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Water footprint in the context of sustainability assessment

Report on the application of life cycle based indicators of water consumption in the context of integrated sustainability impact analysis

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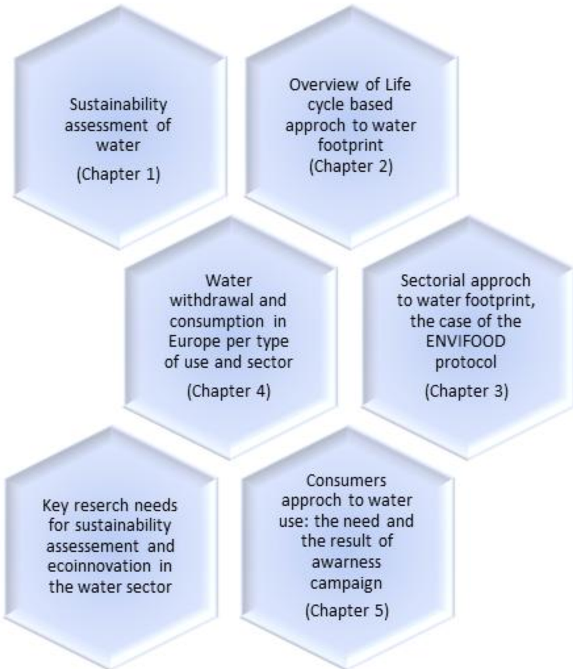
Executive Summary

Sustainability science explores the interactions between human activities on the Earth's life support systems. Unless we understand these interactions, we will not be able to design a path towards sustainable development. In fact, it is widely documented that humanity is now consuming more resources than our planet is able to produce and regenerate. Interventions are needed not just to inform and raise awareness about the environmental consequences of our consumption behaviour but to generate concrete actions that will result in more sustainable consumption styles and patterns. In this report we focus our attention on water as key resource for human health and ecosystem health. Water is moreover an archetypal resource for which sustainability assessment is needed in order to preserve quality and quantity of the resource for present and future generations.

The recent European Communication "A Blueprint to Safeguard Europe's Water Resources" has recently emphasized key themes for fostering and integrating water policies which include: improving land use, addressing water pollution, increasing water efficiency and resilience, and improving governance by those involved in managing water resources. More and more integrated assessment is needed and co-responsibilisation of different actors is considered fundamental.

A holistic approach to sustainability assessment of water requires different methodologies able to capture the magnitude of socio-economic drivers related to water consumption: both from production sectors (such as industries and agriculture) and from consumers (domestic use, consumption patterns).



Aiming a providing additional insight into the relationship between production and consumption patterns and water policies, the present report illustrates different methodologies for depicting sustainability of water use in a life cycle thinking perspective. The rationale of sustainability assessment and water footprint concepts is given in chapter 1, whereas in chapter 2, an overview of existing methodology adopted in the context of Life cycle assessment is reported, evaluated against criteria and discussed. The urgent need for harmonization of the inventory data and for further development of water footprint methods towards a suitable method for policy context are highlighted, beyond the framework development on-going now at ISO (International Standard Organization) level. In chapter 3, the recommendation given in a specific water demanding sector (such as the food production) is presented. In chapter 4, a methodology being developed to map water withdrawals and consumption in Europe for the public, industrial, and agricultural sectors is described. Additionally, in chapter 5, the role of household water consumption patterns is highlighted. Through the document, relevant research needs for better sustainability assessment of water are reported.

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Acronyms

FD	Freshwater depletion
FEI	Freshwater ecosystem impacts
LCA	Life Cycle Assessment
LCI	Life Cycle Inventory
LCIA	Life Cycle Impact Assessment
VW	Virtual water
WBCSD	World Business Council for Sustainable Development
WF	Water footprint
WSI	Water Stress Index
WTA	Withdrawal-to-availability

Definitions

Blue water	Surface and groundwater, in other words, the water in freshwater lakes, rivers and aquifers.
Blue water footprint	Volume of surface and groundwater consumed as a result of the production of a good or service. Consumption refers to the volume of freshwater used and then evaporated or incorporated into a product. It also includes water abstracted from surface or groundwater in a catchment and returned to another catchment or the sea. It is the amount of water abstracted from groundwater or surface water that does not return to the catchment from which it was withdrawn. (Hoekstra et al 2011)
Freshwater degradative use	Characterized by withdrawal and discharge of freshwater into the same watershed after quality alteration
Freshwater consumptive use	This use occurs when used freshwater is not released into the same watershed from which it was withdrawn due to product integration, evaporation, or discharge into different watershed
Green water	The precipitation on land that does not run off or recharge the groundwater but is stored in the soil or temporarily stays on top of the soil or vegetation. Eventually, this part of precipitation evaporates or transpires through plants. Green water can be made productive for crop growth (although not all green water can be taken up by crops, because there will always be evaporation from the soil and because not all periods of the year or areas are suitable for crop growth).
Green water footprint	Volume of rainwater consumed during the production process. This is particularly relevant for agricultural and forestry products (products based on crops or wood), where it refers to the total rainwater evapotranspiration (from fields and plantations) plus the water incorporated into the harvested crop or wood. (Hoekstra et al 2011)
Grey water footprint	The grey water footprint of a product is an indicator of freshwater pollution that can be associated with the production of a product over its full supply chain. It is defined as the volume of freshwater that is required to assimilate the load of pollutants based on natural background concentrations and existing ambient water quality standards. It is calculated as the volume of water that is required to dilute pollutants to such an extent that the quality of the water remains above agreed water quality standards (Hoekstra et al 2011).
Life Cycle Assessment	A methodology to assess environmental impacts associated with all the stages of a product's life from cradle to grave
Life Cycle Impact Assessment	It is the fourth step in LCA. This step is use to quantify potential environmental impacts of product(s), e.g. water scarcity related impacts
In-stream freshwater use	It describes an in situ use of freshwater (e.g. for hydroelectric power or ship traffic)
Off-stream freshwater use	This use comprises any use of freshwater that requires a prior removal of freshwater from the water body
Virtual water (VW)	Mainly use in the context of international trade, generally used to refer to the sum of water used or incorporated in the various steps of the production processes of a commodity
Water footprint (WF) of nations	A “sum of the domestic water use and net virtual water import” (Hoekstra and Hung 2002)

1. Sustainability assessment of water: a holistic approach to an efficient use of the resource

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1.1. Sustainability assessment of water resources

Sustainability science explores the interactions between human activities on the Earth's life support systems, aiming at identifying possible alternatives for human well-being within planetary boundaries (Rockström et al 2009). According to a recent definition, *sustainability science* is a "*solution-oriented discipline that studies the complex relationship between nature and humankind, conciliating the scientific and social reference paradigms which are mutually influenced- and covering multi temporal and spatial scales. The discipline implies a holistic approach, able to capitalize and integrate sectorial knowledge as well as a variety of epistemic and normative stances and methodologies towards solutions' definition*" (Sala et al 2012, p.9). Unless we understand these interactions, we will not be able to design a path towards sustainable development and resource efficiency.

