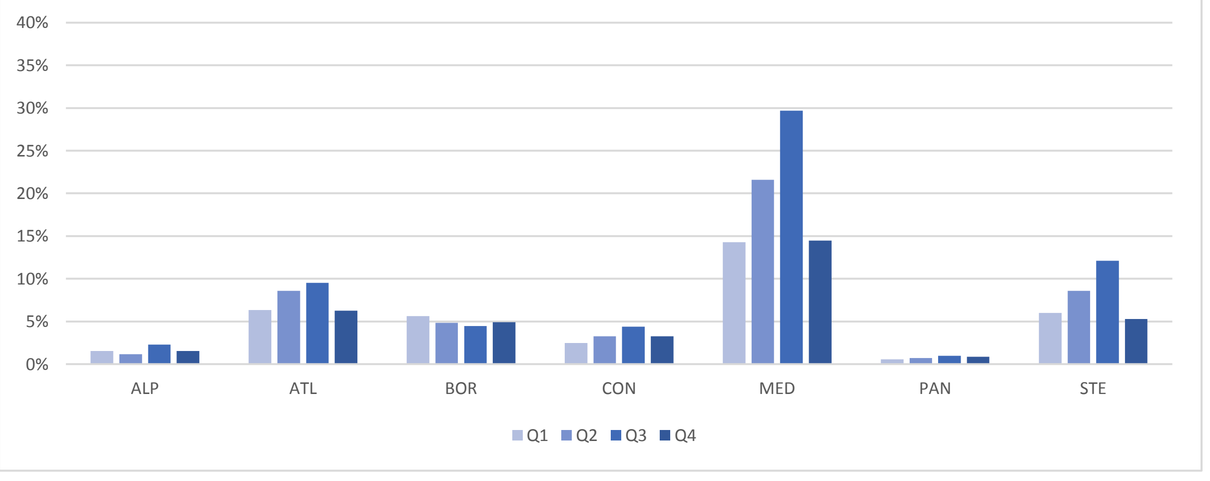
4 Water Exploitation Index across Europe

The Mediterranean region experiences the highest water stress than most other regions in Europe (Figure 4.1). Mostly Mediterranean countries e.g. Malta, Cyprus[26], Spain, Greece and a bit Italy and Albania in summer months live under water stress conditions. But it is also known that particularly in Malta and Cyprus desalinated water gains more importance in meeting the water demand throughout the year.

> During the winter months about 30 million inhabitants live under water stress conditions while in summer this number increases up to 70 million which corresponds to 14% of the total population of Europe.

Figure 4.1 Quarterly average of Water Exploitation Index per Biogeographic region for Formula 1 (above) and Formula 2 (below)



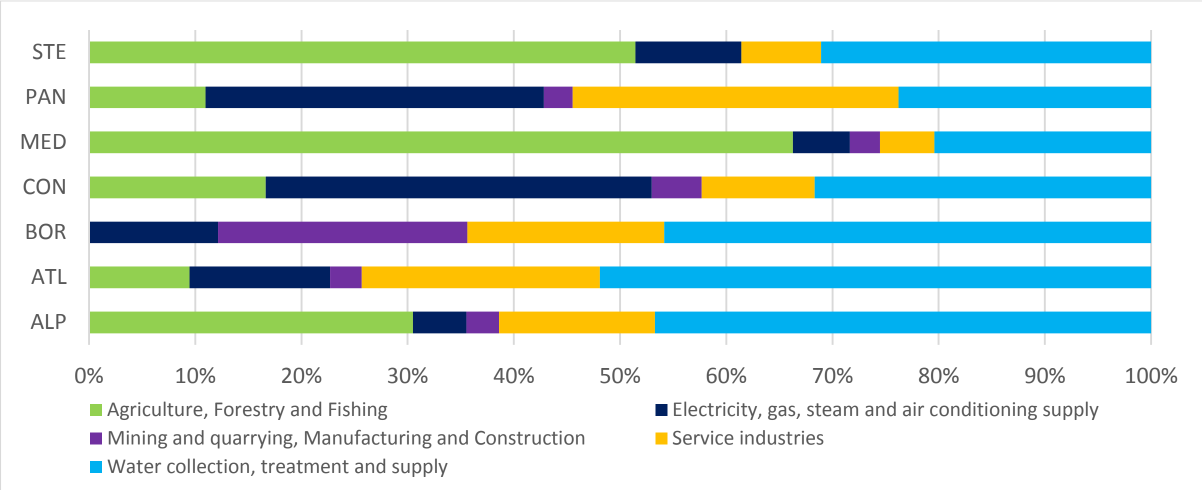


Regarding sectorial pressures emerged from the biogeographical regions, Figure 4.2 illustrates the total share of water use in biogeographical regions per economic sector. According to this analysis

[26] Water Exploitation Index for Cyprus is over estimated due to the wrongly-reported coordinates of the gauging stations under the SoE data flow. Thus it is not possible to integrate the streamflow data from Cyprus into the assessment.

almost 65% of total water use in agriculture, forestry and fishing occurs in the Mediterranean region. Similarly the highest share of water use in electricity sector happens in the Continental region (36%).

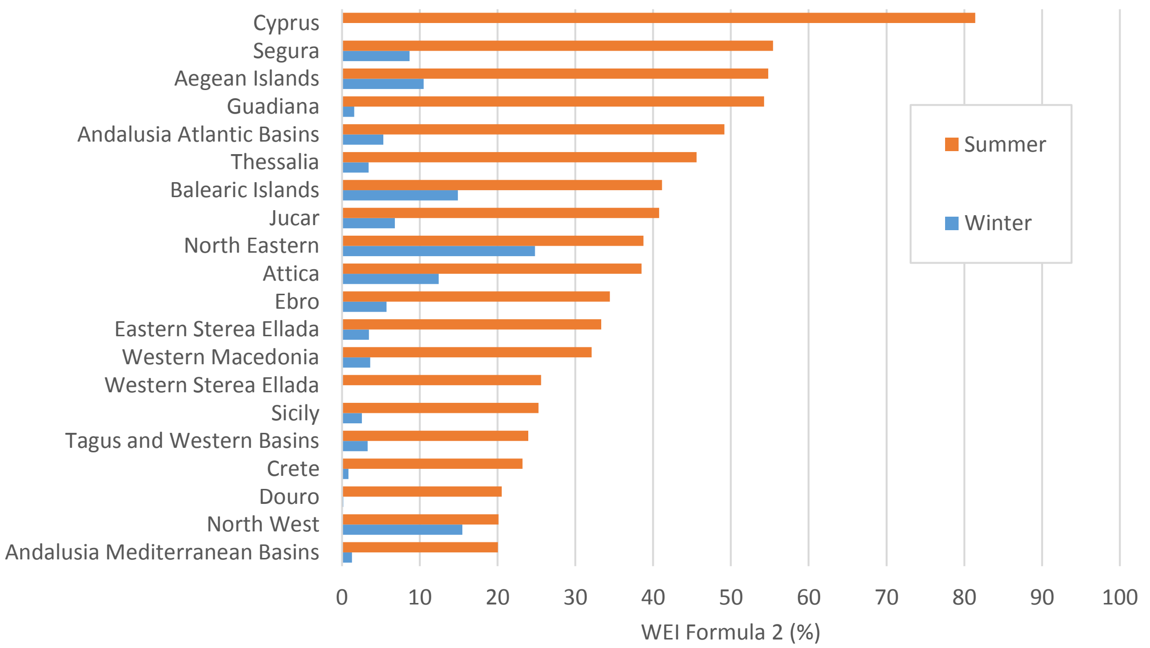
Figure 4.2 Total share of water use (%) per economic sector in biogeographical regions



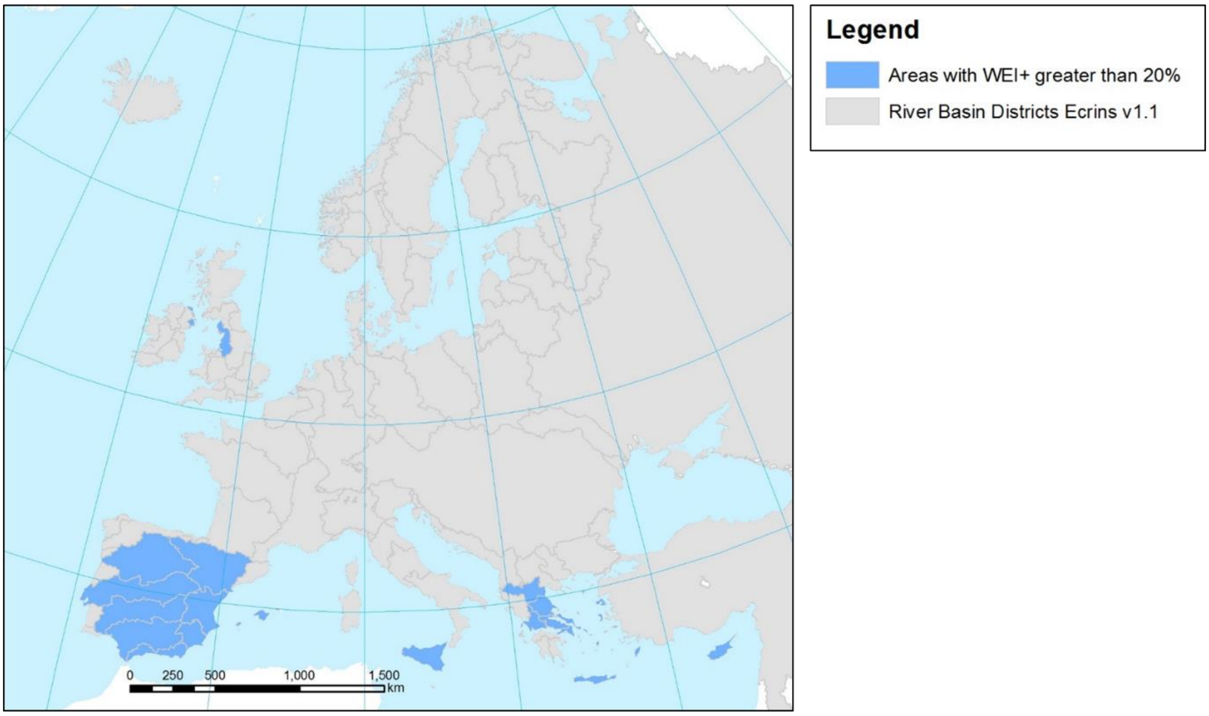
Note: This graph depicts the percentages of water use across the area of study. Water accounts data availability differ from one biogeographical region to another, therefore total spatial coverage is not succeeded for all the regions

Scaling down the analysis of water stress to the River Basin Districts scale indicate that 20 river basin districts are experiencing water stress with higher than 20% of Water Exploitation Index plus (Figure 4.3). Mostly those river basin districts are islands and are located in the Mediterranean (86%) and in the Atlantic (14%) regions. The total population living under water stress in winter is about 30 million. In summer this number increases up to 70 million. When summer comes, the high Water Exploitation Index plus expands its coverage almost all over the Mediterranean islands including Spanish and partly Portuguese river basin districts (Map 4.1).

Figure 4.3 River Basin Districts (Ecrins FRBD) where average WEI+ is greater than 20% (period 2002–2012)



Map 4.1 River Basin Districts (Ecrins FRBD) with WEI+ greater than 20%



Seasonal conditions between summer and winter provide a significantly different pattern than annual scale in the detailed SB spatial resolution (Figure 4.4).

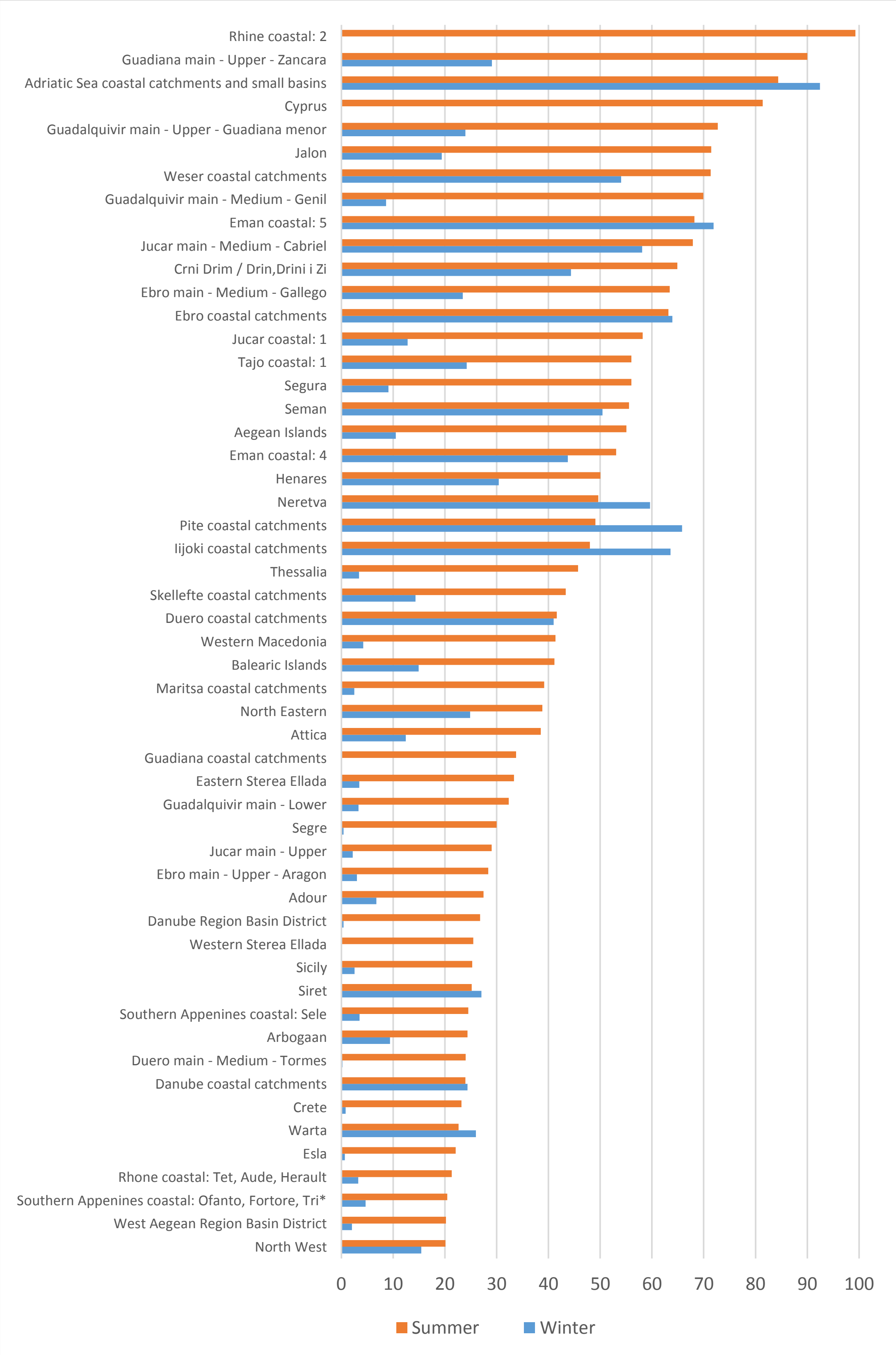
Text box: Water balance and Water Exploitation Index in the United Kingdom
(Kowalski *et al.*, 2011)

Based on the assessment for the years 2006-2007 which has been carried out by WRAP covering the United Kingdom, indicates that the total annual water abstraction in the UK is about 65 000 hm^3. The country scale of WEI+ is estimated 10% for UK. But regional differences in the UK indicate that in south eastern and eastern England the WEI+ increases up to 22%.