In this report, we focus our attention on water as key resource for human and ecosystem health. Water is an archetypal resource for which sustainability assessment is needed in order to preserve its quality and quantity for present and future generations. Notwithstanding water is only one of a larger set of environmental concerns related to resources – e.g. as listed in the resource efficiency communication of the EU (EC, 2011) – it represents one of the resource for which a crucial difference could be made adopting weak or strong approach to sustainability (Pearce at al 1994). In other words, if we treat natural capital as subject to be compensate by others capital or not.

In fact, freshwater is one of the planet's most essential resources, heavily subject to spatial and temporal variability of its own quantity and quality. As an essential life-sustaining element it cannot be substituted. As the main source of drinking water and the basis for hygiene and food supply as irrigation water in agriculture and for livestock, it is indispensable. Also industrial production and many services depend on continuous availability of freshwater. At the same time it represents a key compartment for aquatic ecosystems, a fundamental resource for terrestrial ecosystems and is a key element in regional and micro climates on which we all depend. We are witnessing a steadily worsening situation of rapidly decreasing freshwater resource availability, which directly threatens 1.1 billion people around the globe that lack sufficient access to safe drinking water (UN, 2006). Increasing water scarcity in many regions of the world endangers food production (about 70% of today’s global freshwater consumption feeds agriculture), and burdens human health due to diseases related to unclean drinking water (e.g. in Asia and Africa). The overexploitation of water for the soaring agricultural production (e.g. in China, India, Western USA) may jeopardize the freshwater abundance of future generations. Irrigation and damming cause fragmentation of river basins, often drastically reducing the downstream freshwater availability, and alarmingly threatens aquatic and terrestrial ecosystems. Inappropriate water resource management endangers ecological functions and biodiversity, provokes disturbed water cycling and desiccation of rivers, streams, and land. Freshwater resources and their allocation increasingly play a central role in poverty alleviation and urban water supply, facing growing competition with other economic sectors particularly in low and middle income countries. Rapidly rising urban populations mount the pressure to shift water from agriculture to vastly expanding cities (e.g. in China). Global trade of manufactured goods and services, all of which require water at some point over their life cycle, fuel the demand for capturing the freshwater use related environmental, economic, and social impacts.

Indeed, environmental as well as socio-economic aspects are involved in the water cycle, and the complex interaction between different factors implies the necessity of a multidisciplinary and holistic approach to water management.

This is highlighted also in the recent European Communication “A Blueprint to Safeguard Europe's Water Resources**”** (EC, 2012a) which has emphasized key themes for fostering and integrating water policies which include: improving land use, addressing water pollution, increasing water efficiency and resilience, and improving governance by those involved in managing water resources. The Blueprint reports that it is expected that, by 2030, half of EU river basin will be affected by water scarcity and stress. Therefore, there is there need of: a) water efficiency measures, along the whole supply chain – from extraction of raw material up to production processes, to use and to products’ end of life; b) agreed water accounting methodologies; c) water efficiency targets at sectorial level. Hence, more and more integrated assessment is needed and co-responsibilisation of different actors is considered fundamental.

This needs to couple top-down approaches (e.g. water basin management) with bottom-up ones (e.g. assessing to which extent a product is consuming water in its entire life cycle), in which the carrying capacity of the water cycle is evaluated in terms of quantity, quality, time and location of the water use and release.

Many water footprint concepts have been developed in the past years in order to provide a quantitative and systematic approach to measure and better manage key issues related to water consumption.

Before detailing the rationale of current water footprint methodologies, next section illustrates the key elements that should be taken into account carrying on a sustainability assessment of water related issues.

1.2. Key elements for the evaluation of natural capital: planetary boundaries, carrying capacity and system's vulnerability and resilience

Some cross-cutting issues need to be addressed in the context of the sustainability assessment of natural resource and natural capital. Historically, the values associated to each sustainability pillar (environmental, economic and social) were evaluated as capitals: natural, social and economic ones[1]. Natural capital is the extension of the economic notion of capital (manufactured means of production) to goods and services relating to the natural environment (e.g. the stock of natural ecosystems that yields a flow of valuable ecosystem goods or services into the future). In the sustainability assessment of a system, the environmental pillar could be evaluated through the system capability to maintain the natural capital over time.

One of the main consequences of having different perspectives on sustainability is the difference in the definition and the assessment of different capitals, according to strong and weak sustainability. Strong sustainability is based on the condition that some natural capital provides functions that are not substitutable by man-made capital: each capital needs to be preserved for future generations. Weak sustainability reflects a view whereby natural and man-made capitals together comprise total capital. Natural capital is considered to be substitutable for man-made capital and weak sustainability occurs whereby the level of total capital passed onto future generations does not decrease (the inference being that man-made capital has replaced natural capital to maintain total capital) (Pearce et al 1994).

The main keywords for a comprehensive sustainability assessment of water as natural capital could be listed as follows: planetary boundaries and carrying capacity; vulnerability; resilience and adaptation. The concepts are briefly reported below, indicating relevant references:

- *Addressing limit of the resources/planetary boundaries and carrying capacity of the earth system.* In a recent paper of Rockström et al (2009), availability of evidence-based thresholds for a safe operating space for humanity was discussed, charting research needs for identifying planetary boundaries. The boundaries are related with the evaluation of the Earth's carrying capacity (number of individuals who can be supported or quantity of resources which could be used in a given area within the natural resource limits, and

[1] In the last two decades, the categorization of capitals has been extended, e.g. as the four capital model of Ekins 1992 and in the five capitals framework (natural, human, social, manufactured and financial) developed by Parrett (2007) in which the capitals are not purely of instrumental value but represent an appropriate framework within which particular endpoints of intrinsic value can be identified.

without degrading the natural social, cultural and economic environment for present and future generations), including multi-scale spatial and temporal dynamics. For example some impacts of biodiversity and ecosystem change are local; others are national, regional, or global. Some are extremely fast, others occur on very long time scales (Perrings et al 2011). The limits in case of water are not to be considered only in a quantitatively manner (e.g. availability of freshwater) but also qualitatively (e.g. certain quality requirements to support human health and ecosystem health, closely related to the concept of critical load) and addressing the provision of ecosystems service and function intertwined with the previous two aspects.