Analyzing the proportional distribution of water abstraction per economic sector reveals that half of the water is abstracted for public water supply followed by electricity production (30%) and the remaining for other non-household uses, including agriculture and aquaculture.

Water use is classified by the UK Environment Agency as consumptive use and non-consumptive use. Based on this classification, water for consumptive use is mostly abstracted by manufacturing, electricity and agricultural sectors followed by accommodation and support services.

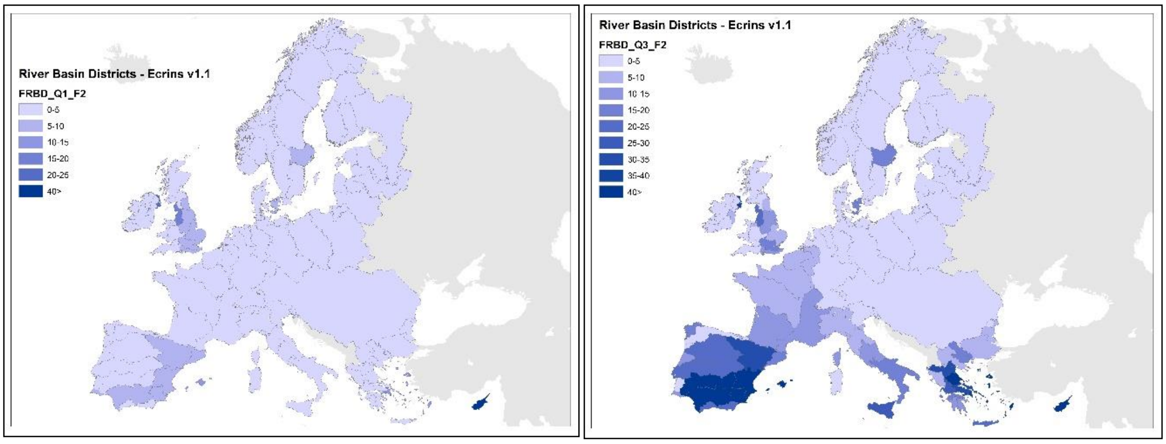
Figure 4.4 Water Exploitation Index at the Sub-basin scale in winter and summer



Note: The names of the Sub-Basin entities are referring to the database coding fields

The main sectors creating pressures over the water resources in the Mediterranean islands are public water supply (55%) and agriculture (32%). There is very limited information available on the services sector in the Mediterranean islands. Mainly water abstracted for tourism is embedded into the public water supply. On the other hand, in order to better analyze the impacts of tourism over renewable water resources, a proxy for quantifying water use by tourism as separate information from the public water supply has been developed in this study. Further clarification on the methodology on tourism data processing can be found in Annex-II. Nevertheless, the findings indicate high pressures from tourism in the Mediterranean islands as well as in some large cities like London, Paris etc. as they attract mass tourism.

Map 4.2 Seasonal (Q1, Q3) WEI+ at FRBD scale of Formula 2



Note: First Quarter (Q1: January–March), Third Quarter (Q3: July–September)

Text box: Water Exploitation Index in Italian Basins

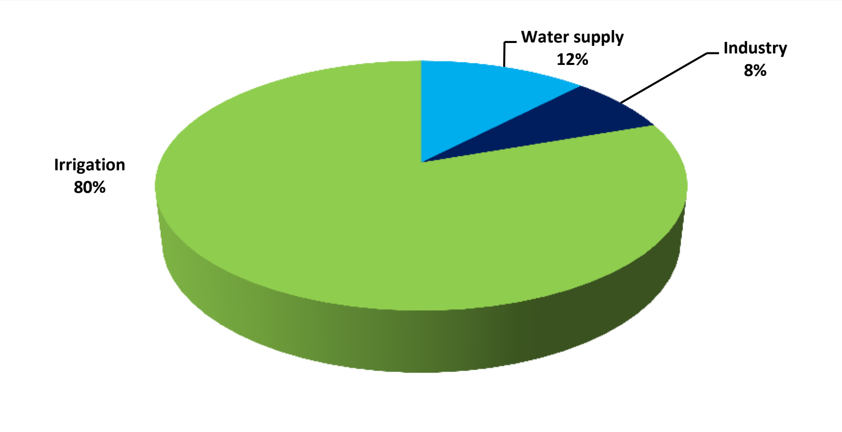
Po Basin Implementation of drought policy in the Po River Basin (Source; Checcucci, 2011)

Po River Basin is one of the largest basins in Italy with 70.000 km^2 of basin area. The area of the basin is occupied as 58% by mountains and 42 % by alluvial plain. Approximately 17 million inhabitants are living in more than 3000 settlement areas including 3 metropolitan cities; Milano, Bologna and Torino.

The annual average of surface flow from the Po River is 45 000 hm^3 per year. The total renewable water resources estimated for the Po Basin is about 87.000 hm^3, of which 89 % is surface water while ground water is consisting of 11%. 1289 hm^3 of water is subject to being stored in reservoirs on an annual scale.

The total water consumption is approximately 20,500 hm^3 which indicates that the annual Water Exploitation Index in the Po basin is about 0.24. This is an indication that corresponds to 24% of total renewable water resources used in the Po basin to meet water demand.

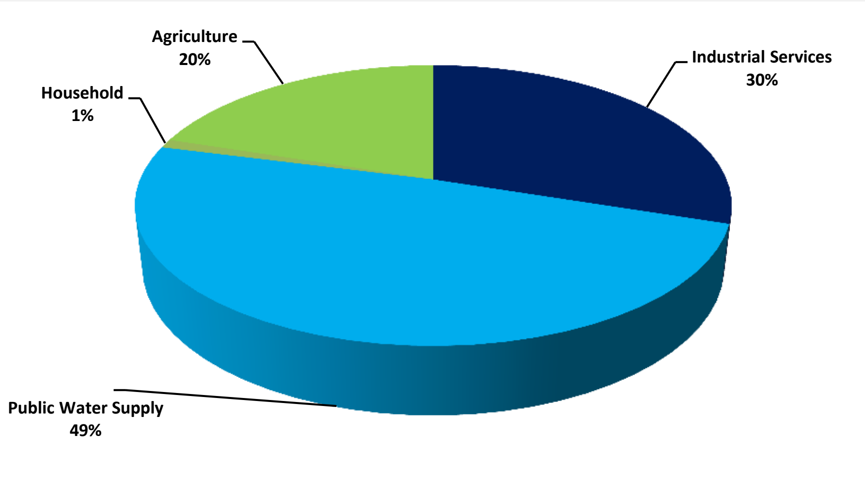
Regarding sectorial water use, irrigation is the major pressure over the renewable water resources followed by water supply.



Water Exploitation Index in the Arno River Basin in Italy

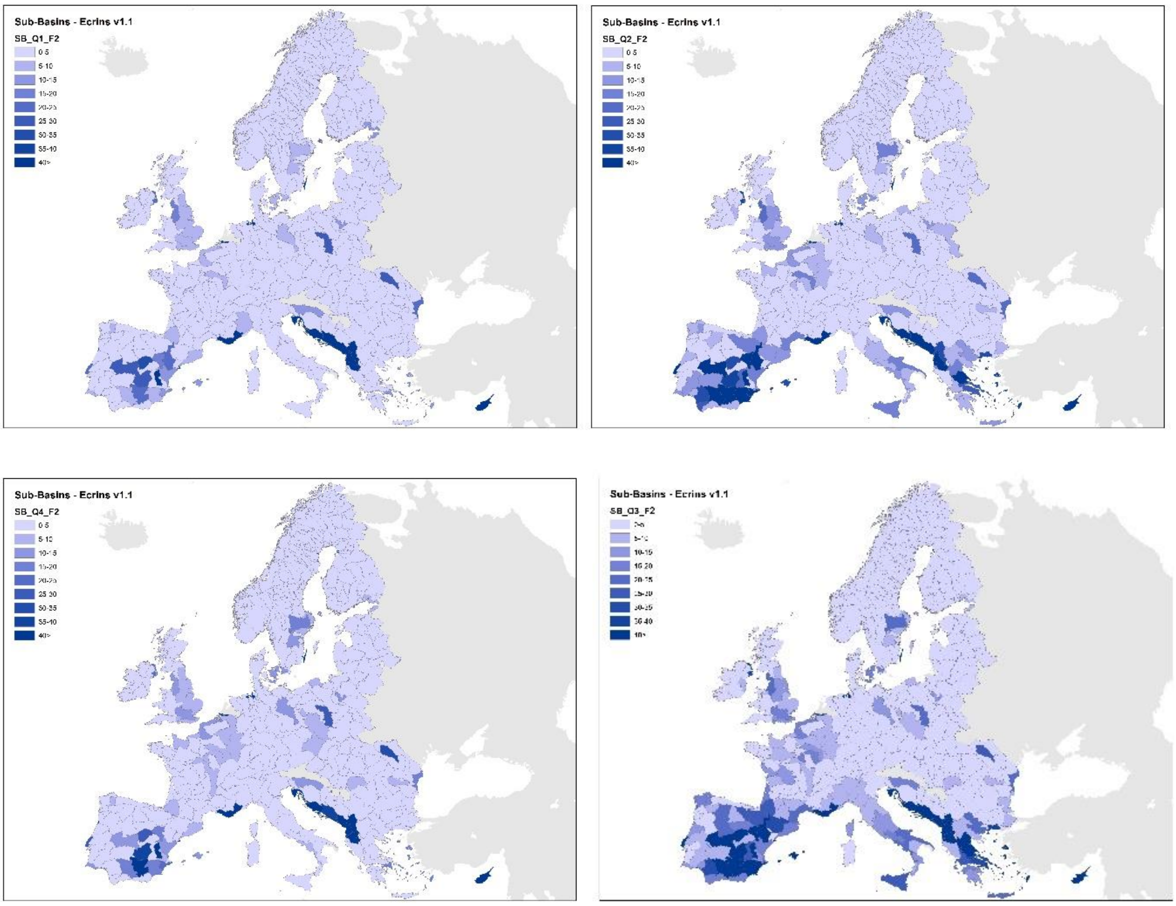
The Arno River Basin is located in the northwestern part of Italy. The total areas of this basin are reported as 9100 km^2. The Arno River is 241 km in length.

The annual average of Water Exploitation Index is estimated at 21% for this sub-basin. Distribution of water abstraction per economic sector indicates that public water supply and industry are the main pressures over the freshwater resources followed by agriculture.



Sub-basin scale provides very detailed information on WEI+ distribution pattern across Europe. Seasonal variations indicate the dominance of climatic conditions in spring and summer (Map 4.3). On the other hand, water abstraction for irrigation and population create water stress conditions diverting from the climatic zonal distribution as well as from seasonal variations. For example, even in winter months some sub-basins from the Mediterranean region still show a high Water Exploitation Index because of water abstraction, irrigation as well as tourism.