- *Assessing vulnerability*. Vulnerability is defined as the degree to which a system, subsystem, or system component is likely to experience harm due to exposure to a hazard, either a perturbation or stress/stressor (White 1974; Cutter 2001) The concept may be applied to environmental as well as to economic and social contexts (De Lange et al 2010). Vulnerability presents formulations of vulnerability to environmental change as a characteristic of social-ecological systems linked to resilience (Adger 2006). According to Turner et al (2003), the vulnerability analysis framework integrated in sustainability assessment proves useful in directing attention to the interacting parts of the coupled system and helps to identify relevant gaps in information and understanding to reduce vulnerability in the systems as a whole.
- *Assessing resilience and adaptation*. The concept and measurement of resilience as developed in ecology was inspired by dynamic systems theory and catastrophe theory. The resilience is the capability of a system to recover after a certain stress. Its use in other disciplines and application to multidimensional systems is increasing, particularly with respect to sustainable systems management (Mayer 2008). Considering vulnerability and resilience in sustainability assessment implies also accounting for indirect and cumulative effects that in some cases may be more critical than the direct ones. The relevance of the concept was recently stressed also in the context of a key document of the United Nations “Resilient People, Resilient Planet: A future worth choosing” (UN 2012).

1.3. A conceptual framework for sustainability assessment of water based on DPSIR

Having set the theoretical foundation of the relationship between sustainability and water as resource, a fundamental step is the definition of a suitable cause-effect conceptual framework to support sustainability assessment. We considered the “Driver-Pressure- State- Impact- Response” (DPSIR) framework (EEA, 2006), described as “causal framework for describing the interactions between society and the environment", an appropriate approach for this evaluation. According to the DPSIR, every environmental process/intervention can be analysed trough a chain of causal links starting with 'driving forces' (economic sectors, human activities) through 'pressures' (emissions, waste) to 'states' (physical, chemical and biological) and 'impacts' on ecosystems, human health and functions, eventually leading to political 'responses' (prioritization, target setting, indicators). Describing the causal chain from driving forces to impacts and responses and quantifying it, especially in the case of water, is a complex task (Borja et al 2006). In Figure 1, we depict an overview of the relationship in order to highlight the key element affecting water quality and quantity.

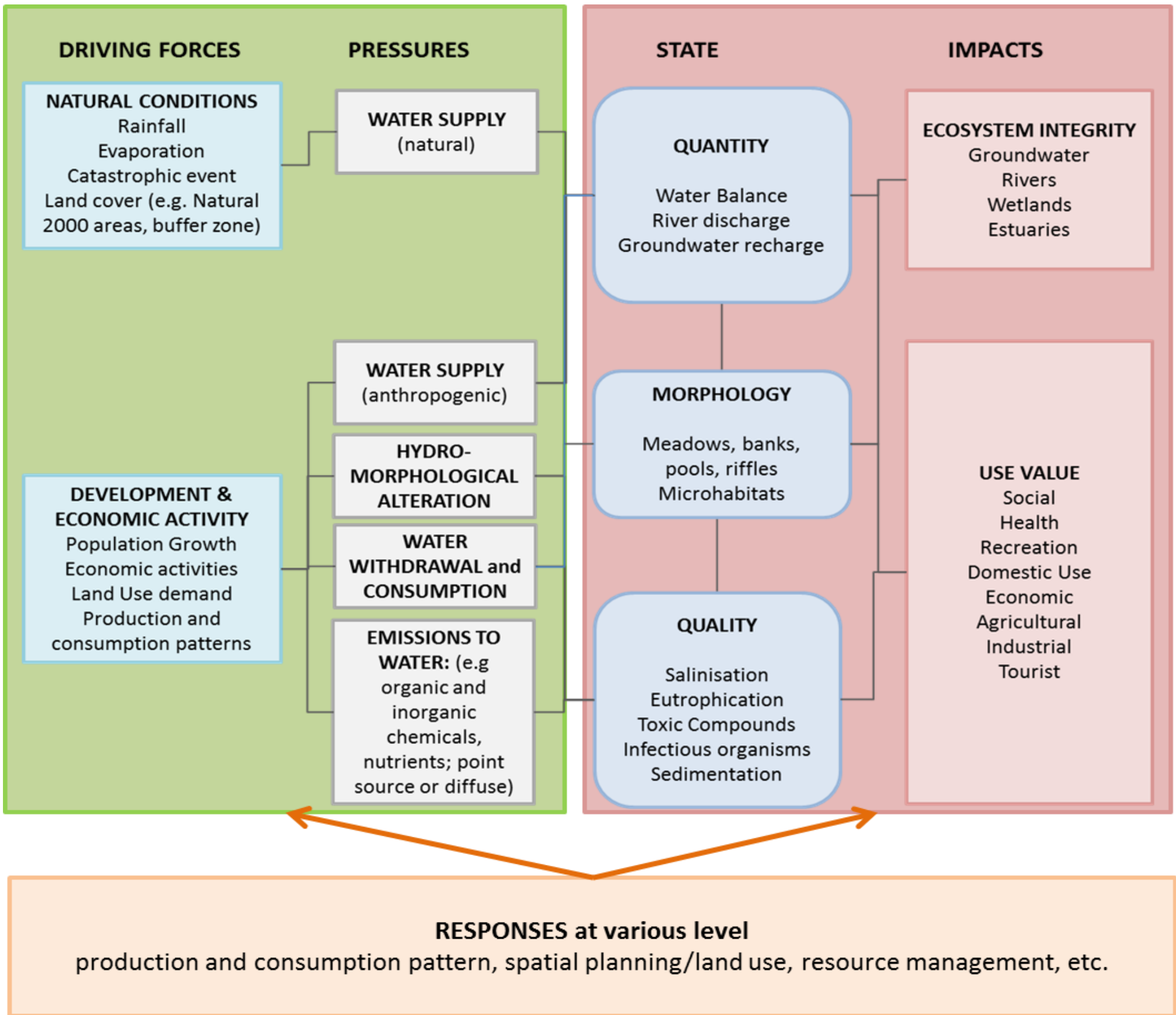


Figure 1. DPSIR scheme adapted to water (modified from EEMRU, 2012)

The targets of the impacts are highly diversified: water typologies (rivers, lakes, seas, coastal zones, groundwater), ecosystems (aquatic and terrestrial), and a range of socio-economic activities.

In table 1, an overview of possible drivers, pressure, state and impacts is reported. With an eye on improvement and on measures especially from policy perspective it is important to differentiate the drivers into at least 2 different types of drivers: direct ones and indirect ones. The direct drivers are industrial and private activities that result in pressures. However, more important are the indirect (the "shadow") drivers that are the goods and services that we purchase and that cause their production. Management of these two different types of drivers requires different policy elements and has to address different actors. Ultimately, the consumption (of citizen and by public authorities) is the key driver behind the pressures and impacts, while policies on industrial activities can address the production side and contribute to improvements and eco-innovation strategies.

Table 1. Overview of the key drivers (D) and associated pressure (P), change in state (S) and impacts (I)

Drivers	Pressures	States	Impacts
- Refineries/Mining (types of plant/mining, age, structure)	Emission of highly polluted water Use of water for cooling	Concentration of pollutant in water	Acidification, ecotoxicity
- Power plants (types of plants, age structure, fuel types)		Change in temperature Scarcity	Ecotoxicity Human health
- Energy use (energy factors per type of activity, fuel types, technology)		Change in temperature Scarcity	Ecotoxicity Human health
- Industry (types of plants, age structure, resource types) - Non-industrial sectors	Water consumption Water pollution	Concentration of pollutant in water Scarcity	Ecotoxicity Human health
- Agriculture (number of animals, types of crops, stables, fertilisers)	Consume of water for irrigation Emission of pollutant	Concentration of pollutant in water	Eutrophication Ecotoxicity Human health Desertification
- Land use change	Building infrastructure	Change in soil permeability Risk of floods	Human health
- Population (number, distribution, access to Waste water treatment plant)	Water consumption Water pollution	Concentration of pollutant in water Scarcity	Eutrophication Ecotoxicity Human health
- Sewage systems (types)	Water pollution	Concentration of pollutant in water	Ecotoxicity Human health
- Landfills (type, age)	Water pollution	Concentration of pollutant in water	Ecotoxicity Human health

Understanding the interaction between drivers and impacts requires an integrated approach that no impact assessment method so far is able to analyse comprehensively and especially not quantitatively.

Regarding specifically the impacts in water ecosystems, although the implementation of the Water Framework Directive- WFD (Directive 2000/60/EC) was successful in general, the achievement of the goals is hampered by limited ability to tackle water management under complex multiple stress conditions. This limitation stems partially from inadequate understanding: of interactions among stressors (EEA, 2012) and among species involved; and, as well, of potential future impacts due to global change.

Water management under this complexity requires novel approaches and user-friendly methodologies, methods, indicators and tool to support:

(a) the identification of stressors;

(b) the assessment of impact of multiple stressors, anthropogenic and biogenic, on ecologically relevant endpoints;

(c) the identification of science-based thresholds, considering carrying capacity of ecosystem and the specific features of the water bio-geochemical cycle;

(d) the definition of suitable mitigation measures capable to reduce impacts under current use, as well as under projected future scenarios by considering global change and socioeconomic boundaries;

(e) the eco-innovation of process and products towards a more efficient use of water resources

(f) the development of adequate communication towards different stakeholders, from water managers to consumers.

Furthermore, the European Commission already recognise the importance of Life cycle thinking in water assessment, innovation and management. For example, The European Innovation Partnership on Water (EC, 2012b)was set up to "Identify, test, scale up, disseminate and deploy innovative solutions for 10 major water related challenges" by 2020. The five priority areas that have been chosen entails the entire life cycle of water from extraction to different uses and treatment at the end of life (Water reuse and recycling; Water and wastewater treatment; Water and energy; Risk management of water related extreme events; Ecosystem services). These priorities focus on challenges and opportunities in the water sector, and on eco-innovative actions that will deliver the highest impact.

1.4. The rationale behind a life cycle-based approach to water assessment

Over their lifetime, products (goods and services) not only provide valuable functions to all of us, but also contribute to various environmental pressures and the depletion of resources. Life Cycle Assessments have originally been developed to help quantifying these pressures and related impacts by analysing the emissions and resources extracted that are related to a product over its entire life cycle. Life Cycle Assessment (LCA) is an internationally standardised framework (ISO 14040 and 14044) for investigating and evaluating environmental impacts of a product or service through all stages of the product cycle, including raw material acquisition and transfer, manufacturing, product use, and disposal. The crucial role in the context of sustainability assessment is increasingly recognized (Wolf et al, 2012; Sala et al 2012).

Life Cycle Assessment is unique combination of several principles, uppermost relevant when dealing with environmental sustainability issues:

- **Life cycle orientation**. LCA integrates the related resource consumptions and emissions over the entire life cycle of the analysed system and the products related to it, from the extraction of natural resources through material processing, manufacturing, distribution, and use, up to recycling/recovery and the disposal of any remaining waste. This helps to avoid resolving one environmental problem while creating others.
- **Comprehensiveness of the impact assessment**. LCA takes into account a wide range of environmental problems such as climate change but also toxic effects on humans and the ecosystem, summer smog effects and so on, as well as material and land resource depletion, bringing them into an integrated assessment framework.
- **Robust and systematic assessment**. LCA captures environmental problems in a scientific and quantitative manner, by inventorying the amount of all related resource uses and emissions, allowing for comparisons, weak-point analysis, and demonstrating absolute improvement potentials, as well as monitoring of achievements over time. Subjective elements can largely be excluded and otherwise made transparent and be systematically addressed in the results interpretation.