Map 4.3 Seasonal (Q1–Q4) WEI+ for formula 2 at Ecrins Sub-Basin scale



Note : First Quarter (Q1: January–March); Second Quarter (Q2: April–June)

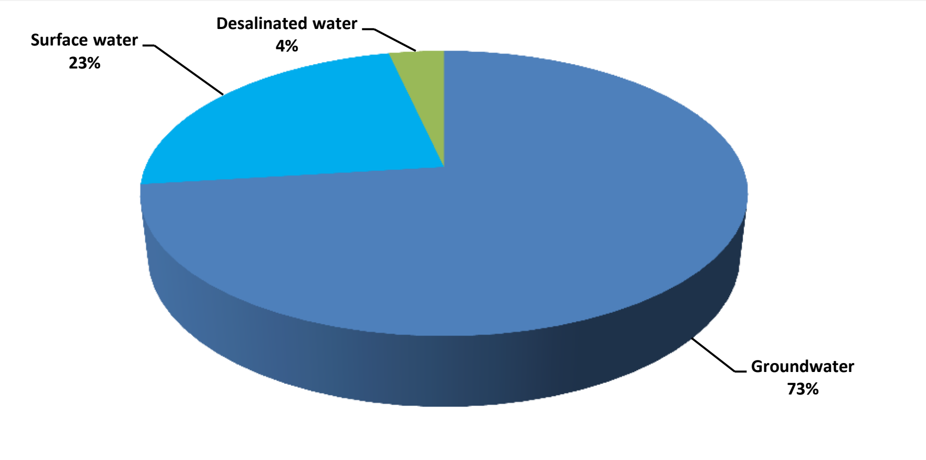
Third Quarter (Q3: July–September); Fourth Quarter (Q4: October–December)

In fact, the results obtained from both WEI+ formulas testify more or less the same distribution pattern of WEI+ values across Europe but the amplitude of the results are completely different between them.

Water Balance in Mallorca (Source: Donta *et al.*, 2005)

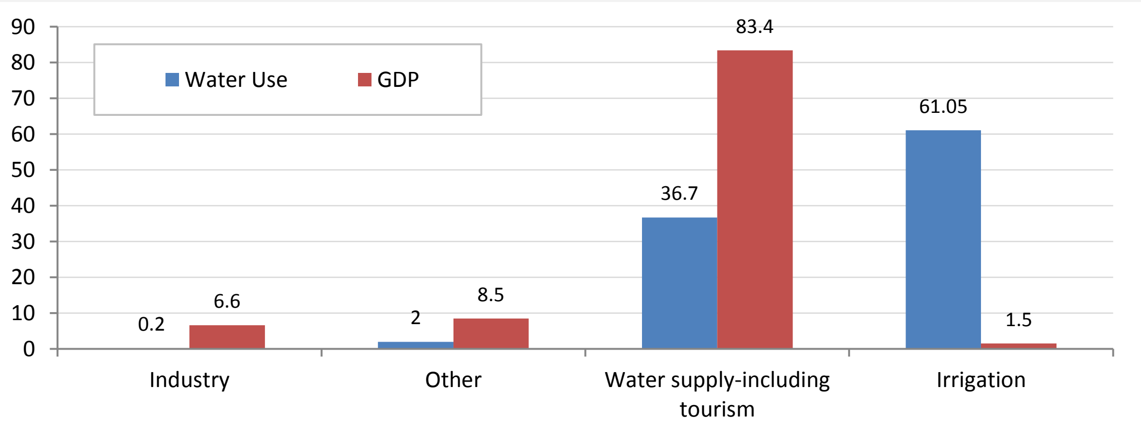
Mallorca is the main island of the Balearic archipelago located to the north-west of the Mediterranean. The area of the island is 3640 km^2 hosting approximately 600.000 permanent residents. During the high season of tourism the total population of the island can increase up to one million.

The annual total renewable water resources estimated for the island is approximately 494 million m^3.



Total water supply is estimated approximately at 246 hm^3 per year. Water losses are estimated at 12 hm^3. Based on annual water balance the net water consumption is about 234 hm^3. Regarding the source of water abstraction, about 90% of water abstraction is from groundwater, while surface water meets 10% of water demand. The annual Water Exploitation Index is 0.47 (47%). WEI+ per source indicates that Groundwater Exploitation Index is 0.59; Surface Water Exploitation Index is 0.20. It can be concluded that groundwater resources on the island are under heavy pressure from water consumption.

Sectorial water consumption indicates that water demand for agriculture is approximately 61% of the total water demand of the island.

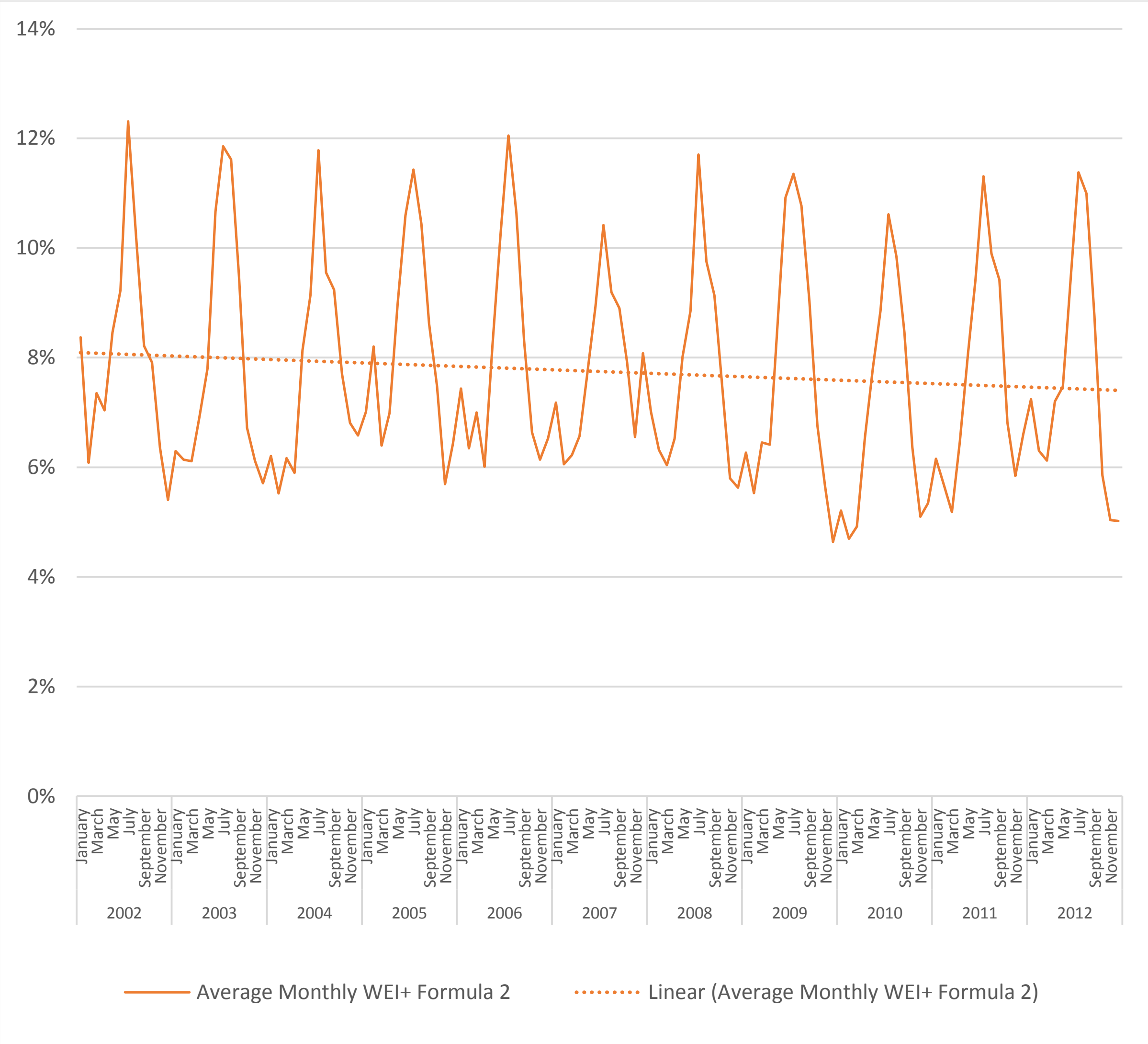


Based on the assessments it has been revealed that while agriculture is using 61% of total water supply, it contributes only 1.5% to the Gross Domestic Product of the Island.

Trends in Water Exploitation Index

Analysing the monthly time series of the WEI+ across Europe (an average values approach) in an attempt to reveal any general tendency during the last 11 years of this study, a minor decreasing is presented based on formula 2 (Figure 4.5).

Figure 4.5 Trend analysis of the average values of the WEI+ across Europe



5 Conclusions

5.1 Water resources and use in Europe

While water is generally abundant in much of Europe, water scarcity and droughts continue to affect some areas. The Mediterranean region and most of densely populated river basins from different parts of Europe are hot spots for the water stress conditions.

About 30 million inhabitants in winter and 70 million in summer live under water stress conditions that corresponding to 14% of total population of Europe.

Around 20% of total population of the Mediterranean region live permanently under water stress condition. Water stress effects more than half (53 %) of Mediterranean inhabitants during summer.

Rivers and groundwater resources meet 80 % of total water demand in Europe. Agriculture and public water supply accounts for 68 % total water use in Europe and put higher pressures on renewable water resources compared to other economic sectors.

From an environmental perspective, groundwater bodies and rivers are under pressure especially in summer, while reservoirs are a very crucial link in the chain of supporting seasonal water demands in summer by tripling their water supply to the economy.

Defining the most appropriate spatial and temporal scale for evaluating water scarcity phenomena across Europe is very important. That fact has been pointed out in several studies (EEA 2012; 2012a; 2012b; 2012c and 2013). In coarser spatial scales such as country and RBD (which also depends on the size of the area and the range of social and economic activities) water stress could not be captured due to the high spatial aggregation of both water assets and water consumption. However, when scaling down the analysis, water scarcity becomes visible over the regional water assets as well as showing which economic sectors create the pressure. This information is very helpful for policymakers and stakeholders to assess the environmental status of the regional interest and further infrastructure or economic measures that may be put into force to protect the water capital.

5.2 Issues to resolve in future EEA water accounting work

5.2.1 Uncertainties with the implementation of WEI+ formulas

Implementing WEI+ formulas at a monthly scale across Europe with so many diverse climatic, hydrologic and land cover conditions by itself is quite a challenging task. Source quality and validated hydrological information arises as one of the top issues to be addressed.

Quality of the index depends on the quality of the data series used in the WEI+ estimation. In reality, the data to populate the indicators are seldom systematically or reliably available regardless the spatial scale due to heterogeneity of the phenomena i.e. relation between environment and economy. For instance, total water abstraction is not always well known, particularly if non-authorized uses are important. The rate (quantity) of water abstraction is often estimated rather than measured. Estimates are subject to large uncertainties, particularly for water abstractions in agriculture (Winpenny, 2012).

Water abstraction to satisfy human needs is the most important quantitative pressure on freshwater resources. Excessive growth of demands in a territory in relation to the available water resources can result in a chronic shortages situation in the medium-long term. Besides, returned water also includes a variety of components which are not easy to measure. It comprises estimation of water abstraction particularly for irrigation, where water efficiency is of quite high concern.

The WEI+ indicator is very helpful in identifying the rate of water abstraction per sector on a comparable basis and thus supporting the assessment on whether water consumption is sustainable or not and its possible impacts on freshwater resources (Faergemann, 2012).

Despite identifying the thresholds for WEI+ dealing with environmental flow which are not yet finalized, thresholds are so crucial in order to provide a certain range of values for a robust indicator result. Having well-identified warning thresholds for the WEI+ will support answers to key questions related to water scarcity and resource efficiency.

Due to high actual evapotranspiration values as well as a lack of data on the total volume of water stored in lakes and reservoirs, negative WEI+ values have been encountered. Normally, that can easily be understood as pressure over the renewable water resources. But still further development is required by experts to assess and provide useful information about the monthly step implementation of the formulas as well as with the extreme and negative seasonal values (*e.g.* summer months).

Another problem is dealt with the difference between water abstraction and return. In some cases, return would be greater than water abstraction either due to the time delay between the exact time of water abstraction and the exact time of water returned back to the environment or due to the data quality. The current data availability didn’t allow for further investigation of this issue.

5.2.2 Data Uncertainties

One of the basic sources of uncertainty during this exercise was the data availability (in terms of spatial and temporal coverage) in the respective area of reference. Data quality is so crucial that it affects not only the filling up of water asset account tables, but also the interpretation of the indicator results. To this end, several statistical and hydrological oriented techniques had to be applied in order to provide to the maximum extent possible, a reliable and continuous time series for the water assets accounts before the implementation of the indicator’s formulas. This causes a chain reaction of data manipulation from source (extrapolation techniques) for avoidance of outliers or extreme values, especially in entities where data coverage (spatial and temporal) was insufficient. Further clarifications can be found in Annex-I and Annex-II.

5.2.3 Tools, applications and further data improvements

The water assets accounts exercise is a highly demanding process on data and IT tools. It requires ensuring horizontal and vertical consistencies between statistical and spatial data by means of a chain-wise iterative procedure to be implemented in an application. This is not usually a very straightforward computation procedure.

6 Annex I – Data for renewable water resources

Water accounts and WEI assessment require very heterogenic data involvements for estimating both renewable water resources and water consumption by source and sector. The following paragraphs clarify data structure, data sources and processing for each component of the Water Exploitation Index including the water asset accounts.

6.1.1 Spatial Data

Spatial data is the information of reference entities and station coordinates. ECRINS is a spatial reference system used in the EEA water accounts work that allows carrying out spatial operations in data integration and assimilation, as well as, displaying the results at the different scales (e.g. catchment, sub-basin, river basin district and country scale ([27]). It includes – among other data – the European Catchments and Drainage Network.

In addition to ECRINS spatial data sets, other spatial data such as river stream flow stations reported under SoE Water Quantity dataflow and water use entities i.e. industries and waste water treatment plants reported for UWWT Directive and cities have been included into the assessment. The Landscan 2010 version has been kept in the database for cities which was updated previously under the DG-ENV contract with Pöyry ([28]). SoE stream flow stations and the UWWTP database have been updated with the latest delivery from the year 2013.

It should be mentioned that ECRINS is quite far from being the perfect spatial reference data due to some inconsistencies in terms of topological relations among the catchments (FEC – Functional Elementary Catchment) and hosts also topological faults, having a wrong connection in some river segments. This has not had drastically significant impacts over the general results but still needs to be fixed ([29]).