  A fourth key principle of LCA is that it facilitates comparisons of the environmental performance of different options on an equal basis and to identify areas for improvement. It ensures a “level playing field”: This is achieved by comparing alternative options strictly on the basis of their so-called “functional unit”. The functional unit is the precise, quantitative description of the function(s) provided by the analysed system, i.e. “what” does it do, “which amount” of function does it provide, and “how well” and “for how long” does it do this. In comparisons that do not consider this functional unit, e.g. a product or a technology that delivers fewer functions or less good functions compared to its competitor might wrongly look environmentally better.

Adhering to these principles, the specific Life Cycle Assessment study is developed in the specific way needed to address the question it is meant to answer.

This smart approach allows for a science-based, quantitative comparison of alternatives, capturing the relevant environmental impacts and quantitatively considering trade-offs both among different impacts and of impacts occurring at different stages of the life cycle. Measures taken to reduce the amount of greenhouse gases emitted at the production stage may otherwise lead to much higher emissions during the product's use for example of substances causing summer smog. Similarly, a well recyclable material that is chosen may cause higher environmental impacts during product use; these life cycle wide interdependencies equally need to be considered to achieve an effective, overall improvement of the product´s environmental performance.

At the same time, the environmental LCA is structurally open for a stepwise, consistent extension to a full sustainability assessment that includes life cycle cost and social life cycle aspects, such as job creation, accidents at work, equal gender remuneration, and others. This is possible because the basis of any environmental LCA is the technical life cycle model, i.e. of its complete supply chain, use and end-of-life treatment steps to which the environmental information on resource use and emissions is related. In the same way, cost and social information can be related to this identical technical life cycle model. Such integrated studies in research and industry have been already performed since about the year 2000, while the development of an integrated authoritative approach for such an integrated Life Cycle Sustainability Assessment is still outstanding.

LCA has informed the development of footprints (e.g. Carbon footprint, Environmental footprint) with its “cradle-to-grave” approach for considering environmental impacts. Among the impacts considered are atmospheric emissions, solid waste and by-products, and water pollutants. Water inputs for the production, use and disposal of a good or service have not historically been accounted for in a LCA, but are now an area of focus.

1.5. The development and use of the water footprint concept

The development and the use of footprint methodologies for environmental assessment are of increasing interest in both the scientific and political communities. The basic idea of all “footprints” is to evaluate human pressure on the environment, related to production and/or consumption, and at micro, meso or macro scale. Inspired by the footprint-idea of the ecological footprint (EF), developed at the beginning of the 90s (Wackernagel and Rees 1996), several other “footprints” were defined, both environmental (e.g. carbon footprint, CF, and water footprint, WF), economic (e.g. economic footprint) and social (e.g. social and poverty footprint) as means of assessing and communicating sustainability elements (see a recent review of Čuček et al 2012). In most of the cases, existing footprints integrate life cycle thinking (Čuček et al 2012) focusing on challenging environmental impacts considered crucial for assessing sustainability of production and consumption patterns - such as: resource consumption, CO_2 emission leading to climate change, and water consumption. So far, the CF is one of the most used measures to assess human pressure on the planet (Galli et al. 2012).

The already developed footprint methodologies usually neglect a relevant source of impact, such as those related to the production and use of chemicals. Recent attempts in this direction are related to the grey water footprint component of the water footprint (Hoekstra et al, 2011) and a proposal towards a "chemical footprint" recently formulated by Sala and Goralczyk (2013).

Human activities consume and pollute a lot of water. Current methodologies for water footprint are based on different understanding of what "footprint" means: on one hand, there are methods that simply make an inventory of the consumption of a resource, (in case of water, e.g. entailing different typology freshwater/groundwater etc.); on the other hand, other methods try comparing the consumption with the availability, integrating somehow the carrying capacity of the system in term of capability of providing the resource (both in the short- and long-term) and keep its quality at the highest level. The challenge is to explore the strength of both perspectives towards an integrated assessment, based on the evaluation of: quantity, quality, location of use and release as well as the elements identified in the section 1.2.

This implies a further development of the impact assessment, overcoming the mere inventory of the water use and consumption (Figure 2). In the last decade, the impact-related aspects have been increasingly modelled (some reference reported as example in the Figure 2, methods thereof explained in chapter 2). The latest two boxes are what the research should aim for in future and where more integrated assessment is needed: firstly, extending the cause-effect modelling of scarcity-related impacts (e.g. desiccation, desertification, salinization etc.); secondly, integrating the modelling with socio-economic impacts; thirdly, properly accounting for pollution-related impacts, as attempted trough evaluation of grey water footprint, or, more comprehensively, throughout chemical footprint.

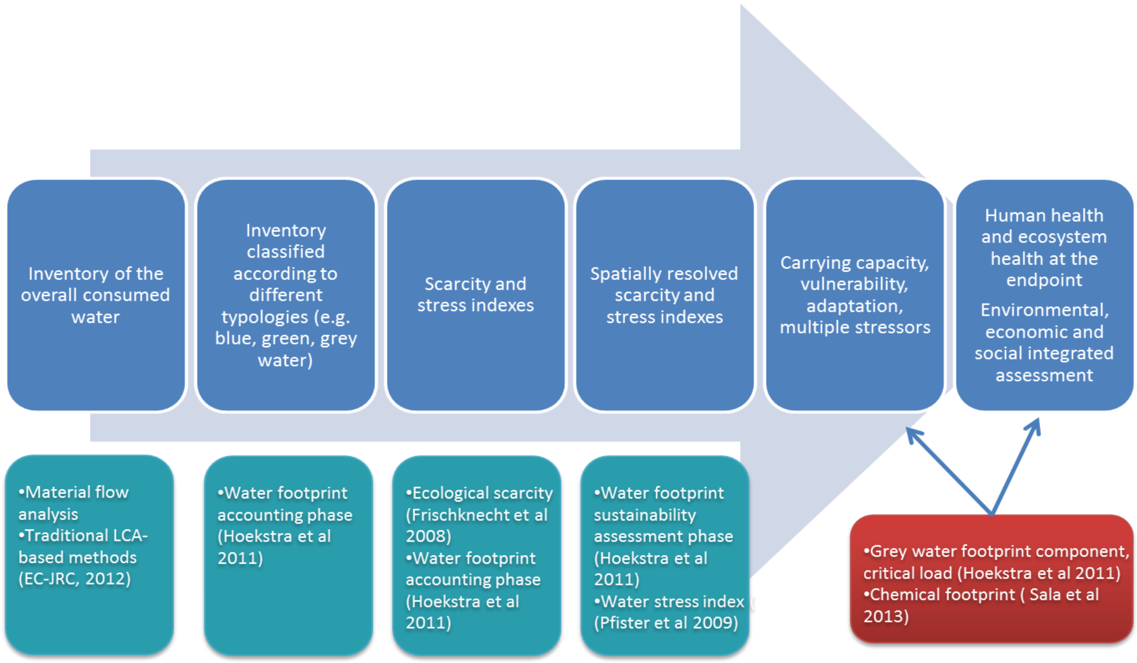


Figure 2. Evolution of footprint concepts according to different perspectives and methods developed in LCA and water footprint network context.