6.1.2 Data for water availability

Water availability consists of climatic and hydrological time series data. In order to ensure the consistency among different components of water cycle, the 2002–2012 period was selected as temporal scale.

Climatic Data

The climatic data is of paramount importance in estimating robust water assets accounts in a given territory. Relation between precipitation and actual evaporation has significant impacts over the general water balance, particularly for the proposed estimation of renewable water resources in Formula 1. Therefore, the full spatial and temporal coverage of climatic parameters across Europe, was one of the main objectives in the context of database acquisition and updates. The current climatic data sets contain the results of modelled interpretation with E-OBS data sets prepared originally in 25 km^2 grids by the EEA for the 2002–2012 period. It hosts precipitation (Rain), actual

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[27] Definition of hydrological units in this study i.e. catchment, sub-basin, river basin district are quite different from those defined under the WFD Article 5. As Ecrins is used as a spatial reference in this report, the hydrological units in Ecrins are purely hydrological without considering the country boundaries.

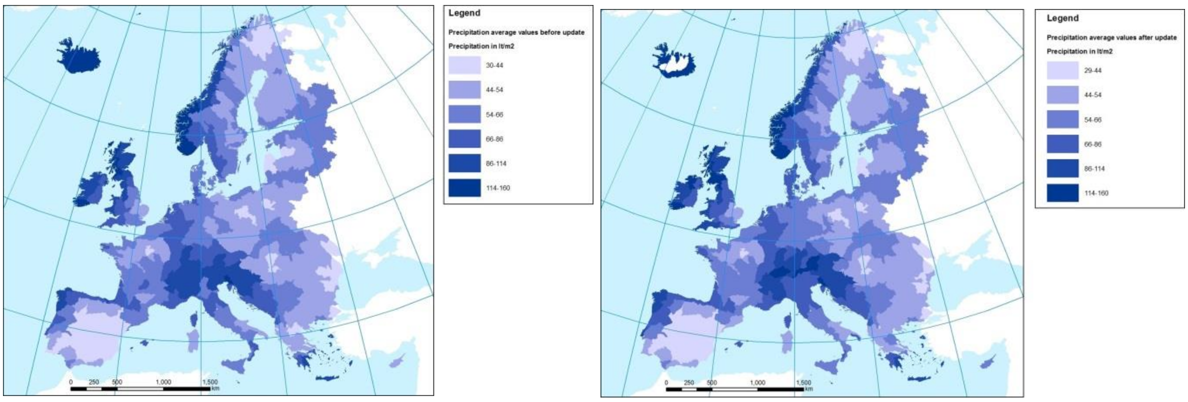
[28] ENV.D.1/SER/2011/0036 - http://ec.europa.eu/environment/archives/funding/pdf/calls2011/specifications_en_11036.pdf

[29] Ecrins is currently being upgraded with the purpose of eliminating such errors from the spatial reference dataset. When EuHydro is available, Ecrins will be replaced with the EuHydro

evapotranspiration (ETReal), potential evapotranspiration (ETPot), soil water balance (SWaBa),water deficit (Defic),Surface run-off (SurRof) and temperature (Tmean, Tlow, Tmax) as the main climatic parameters. Modelling and interpolation of data in some parameters are dictated by the nature of water accounts regardless of the spatial or temporal scales of the analysis. That is also the case for some climatic parameters i.e. evaporation, soil-water balance etc. As mentioned in the previous paragraph, the EEA climatic dataset is prepared as raster at a 25 km resolution which requires disaggregation to the Ecrins catchment scale (250 m vector). The integration procedure is to intersect the 25 km^2 raster with the Ecrins Catchment and calculate average precipitation and actual evapotranspiration in litre/m^2 per catchment. In the second phase the averaged value of precipitation and evapotranspiration are to be converted into million m^3 per catchment and aggregated to the any other upper scale subject to the water accounts calculation. The Map 6.1 illustrates the distribution of the multi-annual average of precipitation aggregated to sub-basin scale before and after the updates. The updates in precipitation is compared with the previous EEA water accounts production database and the current one which has been used in this study.

The precipitation pattern across Europe indicates that mostly mountainous areas receive more rain compared to other lowland areas.

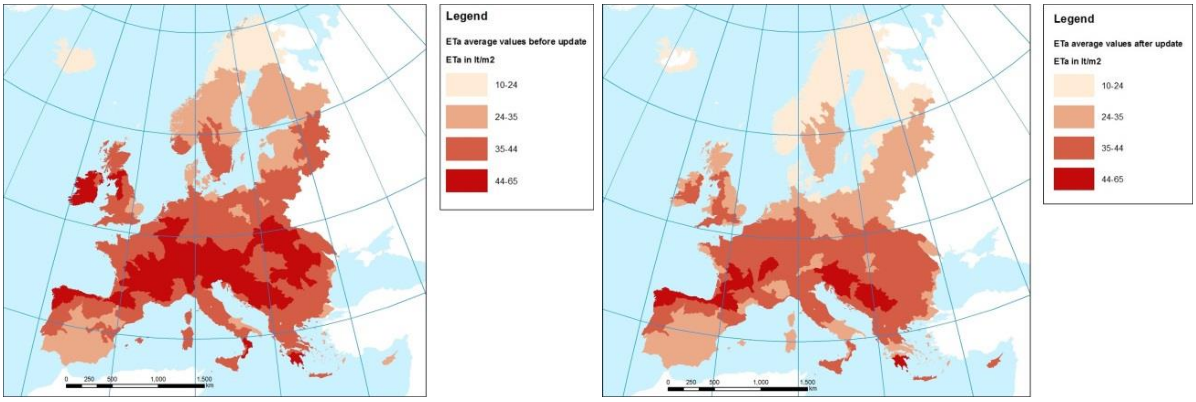
Map 6.1 Precipitation per Sub-Basin area (litre/m^2) across Europe before (left) and after (right) the climatic data update



Note: Values introduced on maps have been calculated over multi-annual average (2002–2012).

The relationship between precipitation and actual evapotranspiration is becoming more critical, since the renewable water resources are calculated on a monthly scale. From the water accounts perspective, higher evapotranspiration values than precipitation is just an environmental deficit for the respective month, which can be recovered in the annual closing stock. Indeed, some summer months are characterized with higher ETa values compared to precipitation particularly for the southern parts of Europe. But, this has a large impact on estimating monthly Water Exploitation Index resulting in negative WEI values, due to a deficit in water balance for the respective month particularly in the case that WEI is calculated using Formula 1. The EEA's modelled data for climatic parameters had higher ETa values than precipitation particularly for winter months in Northern Europe. As the ETa is modelled data and the model itself involves a number of different parameters, such as solar radiation in estimating the ETa values in a given territory, sometimes the model provides negative values for those locations in winter months which are quite unrealistic to the ground truth. This situation has a number of impacts over the Water Accounts and WEI+. In the case of having higher ETa values for winter months combined with a constant trend during the summer months causes a negative water balance over the entire hydrological or calendar year. In order to overcome that uncertainty around the ETa values, in agreement with the content expert developing the EEA climatic data, those ETa values higher than precipitation for December and January in Northern Europe have been converted into zero values. After this modification in ETa, the distribution pattern of annual ETa values has been significantly changed particularly over Northern Europe and Mountainous areas in Central Europe (Map 6.2).

Map 6.2 Actual Evapotranspiration per Sub-Basin area (litre/m^2) across Europe before (left) and after (right) the update

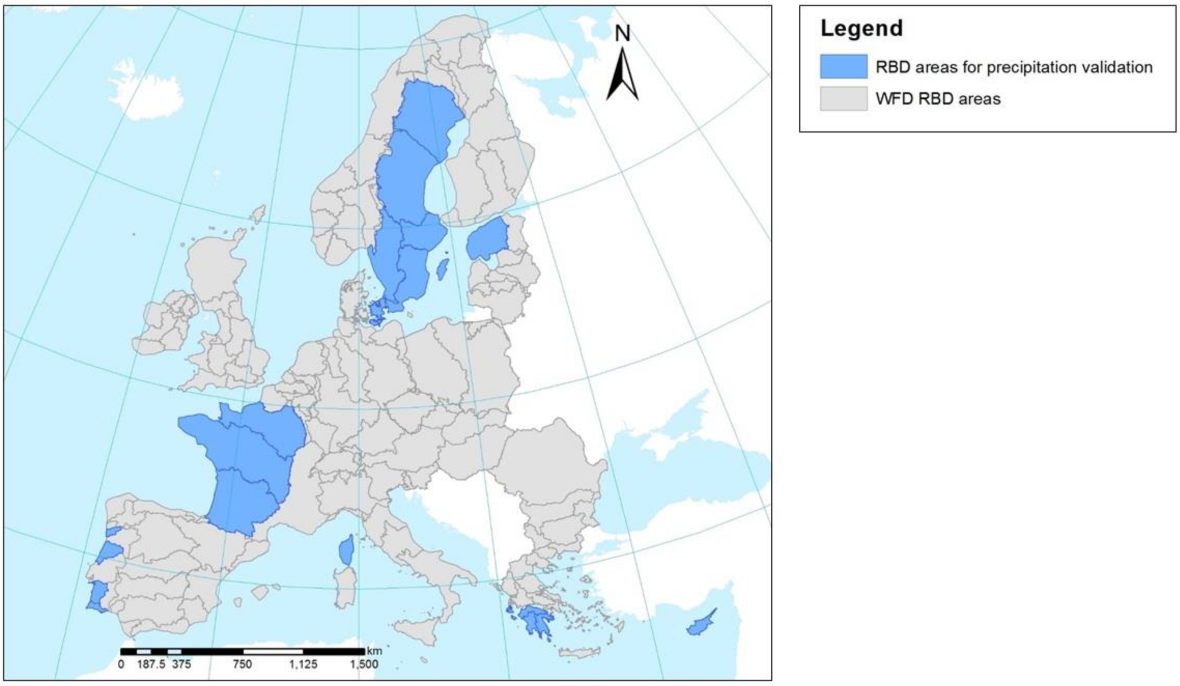


Note: Values introduced on maps have been calculated over multi-annual average (2002–2012).

The modification done with the ETa is very rough and needs to be further calibrated and validated with the country data. The SoE WQ climatic data such as areal precipitation and evaporation have been used in validating the climatic data base of this report.

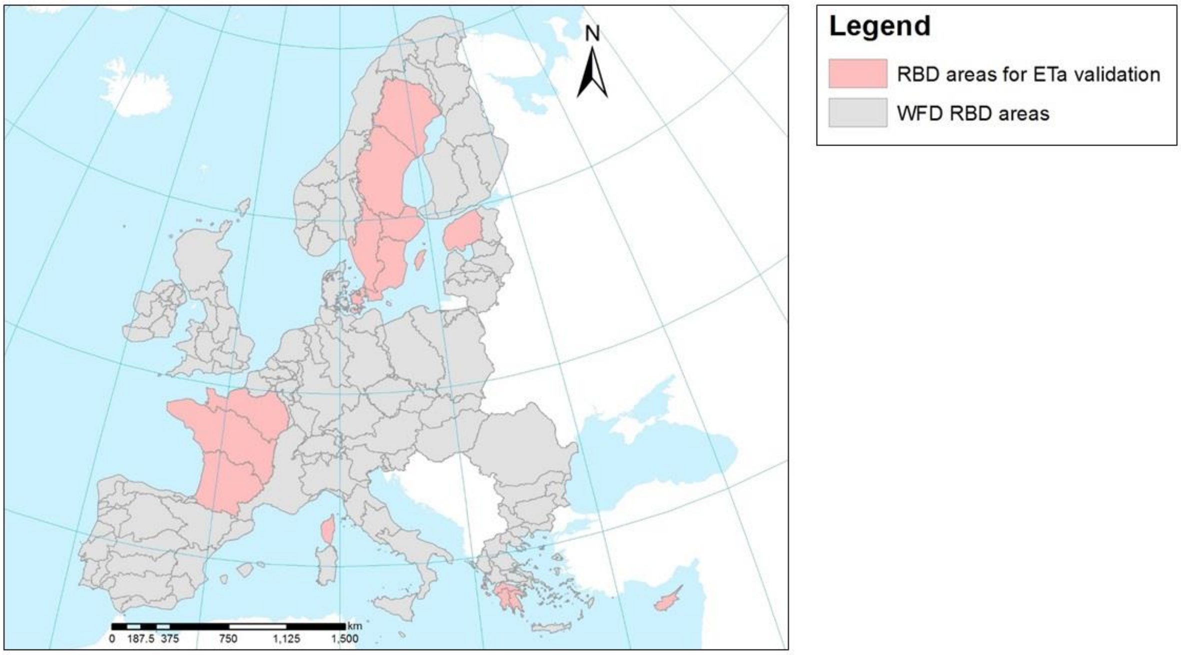
As a result of the validation procedure (ETC/ICM, 2015c) it has to be noted that there is the lack of an extensive time series, especially monthly for both climatic parameters (precipitation and actual evapotranspiration) as shown in the Maps 6.3 and 6.4. However, areal precipitation both in monthly and annual scales presents high correlation and high efficiency coefficient values, which means that modelled data by the WA application are sufficiently expressing the observed/reported values under the SoE dataset for the cases tested.

Map 6.3 WFD RBD areas used for validation of the precipitation parameter



On the contrary, it was found that this is not the case with actual evapotranspiration modelled values both in monthly and annual scales. Due to this reason, it is proposed that whenever the SoE dataset will be enriched with ETa values, at RBD scale this validation procedure should be repeated.

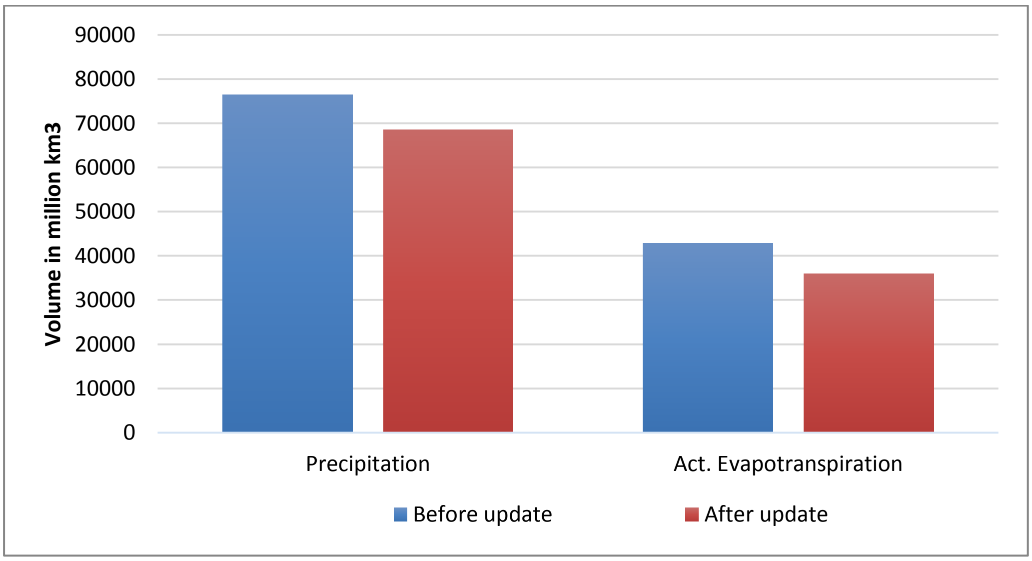
Map 6.4 WFD RBD areas used for validation of the ETa parameter



The outcome of this process indicate that modelled climatic input data are not without meaning, since they are a condensed product of data collected and statistically checked and they are reliable for the WA application.

Based on the above mentioned modification, the updated climatic data contains approximately 70 000 km^3 of precipitation in grand total compared to 35 000 km^3 of ETa for the 2002–2012 period covering spatial territory of this study as presented below in Figure 6.1.

Figure 6.1 Precipitation and actual Evapotranspiration volumes in million m^3 across Europe (2002–2012)



Stream Flow Data

The stream flow data contains information about stream flow stations and river discharge time series. The stations data includes information about the coordinates, river catchment, FEC assignment and other hydrological and spatial information.

In this study, daily and monthly stream flow data that are reported on monitoring stations under the SoE reporting stream has been used including some ad-hoc data compilation done in the previous EEA and DG-ENV water accounts work. In addition to that, LISFLOOD data provided by JRC for the years 2002–2012 has also been integrated into the streamflow data of the EEA WA production database.

It should be mentioned that the number of stations reported under the SoE Water Quantity is increasing over the years and that is very ambitious development in terms of data provision, as well as, future work with the water accounts and Water Exploitation Index at European scale. Figure 6.2 illustrates this positive trend in the stream flow data provision in SoE. Comparing 2007 with 2012 indicates that 10 times more data are provided by member countries.

Figure 6.2 Stream flow data provisions under the SoE data flows (2007–2012)

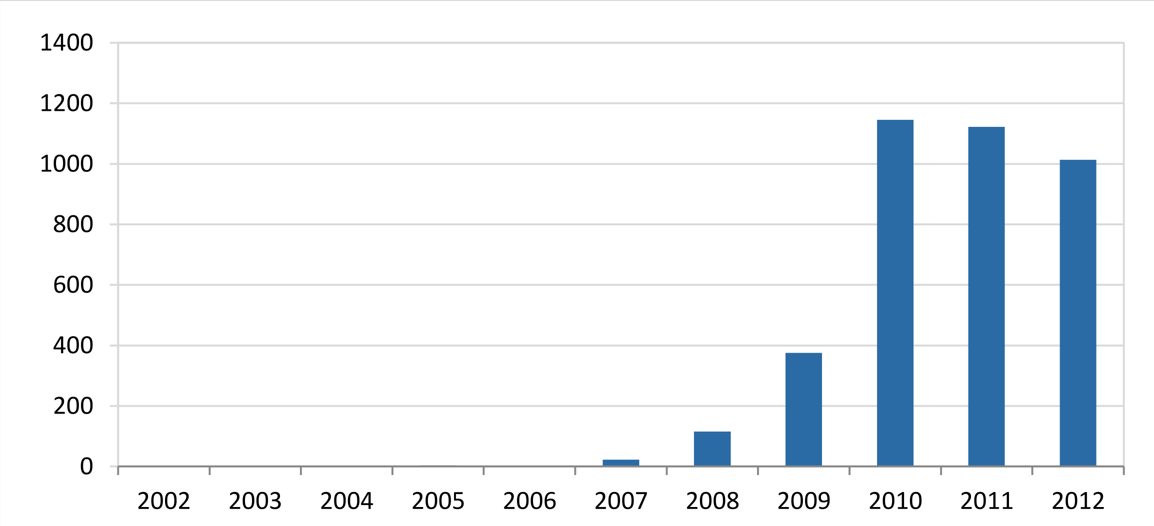
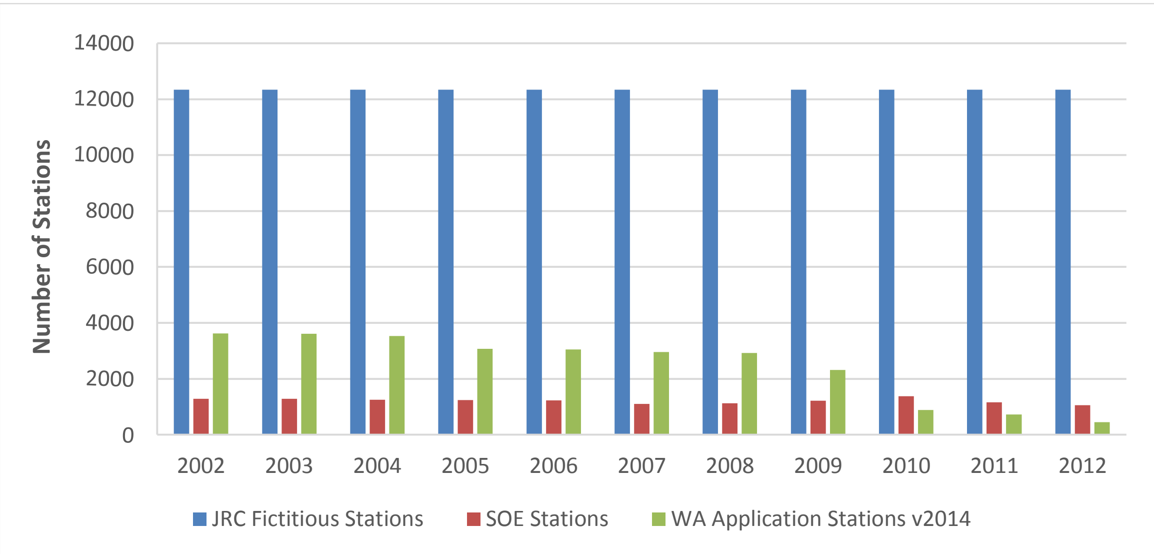


Figure 6.3 Stream flow gauging stations after update



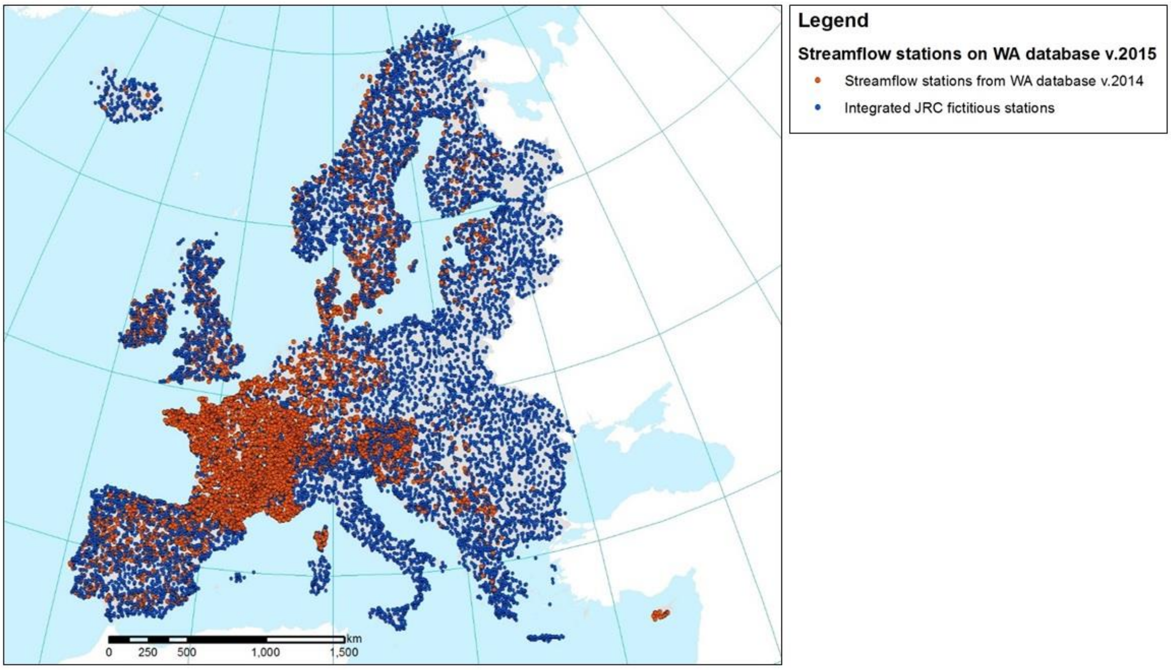
The previous version of the EEA Water Accounts Database was hosting 5 472 stream flow stations (with at least one discharge value) outpouring in grand total approximately 25 000 km^3 discharge for the 2002–2012 period.

Figure 6.3 indicates that initially ad-hoc data compilation was the building block for Water accounts and WEI. But the latest years as can be seen from Figure 6.2, clearly indicates this by means of SoE Water Quantity data flows, the updates are getting more stable and institutionalized. Besides that, the spatial and temporal coverage of SoE Water Quantity data have to be improved in the coming years, otherwise, the European scale of water accounts assessment will be quite difficult to be accomplished.

In order to provide a compiled overview covering all parts of Europe, as mentioned earlier the JRC LISFLOOD data has been integrated into the streamflow data. The integration has supported to fill gaps in both spatial coverage and the time series. Further clarifications on the stream flow data integration can be found in the (ETC/ICM 2015a). The final number of stations integrated in the water accounts database are 20 133, where 16 000 of them were used in the production of the Asset Account tables under SEEA-W covering the EEA as shown in Map 6.5 below.

Stream flow data is crucially important in calculating renewable water resources. The lack of stream flow data causes either having water deficit in water accounts and thus indicates higher WEI values for the territories concerned or has to be taken out from the assessment because of high uncertainties in the calculation.

Map 6.5 Stream flow stations coverage before LISFLOOD data integration (red) and after LISFLOOD data integration (blue) update



Streamflow data is also important for quantifying external inflow from the upstream territories to the reference territory and outflow to the downstream or to the sea that are main components in the UN-SEEA-W framework. These are very important in estimating water exchange between different water agents within the same territory. In addition to that, these two parameters are also used in estimating Water Exploitation Index.

Calculating external inflow from upstream to the territory of reference to some extent requires implementing a calculation method in the case there is no observed data available. Water comes from upstream and joins renewable water resources in the reference territory and further also contributes to outflow to the downstream areas. This travel of water should be accurately calculated without causing any double counting. This component of the EEA Water Accounts calculation is called “flow linearization or linearized flow”. Discharge data (daily and monthly) reported by member countries under the SoE Water Quantity dataflow is extrapolated between stations along the main drains of the Ecrins drainage network to populate each and every one of the river segments presented in Ecrins with a monthly value. Therefore, the Ecrins segment represents the statistical unit of the accounts for rivers. By doing so, discharge is extended up to the source of the river and considers the affluent and reservoirs as well. Calculating Standard River Unit (river length (km) x discharge (m^3) is the fundamental part of the flow linearization ([30]).

Change in Storage

Change in storage is presented in both formulas and it has an significant impact over the WEI results. The lack of data on reference volume of water stored in lakes and reservoirs at a certain time causes a chain effect in computing the opening and closing stocks. Without knowing how much water is stored and available in the natural or man-made water reserves, estimating the change in reservoirs remains completely relative. Unfortunately, these data are not available for all reservoirs and lakes in the SoE database. The current algorithm of estimating change in reservoirs as a component of renewable water resources is based on water deficit resulted from a relationship between other agents in the renewable water resources. Whenever water deficit occurs, the theoretical volume of water is taken from the reservoirs and registered as “changes in reservoirs” in the accounting period. The impacts of this approach by applying the same change in storage for both formulas, due to the lack of data, cannot not be fully checked over the Water Exploitation Index, and it does not make possible to close the stock in the Assets Account Table, and thus creates some uncertainties over the actual water abstraction from the reservoirs.

The EEA water accounts production database covers approximately 71 000 lake entities. In the SoE water quantity database only 105 reservoirs are presented with information on the reference volume of water. The WaterBase-Lakes database has also around 1 860 lake water bodies presented with the information on either area together with mean, max and min. depth or total volume of water which can be used as a proxy in estimating the reference volume of water stored in lakes and reservoirs. But on the other hand, still that the numbers of lakes with available information is far from good enough to include reference volume of water stored in the reservoirs for closing the stock calculation in the Asset Accounts.