At a global scale and measure only on quantity of water yet not considering the quality effects, most of the water use occurs in agricultural production, but there are also substantial water volumes consumed and polluted in the industrial and domestic sectors (UNESCO, 2009). Freshwater is increasingly becoming a local resource of global concern, driven by growing international trade in water-intensive commodities. Apart from regional markets, there are also global markets for water-intensive goods such as crop and livestock products, natural fibres and bio-energy (Water footprint network, 2011). Moreover, more and stronger disputes across country borders regarding water use by upstream nations are a growing global concern.

Total water consumption and pollution are generally regarded as the sum of a multitude of independent water demanding and polluting activities. The idea of considering water use along supply chains has gained wider interest after the introduction of the 'water footprint' concept by Hoekstra in 2002 (Hoekstra, 2003). However, the concept of virtual water (VW) (Allan, 1998) was the first attempt towards product water footprinting and was developed by Allan already in the early 1960s (Bösch, 2007).

The term "water footprint" (WF) has been used as a measure of a nation's actual appropriation of global water resources and has been defined as the "sum of the domestic water use and net virtual water import" (Hoekstra and Hung, 2002). Some studies have used the concept to refer to water appropriation by individuals and other well-defined groups of consumers (e.g. a city, a region or a state) and producers (e.g. a public organization, private enterprise or economic sector). The WF of an individual, business or nation has, therefore, been defined as the total volume of fresh water that is used to produce the goods and services consumed by an individual, business or nation (Hoekstra and Chapagain, 2008). On the micro-level, the term WF has also been used to describe the VW content of a range of products (e.g. cotton, tea and bio-energy) summed over their life cycle.

Both VW and the WF are measures of direct and indirect water consumption and only account for freshwater appropriation. The difference between these two is that the WF is a "multidimensional indicator, not only referring to a water volume used, but also making explicit where the water footprint is located, what source of water is used and when the water is used" (Hoekstra et al., 2011), unlike VW. Additionally, also the quantity and the quality of the water again released should be considered.

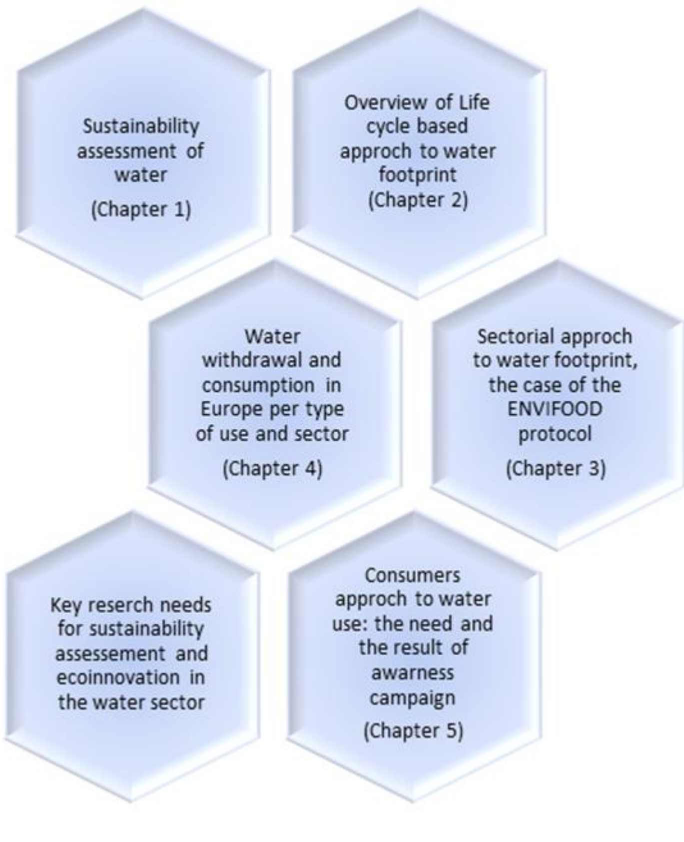
It has been suggested that international trade could be used to move processes that cause a high amount of "virtual water" consumption from comparatively advantaged regions to regions where water is scarce, thereby creating a means for water-poor countries to achieve water security (Allan, 2003). Conversely, such a shifting of water-intensive production to water-rich countries also allows water-rich countries to benefit economically from their natural resources. This would be similar to the development of energy-intensive industries such as aluminium primary production moving to water-power or geothermal power rich countries such as Norway, Brazil and Iceland.

1.6. Outline of the report: the element of a multidimensional approach to sustainability assessment of water

A holistic approach to sustainability assessment of water requires different methodologies able to capture the magnitude of socio-economic drivers related to water consumption: both from production sectors (such as industries and agriculture) and from consumers (domestic use, consumption pattern). The present report aims at presenting different methodologies for depicting sustainability of water use in a life cycle thinking perspective supporting the integration of different methodologies and perspectives for the assessment.

The report would represent also a step towards closing the gap between water stress indicator developed in the context of LCIA and the water stressor indicator as foreseen by the Blueprint and to be defined within the Common Implementation strategy (CIS) of the Water Framework Directive (WFD). In this context, LCA may contribute to policy objectives, especially when location- related pressures may vary significantly. E.g. for the agriculture production, the impact of water consumption is sensitive to spatial differentiation. The same amount of water might imply no impact in certain river basin whereas a potential threat in others.