[30] See the POYRY report for further clarifications on the method and algorithm used for the interpolation and extrapolation in stream flow data

7 Annex II – Data for water use

The current SoE Water Quantity database has limited temporal and spatial coverage across Europe with a very heterogeneous composition of reported scales. Therefore, dealing with the water use assessment in the water accounting framework, requires modelling and proxies to be implemented in the case the reported data is not available. The modelling in the EEA water accounts work with the water use component generally takes information into account on the population of urban and rural areas for estimating the water supply; technical specifications of industrial installations for estimating water consumption by economic sector and information on crop area distribution and crop water demand for estimating water abstraction by the agricultural sector. In addition to that, UWWTPs capacities and the EPRTR database are also included into the estimating of water use and returns. Final validation is carried out by Eurostat data which is reported by the member countries at RBD or SU scale on an annual resolution. Detailed information on the method for calculating water abstraction, water use and return can be found in previous reports on the Water Accounts Tool ([31]).

The following paragraphs outline the content of the data updates in different domains of the Water Use database and the technical procedure followed in data integration and assimilation.

7.1.1 Update of data on the population of Large Cities

Population is one of the main drivers on water abstraction and use. Particularly water consumption for household and public supply, which is estimated via the population data together with the UWWTPs database. In the EEA water accounts exercise population is classified as rural and urban population in order to estimate the water abstraction and return via the UWWTPs database. Urban Morphological Zones (UMZ) is used as a proxy in distinguishing the boundaries of urban and rural areas while the spatial distribution of population across Europe is identified in the Landscan 2010 database. Furthermore, cities are classified as Large, Medium and Small based on population size. Large cities have significant impacts over the water abstraction and consumption.

In order to update the population of large cities, the Eurostat Urban Audit dataset ([32]) has been used. The Urban Audit data collection of Eurostat provides information and comparable measurements on various aspects of the urban life of European cities. The Urban Audit Table includes population data for European Large cities up to 2013.

Population data for medium and small cities including the rural areas could not be updated due to lack of publicly available data sources particularly in the Landscan database.

7.1.2 Update of tourism data

The Eurostat Tourism Database ([33]) has been used for the purpose of disaggregating the number of tourists at catchment scale to better reflect the impacts of tourism over the renewable water resources.

In order to disaggregate the total number of tourists over the catchment, two Eurostat datasets were used, namely:

- “Nights spent at tourist accommodation establishments by NUTS2 regions” and
- “Nights spent at tourist accommodation establishments – monthly data”

[31] Service Contract to contribute to the building of Water and Ecosystem accounts at EU level, Final Report 2 Uses & Supply

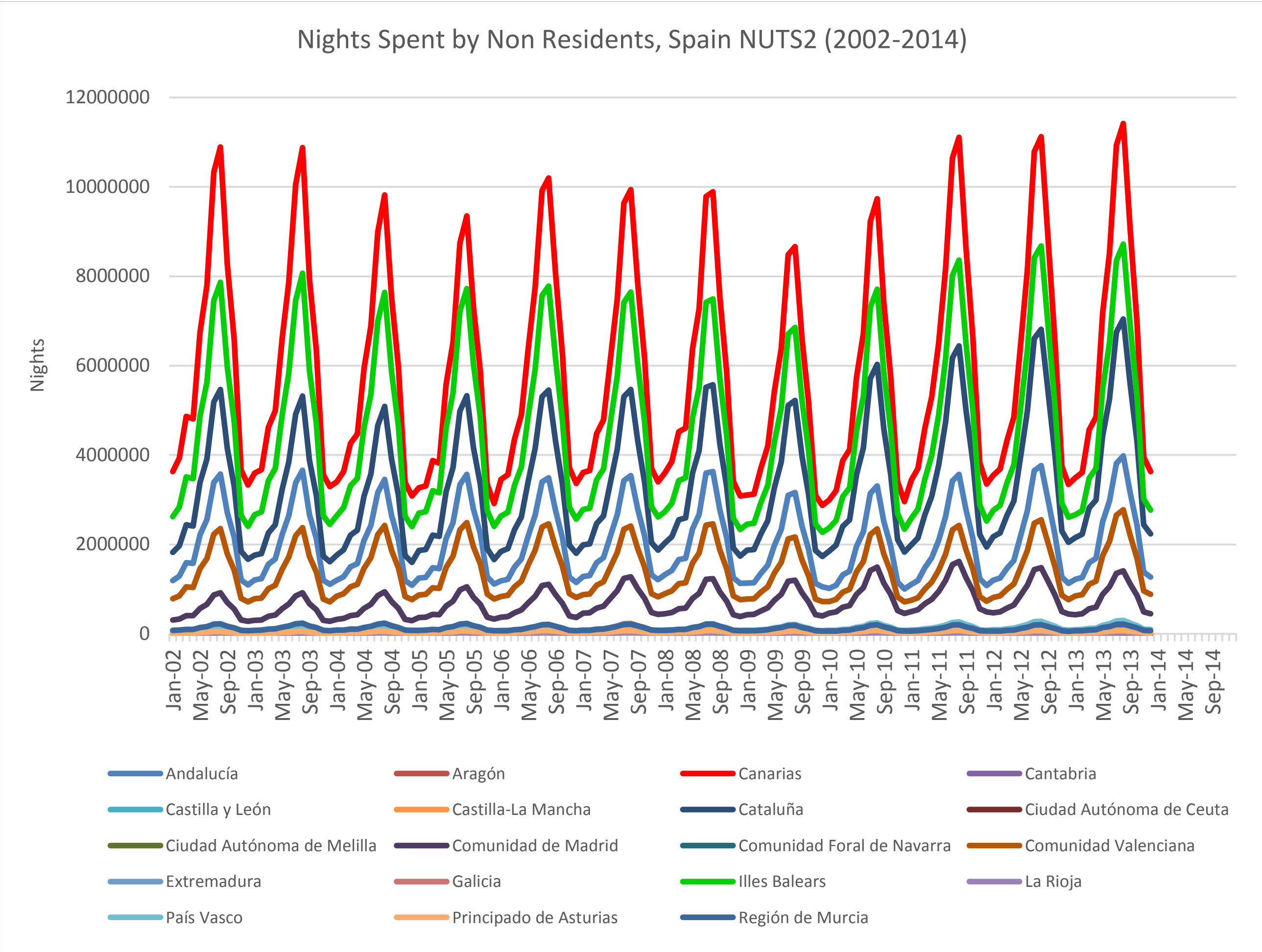
[32] Eurostat- Urban Audit

[33] Eurostat tourism (tour) dataset

A disaggregation procedure of the tourism data in finer temporal and spatial scales had to be implemented. Eurostat monthly data of the latter dataset were disaggregated to NUTS2 level based on the annual data of the former dataset. Then the disaggregation procedure was extended, in order to estimate the tourist presence at FEC scale.

The first step was to calculate NUTS2 tourism ratios for each country. These ratios were defined by the number of tourists on a particular region to the total number of tourists arriving in the country. Then each ratio was multiplied by the respective monthly "Country nights spent" data, in order to produce monthly information per NUTS2 level. The next step was to spatially disaggregate from NUTS2 level to FEC level. In order to perform this task, an assumption was made, that tourists are proportionally distributed in each FEC based on the respective resident population size. Following this assumption, monthly tourism population data were multiplied by the population ratio of each FEC in every NUTS2 region. On the water abstraction and returns calculation the monthly tourism nights translated to population were multiplied by the respective water domestic coefficients in order to produce water volumes. The Figure 7.1 for Spanish NUTS2, indicates that the Canarias and Balearic islands seem to have the highest tourism presence over the months of spring and summer.

Figure 7.1 Nights Spent by non-Residents in Spain

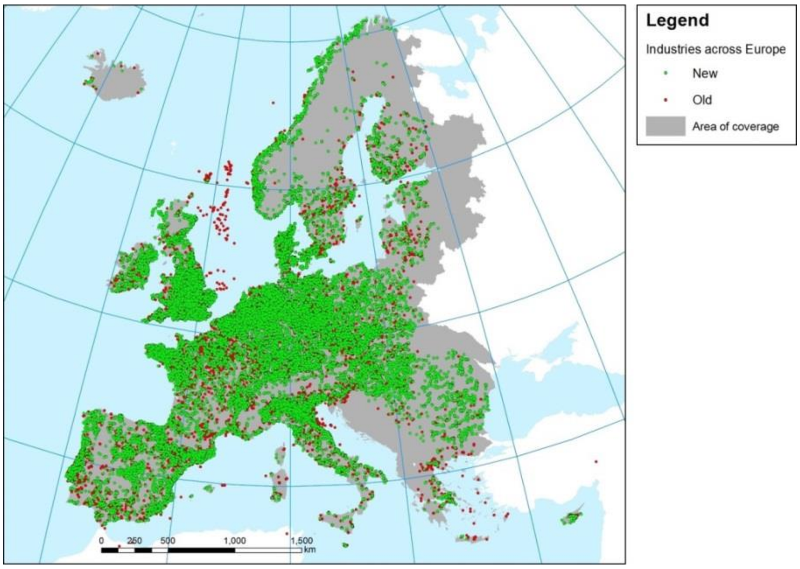


7.1.3 Industrial data updates

For updating the industry related entities and their water use in the database, three main source data have been encountered; UWWTP, European Pollutant Release and Transfer Register (E–PRTR) and the Cooling Water Database developed under a Commission contract in 2014. The Map 7.1 illustrates the status of industries spatial coverage before and after the update.

Industries across Europe as updated from the E-PRTR database before (red) and after (green) update.

Map 7.1 Industries across Europe as updated from E-PRTR database before (red) and after (green) update

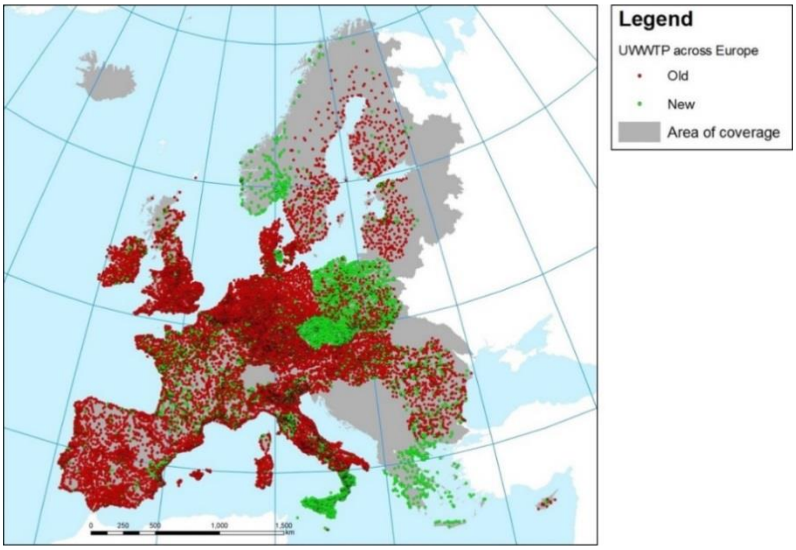


By use of the cooling water database developed by the DG-ENV it was possible to better capture the water abstraction and water use by industrial plants across Europe.

7.1.4 UWWTP database updates

The capacity of UWWTP is one of the main data sources in estimating water abstraction and return in the EEA WA assessment. It is designed to use waste water treatment plants in order to calculate water abstractions and returns. A procedure has been followed for the update of corresponding database tables with the latest delivery (2012) covering the 2007–2011 time period. The update enriched the database with 1 359 more UWWTPs increasing the total capacity by 175 466 522 equivalent population (p.e.) based on the last version of the Urban Waste Water Treatment Plants Directive (Map 7.2).

Map 7.2 Urban waste water treatment plants across Europe, before (red) and after (green) update



7.1.5 Updating Water Use Coefficients

Water consumption for domestic and services purposes are estimated by water use coefficients. The source for those coefficients is statistical data from country and European statistical authorities like Eurostat. Based on the available data from the countries as well as from Eurostat ([34]) the previous coefficient per country per sector have been further updated. Table 7.1 illustrates the updated coefficients in the current water accounts study.