The outline of the report is as follows. The rationale of sustainability assessment a water footprint concept is given in chapter 1, whereas in chapter 2, an overview of existing methodology adopted in the context of Life cycle assessment is reported, evaluated against criteria and discussed. In chapter 3, the recommendation given in a specific water demanding sector (such as the food production) is presented. In chapter 4, a methodology being developed to map water withdrawals and consumption in Europe for the public, industrial, and agricultural sectors is described. So far, only the usage of “blue water” is considered,



namely the withdrawal of water from freshwater sources, both from surface and groundwater bodies. Water withdrawals and consumption are mapped for the following sectors: Public - Domestic; Industry - Manufacturing and Electricity Production; Agriculture - Irrigation and Livestock. In chapter 5, the role of consumption patter is also highlighted.

In fact, it is widely documented that humanity is now consuming more resources than our planet is able to produce and regenerate. Interventions are needed not just to inform and raise awareness about the environmental consequences of our consumption behaviour but to generate concrete actions that will result in more sustainable consumption styles and patterns. Through the document, relevant research needs for better sustainability assessment of water are reported.

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2. Overview of current methods for water footprinting in the context of Life Cycle Assessment

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2.1. Introduction

In Life Cycle Impact Assessment (LCIA), the effects of the resource use and emissions generated by processes are grouped and quantified into a limited number of impact categories such as climate change or eutrophication, which may then be aggregated further after weighting them by importance. Water consumption data from the Life Cycle Inventory (LCI) is transformed to water use impacts (i.e. the Water footprint) by multiplication with appropriate characterization factors to account for the differing impacts associated with using[2] water from different sources. Three main types of freshwater resources can be identified which differ in respect to their intrinsic regeneration potential: deposits, funds, and flows. Freshwater deposits are represented exclusively by fossil groundwater stocks that are only very slightly or not replenished within human lifetimes and are therefore effectively exhausted when tapped. Freshwater funds, such as groundwater aquifers and lakes, decline temporarily when being extracted. As long as they are not irreversibly impaired or the extraction rate exceeds the natural replenishment rate, their natural renewability allows them to fully regenerate. Streams and rivers belong to the flow-type resources and are characterized by a continuous flow from which humans can redirect certain quantities.

Some LCIA methods use the withdrawal-to-availability (WTA) ratio for calculating characterization factors, so water withdrawn from a water body that is over-exploited would have a much higher characterization factors than water withdrawn from an under-utilised water catchment. Methodological frameworks for the integration of water use impacts in the LCIA stage of LCA have recently been proposed, for example by Frischknecht et al. (2008), Mila i Canals et al. (2009) and Pfister et al (2009). The approach by Frischknecht et al. (2008) has been recommended as first water-scarcity method as part of the ILCD 2011 Recommendations for Life Cycle Impact Assessment (EC-JRC, 2011). The need for further development or selection of a more advanced method has been stated.

This chapter is intended to provide an input on how to further develop methods to assess water use as part of sustainability assessment in micro and macro scale analysis, adopting a life cycle thinking

[2] "Use" and "consumption" of water may refer to different meaning, affecting the impact modelling, namely: dissipation, temporary storage in products, and release into other media (from water bodies to the air, from groundwater to surface water, reduction of quality (chemical, temperature) etc. Those are elements that could be differently accounted for.

perspective from the inventory to the impact assessment. It also provides an overview of available methods with the aim of an initial recommendation. In the end, optimal water resource use methods have to capture the quantity, quality and - for local and regional resources including water - location of resource use.

Key questions of this chapter are:

- Which water footprint methodologies and applications are appropriate for different types of assessments, including for products (micro-level), companies (meso), and countries or catchments (macro)?
- What is already understood from other water resource methods adopted outside LCIA? Specifically, how can the water footprint contribute to the private sector to understand water risk, and how can it be used by the public sector to inform policy development and planning?
- What could be the direction of the European Commission for freshwater use assessment?

While there is some common agreement on basic principles, there is no generally agreed methodology for water footprinting. There is variability with regard to the types of water use and the specific water resource types to be accounted for, the inclusion of local water scarcity conditions, as well as the differentiation between water sources and importantly between various water quality aspects.

This situation is also the setting for the work being undertaken by the International Organization for Standardization (ISO) to currently establish an international standard to assess water use in Life Cycle Assessment (LCA).

Moreover the additional reduction of freshwater availability as a consequence of deteriorated quality of freshwater reservoirs has not been addressed so far; accordingly an evaluation of impacts resulting from this cause–effect chain is neglected.

2.2. Overview on recommendations for next steps

The first effort should be put mainly in harmonization of the methods towards comprehensive approach to water footprint assessment. An effort toward this goal and the potential integration of several methods has been recently made in the context of the UNEP-SETAC Life Cycle initiative (Kounina et al 2013). Importantly this should start from aligning the metrics for water-related inventory parameters so the same inventory can serve all relevant methods that address different water related issues. Based on this, the Life Cycle Inventory (LCI) data sets developed by different actors can be stepwise adjusted or expanded towards inclusion of suitable and compatible water use inventories. The development of regional availability and scarcity data is a second essential step.

There are further relevant qualitative aspects, such as heat releases and microbial contaminations that should be considered. Likewise, the additional reduction of freshwater availability as a consequence of deteriorated quality of freshwater reservoirs should be addressed.

2.3. Criteria for assessing the water footprint methods

The criteria -adopted in this comparison and preliminary assessment- are grouped in 4 main groups and 17 sub-criteria. The main groups are: Acceptance, Suitability (also named: relevance), Practicality (also named: applicability, easiness), and Scientific soundness.

"**Acceptance**" is an overarching criterion that initially refers to the intended user of the method, what implies that it includes all other criteria. Typically and also here it is used however to capture the acceptance by the target audience of the method application results, e.g. here the users of the environmental indicator, and indirectly to those stakeholders the intended audience considers relevant. Sub-criteria under this criterion are: General acceptance by stakeholders, International stakeholder development process.

"**Suitability**" refers to the question, whether a method can provide relevant results for the intended application. Sub-criteria under this criterion are: Appropriateness for policy need, Life-cycle based approach, Coverage of water type, Quality of water considered, Applicable for broad range of products and services, Social aspects considered, Spatial differentiation.

"**Practicality**" refers to whether a method can be implemented efficiently and at acceptable cost, including for actors with limited experience and resources such as SMEs. Sub-criteria under this criterion are: Data availability, Tool availability, Connection to midpoint and/or endpoint (AOP) in LCA (while the latter could also be grouped under "suitability").

"**Scientific soundness**" refers to whether a method meets requirements to receive scientific acceptance. Sub-criteria under this criterion are: Reproducibility, Absence of (or limited) subjectivity, Transparency, Un-biasedness, and Robustness of modelling (if any modelling).