Table 7.1 Water use coefficient per country

Country code	Households' consumption/total public water supplied (%)	Year of update	Households consumption ratio (m3/inhab/day)	Connected services consumption ratio (m3/inhab/day)
AT	86.97	2010 (Germany data)	0.12	0.02
BE	56.57	2009	0.10	0.08
BG	71.89	2011	0.10	0.04
CY	61.65	2010	0.28	0.17
CZ	66.06	2011	0.09	0.04
DE	86.97	2010	0.12	0.02
DK	65.23	2004	0.13	0.07
EE	58.00	2011 (Lithuania data)	0.06	0.04
ES	74.59	2010	0.16	0.05
FI	58.82	2011	0.10	0.07
FR	87.28	2008 (estimated by Poyry)	0.16	0.02
GR	63.10	2007	0.10	0.06
HR	63.10	2011	0.12	0.07
HU	73.75	2011	0.09	0.03
IE	71.87	2011 (UK data)	0.29	0.11
IT	74.59	2010 (Spain data)	0.19	0.07
IS	44.78	2004	0.28	0.35
LT	58.00	2011	0.05	0.04
LU	56.57	2009 (Belgium data)	0.10	0.08
LV	58.00	2011 (Lithuania data)	0.18	0.13
MK	57.32	2009	0.13	0.09
MT	36.67	2011	0.07	0.12
NL	72.18	2010	0.13	0.05
NO	58.82	2011 (Finland data)	0.10	0.07
PO	77.80	2011	0.09	0.02
PT	86.21	2009	0.16	0.03
RO	64.82	2011	0.07	0.04
RS	70.02	2009	0.12	0.05
SE	70.91	2010	0.14	0.06
SI	71.55	2011	0.11	0.04
SK	45.39	2011	0.07	0.08
TR	0.00	2010	0.00	0.12
UK	71.87	2011	0.14	0.05
CH	57.97	2011	0.19	0.14

The abstraction volumes depending on the water resources' type are presented on the following table:

[34] Annual freshwater abstraction by source and sector (env_wat_abs table) - http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=env_wat_abs&lang=en

Table 7.2 Water resources abstracted by the public sector

country code	Surface water abstraction for public activities by EUROSTAT Mm3/year	Year	Surface water abstraction/total abstraction (%)	Groundwater abstraction for public activities by EUROSTAT Mm3/year	Year	Groundwater abstraction/total abstraction (%)	Sea water abstraction for public activities by EUROSTAT Mm3/year	Year	Sea water abstraction/total abstraction (%)	Total Abstraction Mm3/year
AT	1	2008	0	607	2008	100			0	608
BE	249	2009	35	458	2009	65			0	707
BG	480	2011	52	436	2011	48			0	916
CY	26	2011	25	27	2011	26	49	2011	48	102
CZ	327	2011	51	311	2011	49			0	638
DE	1546	2010	30	3535	2010	70			0	5081
DK	0	2010	0	387	2010	100			0	387
EE	28	2011	27	34	2011	55			0	61
ES	3760	2010	65	1590	2010	28	425	2006	7	5775
FI	160	2011	40	240	2011	60			0	400
FR	1616	2010	29	3875	2010	71			0	5491
GR	604	2011	47	689	2011	53			0	1293
HR	62	2011	12	461	2011	88			0	523
HU	255	2011	42	346	2011	58			0	601
IE	489	2007	80	120	2007	20			0	609
IT	1366	2008	15	7729	2008	85			0	9095
IS	3	2005	4	76	2005	96			0	79
LT	0	2011	0	124	2011	100			0	124
LU	24	2011	53	21	2011	47			0	45
LV	35	2010	16	187	2010	84			0	222
MT	0	2011	0	13	2011	43	17	2011	57	30
MK	227	2009	83	47	2009	17			0	274
NL	456	2010	37	761	2010	63			0	1217
NO	740	2011	90	79	2011	10			0	819
PO	611	2011	30	1423	2011	70			0	2034
PT	611	2009	65	323	2009	35			0	934
RO	622	2011	62	378	2011	38			0	1000
RS	200	2011	30	473	2011	70			0	673
SE	708	2010	78	200	2010	22			0	908
SI	4	2011	2	165	2011	98			0	169
SK	49	2011	16	254	2011	84			0	303
TR	2559	2010	44	3233	2010	56			0	5792
UK	4614	2011	73	1719	2011	27			0	6333
CH	191	2011	20	763	2011	80			0	954

Table 7.2 is an update of the former work performed under the construction of the water accounts tool for the EEA[35] in 2012. The table columns are referring to:

- Surface water abstraction for public activities
- Groundwater abstraction for public activities
- Sea water abstraction for public activities

[35] http://ec.europa.eu/environment/water/blueprint/pdf/WaterEcosystemAccount2.pdf

For the update, Eurostat dataset "env_wat_abs"([36]) has been used. Table 7.2 adds seven more countries in comparison to the 2012 work. These countries are Croatia, Iceland, FYROM, Norway, Serbia, Turkey and Switzerland. The total number of countries with data on this Table has risen to 34. The latest year covering this update is 2011.

The next Table 7.3 indicates the water volumes supplied by the public sector that have been derived by Eurostat data, in comparison with the respective abstracted volumes.

In the same way as Table 7.2, Table 7.3 is correlated to the former work on the water accounts tool ([46]) in 2012. It is referring to:

- Total Abstraction
- Total Public water Supply
- % of water lost (system water losses)

In Table 7.3, also 7 countries have been inserted in comparison to the older Table([45]). For the initial update, Eurostat data has been used. The relevant datasets are "env_wat_abs" and "env_wat_cat"([47]) .

In order to calculate losses of the public water supply system, an estimation methodology was performed; total water supply volume was divided by the respective total abstraction volume, in order to find the efficiency "e" of the supply system. Then losses, "L" were calculated as L=1-e. The implementation of this methodology gave unrealistic results in 11 cases. In these latter cases abstractions were lower or equal to water supply leading to negative losses or close to zero. For that reason a research has been used in order to find the water supply system losses. More particularly for Austria, losses have been reported in the range of 7–11%([37]). In Belgium losses are 13%([38]), in Cyprus the respective losses are reported as 17–23%([39]) , while in Malta are 23%([40]). Finally in Switzerland losses have been reported as 11% ([41]).

European countries' water supply system losses have been also gathered by various official organizations and the EU([42]). These sources of actual data were preferred than the derived data based on the estimation methodology. Finally some assumptions, based on spatial proximity of some countries, were inevitable in the case of existing data gaps.

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[36] Eurostat, http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=env_wat_abs&lang=en

[37] Experiences with Water Loss PIs in the Austrian Benchmarking Project, J. Kölbl, H. Theuretzbacher-Fritz, R. Neunteufel, R. Perfler, G. Gangl, H. Kainz & R. Haberl

[38] Secteur Public Fédéral - Economie, PME, Classes moyennes et Energie:Ressources et utilisations de l'ea, PME, 2009

[39] Auditor General of the Republic of Cyprus, 2008. Republic of Cyprus Annual Report 2006 -2007, http://www.audit.gov.cy/audit/audit.nsf/annualrpt_en/annualrpt_en?OpenDocument

[40] Water Loss Control Management by the water services corporation in Malta, NAO, 2008

[41] The cost structure of water utilities in Switzerland, Andrea Baranzini and Anne-Kathrin Faust, 2009

[42] http://www.bdew.de/bdew.nsf/id/DE_Profile_of_the_German_Water_Industry/$file/Profile_German_Water_Industry_2008.pdf

Table 7.3 Public water supplied and comparison with abstraction

country code	Total Abstraction by EUROSTAT Mm3/year	Year	Total Public water Supply by EUROSTAT Mm3/year	Year	% of water lost	% of water lost using EUROSTAT and data from neighbouring countries	% of water lost from extra sources	PROPOSED FINAL
AT	608	2008	608	2008	0		7–11	11
BE	707	2009	700	2009	1		13	13
BG	916	2011	370	2011	60	60	50	50
CY	102	2011			-		17-23	20
CZ	638	2011	492	2011	23	23	32	32
DE	5081	2010	4113	2010	19	19	7	7
DK	660	2009	386	2009	42	42	10	10
EE	103	2011	48	2011	53	53		53
ES	5775	2010	3621	2010	37	37	22	22
FI	400	2011	340	2011	15	15	15	15
FR	5491	2010			-		26	26
GR	846	2007	626	2007	26	26		26
HR	523	2011	290	2011	45	45		45
HU	601	2011	461	2011	23	23	35	35
IE	609	2007	609	2007	0		34	34
IT	9095	2008	5533	2008	39	39	28	28
IS	79	2005	67	2005	15	15		15
LT	124	2011	100	2011	19	19		19
LU	45	2011			-	13 (Belgium)		13
LV	211	2007	249	2007	-18	19 (Lithuania)		19
MT	30	2011	30	2011	0		23	23
MK	274	2009	164	2009	40	40		40
NL	1217	2010	1089	2010	11	11		11
NO	819	2011			-	15 (Finland)		15
PO	2034	2011	1545	2011	24	24		24
PT	934	2009	718	2009	23	23		23
RO	1000	2011	830	2011	17	17	31	31
RS	673	2011	457	2011	32	32		32
SE	908	2010	671	2010	26	26	17	17
SI	169	2011	116	2011	31	31	40	40
SK	303	2011	304	2011	0		27	27
TR	5792	2010	3013	2010	48	48		48
UK	6333	2011	4487	2011	29	29	22	22
CH	954	2011	954	2011	0		11	11

Following the procedure of the former work of 2012, Table 7.4 has been derived. This table contains:

- Initial total public water supply ratios per inhabitant and day
- Final total public water supply ratio per inhabitant and day

Also the same 7 countries, mentioned previously, have been added. For the update of this table, data from Eurostat and OFWAT (Water services regulation authority in England and Wales) [43] were used. More particularly the Eurostat dataset "env_wat_cat", has been used for the update of "initial total public water supply" in m^3/inhab/day. In order to calculate the final consumptions, including water lost in the distribution network through leakage, the percentage of losses estimated in the previous table was added in the initial total public supply ratios, giving the "final public supply" consumptions in m^3/inhab./day. OFWAT's data, were used as a consistency check of the derived results, although in case of deviations, the calculated results were preferred instead of these data.

By means of updates made with the above tables, the final abstractions are presented in the Table 7.4:

Table 7.4 Final ratios used for abstracted water and supplied water (m^3/inhabitant/day)

Country code	Total public water supply ratio per inhabitant (m3/inhab/ day)	year of update and also estimation on neighbouring countries for public water supply ratio (EUROSTAT)	% of water lost using EUROSTAT and data from neighbouring countries	% of water lost from extra sources	Proposed final	Total abstraction ratio per inhabitant (m3/inhab/ day)
AT	0.14	Estimation with German data		7–11	11	0.20
BE	0.18	2009		13	13	0.18
BG	0.14	2011	60	50	50	0.34
CY	0.45	2010		17–23	20	0.17
CZ	0.13	2011	23	32	32	0.17
DE	0.14	2010	19	7	7	0.17
DK	0.19	2009	42	10	10	0.19
EE	0.10	2011	53		53	0.21
ES	0.21	2010	37	22	22	0.32
FI	0.17	2011	15	15	15	0.20
FR	0.18	Estimation with Netherlands data		26	26	0.23
GR	0.15	2007	26		26	0.32
HR	0.19	2011	45		45	0.33
HU	0.13	2011	23	35	35	0.16
IE	0.40	2011		34	34	0.38
IT	0.26	2008	39	28	28	0.42
IS	0.63	2005	15		15	0.74
LT	0.09	2011	19		19	0.11
LU	0.18	Estimation with Belgium data	13 (Belgium)		11	0.24
LV	0.31	2007	19 (Lithuania)		19	0.28
MK	0.22	2009	40		40	0.37

[43] https://www.ofwat.gov.uk/

Country code	Total public water supply ratio per inhabitant (m3/inhab/ day)	year of update and also estimation on neighbouring countries for public water supply ratio (EUROSTAT)	% of water lost using EUROSTAT and data from neighbouring countries	% of water lost from extra sources	Proposed final	Total abstraction ratio per inhabitant (m3/inhab/ day)
MT	0.20	2011		23	23	0.09
NL	0.18	2010	11		11	0.20
NO	0.17	Estimation with Finland data	15 (Finland)		15	0.45
PO	0.11	2011	24		24	0.15
PT	0.19	2009	23		23	0.24
RO	0.11	2011	17	31	31	0.14
RS	0.17	2011	32		32	0.25
SE	0.20	2010	26	17	17	0.27
SI	0.16	2011	31	40	40	0.22
SK	0.15	2011		27	27	0.16
TR	0.12	2010	48		48	0.22
UK	0.20	2011	29	22	22	0.27
CH	0.33	2011		11	11	0.33

Finally Table 7.5 was updated in relation with the 2012 work. This table splits the total public supply consumption into two parts: Households and the connected services in the economy. Units are in m^3/inhab/day. As mentioned earlier, seven countries have been additionally inserted. The households' consumptions have been found in Eurostat, while the connected services' consumptions were estimated by the abstraction of households' consumptions from the overall public supply consumptions.

All the updates of data coefficients mentioned above affected the Tp_act_domes table (stored into EU_Uses.mdb) of the EEA WA Production Database.

Table 7.5 Ratios used for households and connected services supplied water

country code	Households consumption/total public water supplied (%)	Year of update	Households consumption ratio (m3/inhab/day)	Connected services consumption ratio (m3/inhab/day)
AT	86.97	German data	0.12	0.02
BE	56.57	2009	0.10	0.08
BG	71.89	2011	0.10	0.04
CY	61.65	2010	0.28	0.17
CZ	66.06	2011	0.09	0.04
DE	86.97	2010	0.12	0.02
DK	65.23	2004	0.13	0.07
EE	58.00	Lithuania data	0.06	0.04
ES	74.59	2010	0.16	0.05
FI	58.82	2011	0.10	0.07
FR	87.28	POYRY	0.16	0.02
GR	63.10	2007	0.10	0.06
HR	63.10	2011	0.12	0.07
HU	73.75	2011	0.09	0.03
IE	71.87	UK data	0.29	0.11

country code	Households consumption/total public water supplied (%)	Year of update	Households consumption ratio (m3/inhab/day)	Connected services consumption ratio (m3/inhab/day)
IT	74.59	Spain data	0.19	0.07
IS	44.78	2004	0.28	0.35
LT	58.00	2011	0.05	0.04
LU	56.57	Belgium data	0.10	0.08
LV	58.00	Lithuania data	0.18	0.13
MK	57.32	2009	0.13	0.09
MT	36.67	2011	0.07	0.12
NL	72.18	2010	0.13	0.05
NO	58.82	Finland data	0.10	0.07
PO	77.80	2011	0.09	0.02
PT	86.21	2009	0.16	0.03
RO	64.82	2011	0.07	0.04
RS	70.02	2009	0.12	0.05
SE	70.91	2010	0.14	0.06
SI	71.55	2011	0.11	0.04
SK	45.39	2011	0.07	0.08
TR	0.00	2010	0.00	0.12
UK	71.87	2011	0.14	0.05
CH	57.97	2011	0.19	0.14

7.1.6 Modulation Coefficients Update

Water use volumes per sector are calculated by the use of monthly modulation coefficients ETC/ICM, 2015b). The economic sectors follow the ISIC classification under UN SEEA. Main sectors of the application are:

- A (Agriculture, forestry and fishing)
- B (Mining and quarrying)
- C (Manufacturing)
- D 35 (Electricity, gas, steam and air conditioning supply) and
- E 36 (Water collection, treatment and supply).

Eurostat provides monthly data for “Production in industry”[44] with the year 2010 as a reference. This was the proxy to identify the water use modulation coefficients at country scale and monthly level. Such coefficients were multiplied by the water volume of each catchment (industrial and domestic use) in order to provide a monthly variation of water abstraction and use.

The analysis is based on sectors B–C, D35 and E36. Figures 7.2 to 7.4 indicate the variation of water uses considering the reference year of 2010.

[44] Production in industry - monthly data - http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=STS_INPR_M&lang=en

Figure 7.2 Production in Industry sectors B–C (2010)

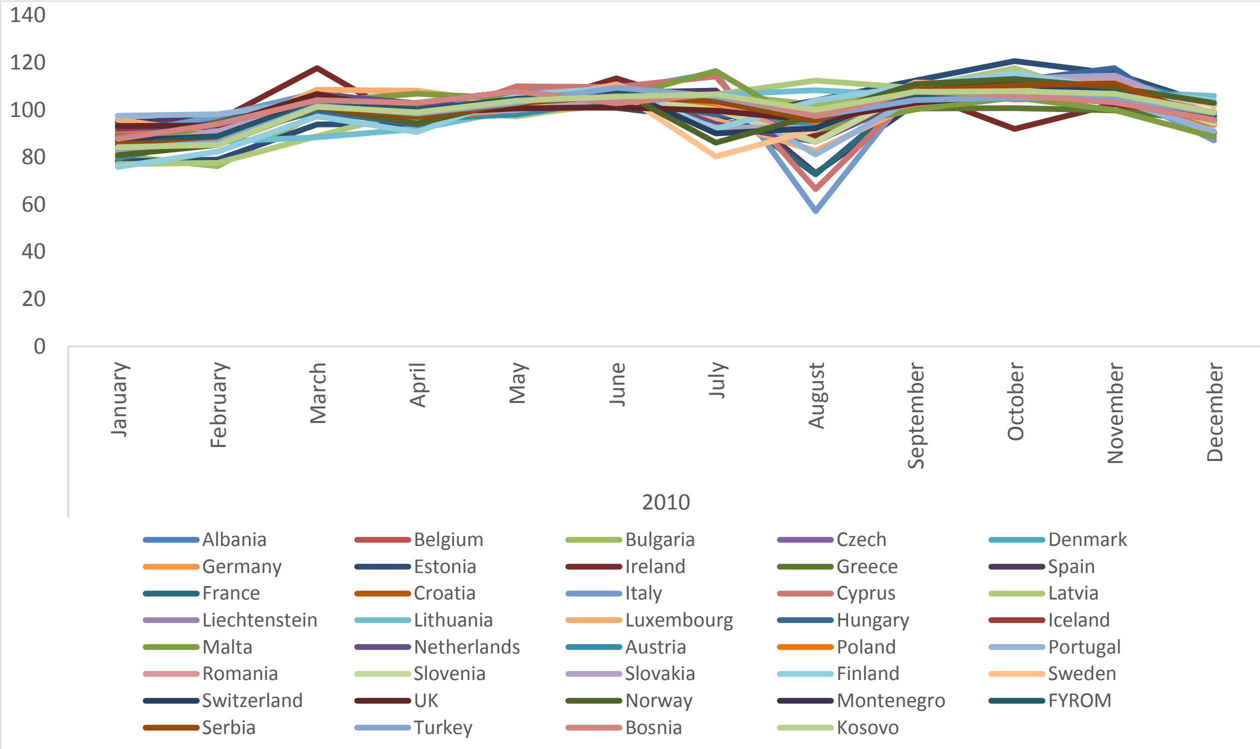


Figure 7.3 Production in Industry sector D35 (2010)

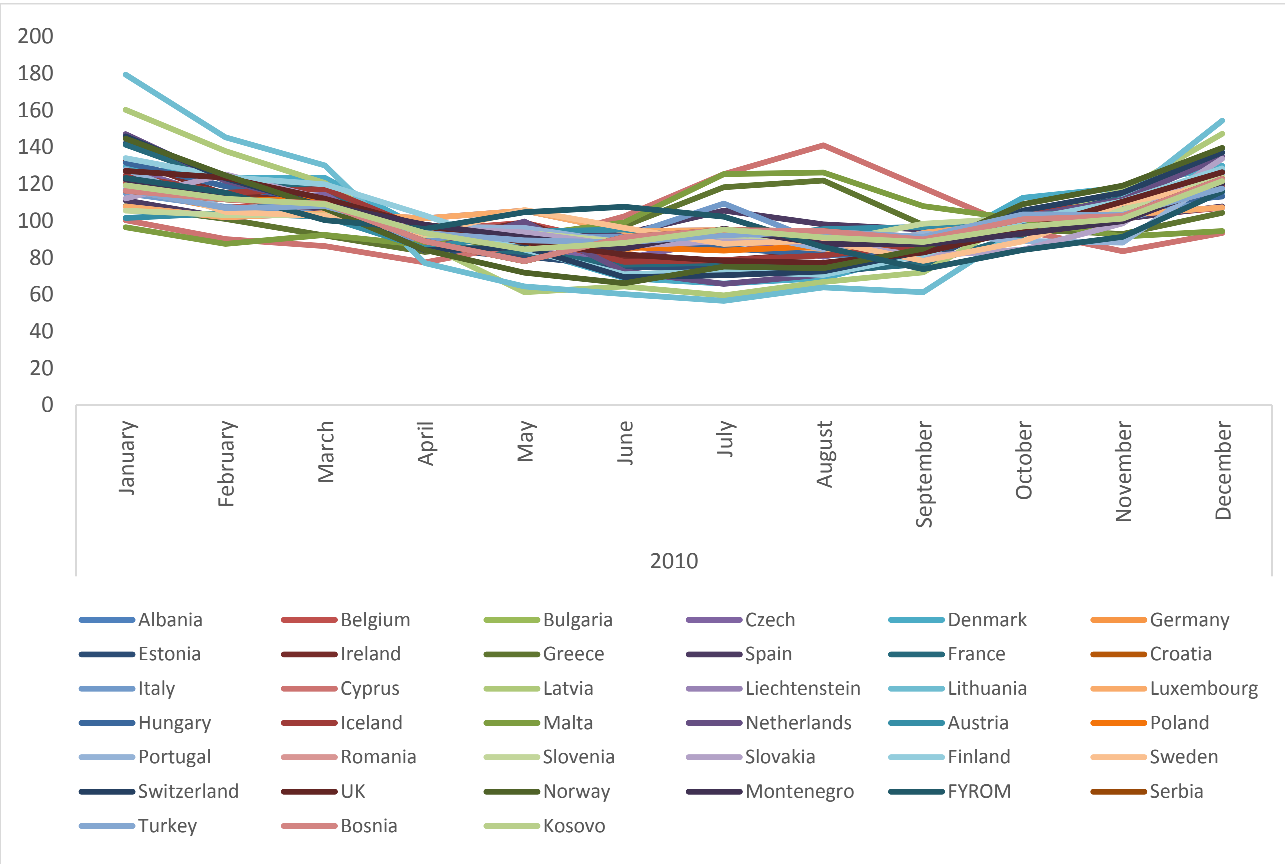
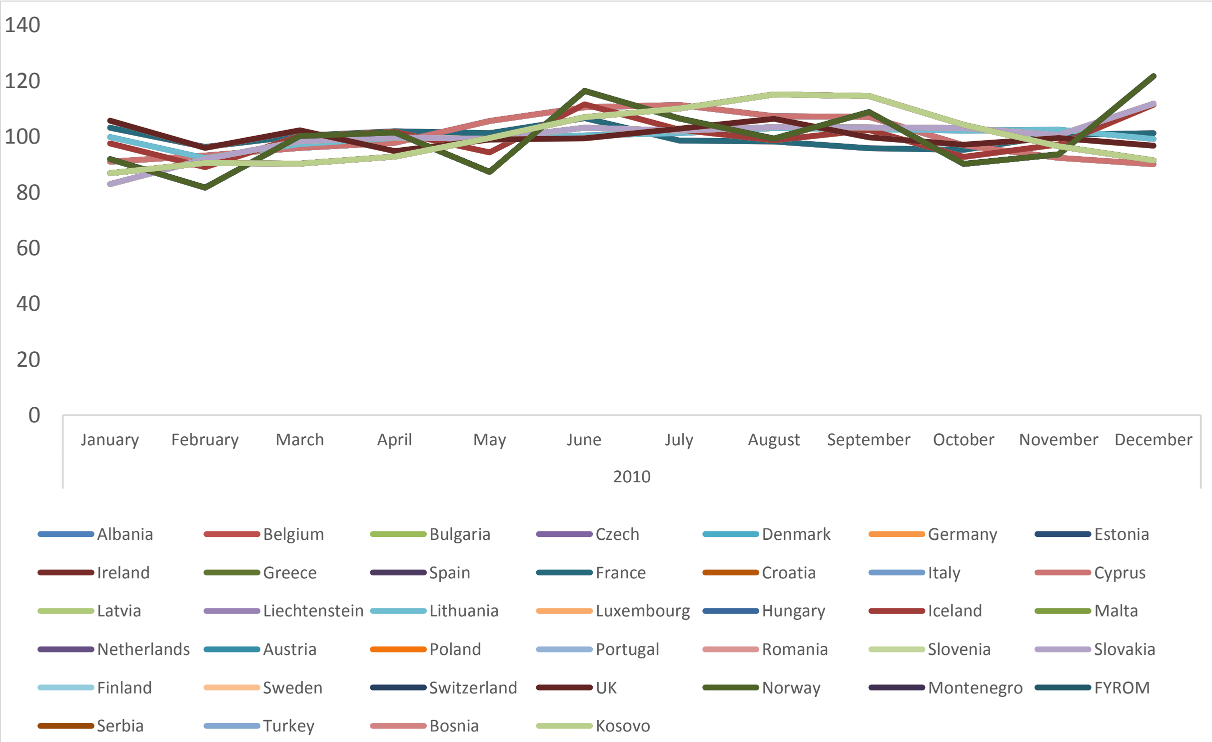


Figure 7.4 Production in Industry sector E36 (2010)



For countries with no data on Eurostat "Production in industry" dataset, the gap filling was made by other countries based on the closest GDP. Table 7.6 illustrates the gap filling assumptions.

Table 7.6 Gap filling in Industry Coefficients

COUNTRY	SECTOR B,C	SECTOR D35	SECTOR E36
Belgium	OK	OK	OK
Bulgaria	OK	OK	OK
Czech Republic	OK	OK	Poland
Denmark	OK	OK	Netherlands
Germany (until 1990 former territory of the FRG)	OK	OK	Average of Belgium, Netherlands
Estonia	OK	OK	Lithuania
Ireland	OK	United Kingdom	Average of Belgium, Netherlands
Greece	OK	OK	OK
Spain	OK	OK	Greece
France	OK	OK	Belgium
Croatia	OK	OK	Bulgaria
Italy	OK	OK	Greece
Cyprus	OK	OK	Greece
Latvia	OK	OK	Poland
Lithuania	OK	OK	OK

COUNTRY	SECTOR B,C	SECTOR D35	SECTOR E36
Luxembourg	OK	OK	Average of Belgium, Netherlands
Hungary	OK	OK	Poland
Malta	OK	OK	Poland
Netherlands	Average of Belgium, Luxembourg	OK	OK
Austria	OK	OK	Netherlands
Poland	OK	OK	OK
Portugal	OK	OK	Poland
Romania	OK	OK	Bulgaria
Slovenia	OK	OK	Poland
Slovakia	OK	OK	Poland
Finland	OK	OK	OK
Sweden	OK	OK	Finland
United Kingdom	OK	OK	Finland
Norway	Average of Finland, Sweden	OK	Netherlands
Montenegro	Croatia	Croatia	Bulgaria
Former Yugoslav Republic of Macedonia, the	Average of Bulgaria, Greece, Croatia	OK	Bulgaria
Serbia	Average of Bulgaria, Croatia, Hungary, Romania	Bulgaria	Bulgaria
Turkey	Average of Bulgaria, Greece	Romania	Bulgaria
Bosnia and Herzegovina	Croatia	Bulgaria	Bulgaria
Kosovo	Average of Bulgaria, Croatia	Average of Bulgaria, Croatia	Bulgaria

The aforementioned industrial sectors affected the modulation coefficients and the water distribution at monthly scale for the period 2002–2012.

Table 7.7 Region assignment for annual abstraction Eurostat data analysis

Region	Country	Region	Country
East	Bulgaria	West Balkans	Albania
East	Czech Republic	West Balkans	Serbia
East	Estonia	West Balkans	Bosnia and Herzegovina
East	Latvia	West Balkans	Kosovo (under United Nations Security Council Resolution 1244/99)
East	Lithuania	West	Belgium
East	Hungary	West	Denmark
East	Poland	West	Germany (until 1990 former territory of the FRG)
East	Romania	West	Ireland
East	Slovenia	West	France
East	Slovakia	West	Luxembourg
South	Greece	West	Netherlands
South	Spain	West	Austria
South	Italy	West	Finland
South	Cyprus	West	Sweden
South	Malta	West	United Kingdom
South	Portugal	West	England and Wales
Turkey	Turkey	West	Iceland
West Balkans	Croatia	West	Norway
West Balkans	Former Yugoslav Republic of Macedonia, the	West	Switzerland

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