In view of this being a preliminary assessment and in perspective on a more comprehensive stakeholder process towards a method selection and improvement process, the inclusion of further sub-criteria and their exact definition for use in the final selection/adjustment of methods should be part of such a stakeholder process to ensure subsequently a wider agreement and uptake of the outcomes.

2.4. Assessed methods

This work is based on a literature review based on methods published until mid-2012. The list of documents is presented as reference at the end of this chapter. A qualitative scoring system was then applied. Each sub-criterion was assigned a value A, B, or C ranging from "complete / very well meeting the criterion", “need for some improvement” and "largely incomplete / not meeting criterion" of the method.

Six widely recognised methods have been selected, based on the study “Assessment of the efficiency of the water footprinting approach and of the agricultural products and foodstuff labelling and certification schemes” (ENV.D.4/SER/2010/0051r) as well as considering the ISO 14046 (draft) on water footprinting:

1. Water footprint by Hoekstra (Chapagain & Hoekstra 2004)
2. ISO 14046 water footprint (draft, 2012)
3. Stress weighted approach by Brent (Brent 2004)
4. Swiss Ecological Scarcity Method (Frischknecht et al. 2008)
5. Life Cycle Inventory by Owens (Owens 2001)
6. Impact Assessment of Freshwater Consumption According to Pfister and Colleagues (Pfister et al. 2009)
7. Impact Assessment of Freshwater Consumption According to Mila i Canals and colleagues (2009)

2.5. Description of water footprint approaches and related methods

There are three principally different approaches currently being applied for the calculation of a water footprint (RPA & Cranfield University 2011):

I. the volumetric approach, which is based on an assessment of the volume of water associated with a particular production activity;
II. the stress weighted approach, which is based on an assessment of the amount of freshwater consumed in an activity combined with an assessment of the implications of that consumption in terms of water stress; and
III. the impact assessment approaches, which draw on water consumption using an inventory analysis similar to that of the volumetric approach but additionally including an element of impact assessment.

2.5.1. Volumetric approach

The Water footprint network (http://www.waterfootprint.org) proposed the initial ‘water footprint’ concept (Chapagain & Hoekstra 2004), which accounts for the total volume of water used within the life cycle of products, taking into account the geographical location of withdrawals (e.g. source country). From an LCA perspective, the water footprint of a product corresponds to the output of an LCI: the quantification of the elementary flow ‘freshwater’ crossing the system boundary from nature to technosphere. The flow is subdivided into ‘green,’ ‘blue,’ and ‘grey’ water (see definitions).

According to Hoekstra et al. (2009), the volumetric Water Footprint approach provides a potentially useful methodology for quantifying water use for LCI. However, in the volumetric water footprint approach, water consumed is separated into green, blue and grey water, whereas in LCI data green water is usually not considered and blue water may be subdivided into many classes according to its occurrence (e.g. surface water/ groundwater) or quality. Grey water is not considered in LCI because the impacts associated with pollution are dealt with elsewhere, cross-cutting several impact categories and adopting different models for each of them (e.g. in the impact categories related to ecotoxicity, human toxicity, eutrophication, ionizing radiation, etc.). Grey water can also be interpreted as a distance-to-target related LCIA method concept for water pollutants, expressed in terms of natural water use for dilution.

2.5.2. Stress weighted approaches

Stress weighted approaches by Brent (2004)

Stress weighted approach by Brent (Brent 2004) is an assessment method to compare the use of different types of resources through a distance-to-target normalization approach in the South African context. However, while allowing for a comparison of freshwater use with other types of resources such as land or minerals, this method does not model the environmental mechanisms ("impact chain") involved in freshwater use.

Swiss Ecological Scarcity Method

Swiss Ecological Scarcity Method (Frischknecht et al. 2008) provides a set of 'eco-factors' to assess freshwater resource use. Frischknecht and colleagues used two concepts: the relationship between water scarcity and the rate of depletion (i.e. the scarcer the resource, the higher the weighting factor assigned to freshwater depletion) and the spatial variability of that rate. Their proposed eco-factors pinpoint six categories of water stress, which are calculated by comparing the current pressure on the freshwater resource (expressed by the water consumption to renewable water resource ratio) in a specific area (such as many countries, individually) to the critical values defined by the OECD (OECD 2004). Though the methods allow direct and broad applicability for different countries and generic scarcity situations, some results lack plausibility: e.g. the method has essentially the same scarcity-factors for water use in Germany compared to Spain, which, however, suffers regularly and in most parts of the country severe water scarcity.

2.5.3. Impact assessment approaches

The impact of water use in LCA is based on estimates of water consumption, and an inventory list of all inputs and outputs of water is created for a product or a service, and net water consumption is determined then from the difference between inputs and outputs. A broad range of methods have been developed to incorporate water use in life cycle analysis (LCA). Most of these have been developed to support life cycle inventory (LCI) and life cycle impact assessment (LCIA) modelling within LCA (Berger & Finkbeiner, 2010). Guidance for carrying out a LCA is provided within the ISO 14040 and 14044 standards and further detailed and operationalized in the International Reference Life Cycle Data System (ILCD) Handbook (EC 2010 and 2011) as well as the Product and the Organisation Environmental footprint (EC2012).

ISO 14046 (draft 2012)

ISO is developing a new standard to provide internationally harmonized metrics for water footprints. When writing this chapter (end of 2012) the efforts are at the stage of a "Preliminary Work Item (PWI), ISO 14046, Water footprint – Requirements and guidelines", would complement existing standards on life cycle assessment (LCA) and on-going work on carbon footprint metrics by the ISO technical committee ISO/TC 207 on Environmental management. It would also take into account the ISO 14064 standards on the accounting and verification of greenhouse gases (GHG). The work on ISO 14046 Water footprint began in 2009 and is still on-going (first quarter of 2013).
The scope defined for the standard is that it will specify "requirements and guidelines to assess and report water footprints based on LCA". The standard is expected to:

- Deliver principles, requirements and guidelines for a water footprint metric of products, processes and organizations, based on the guidance of impact assessment as given in ISO 14044
- Define how the different types of water sources (e.g. ground water) and water releases (e.g. grey water) should be considered and how local environmental (e.g. dry/wet areas) and socio-economic (e.g. developed/developing countries) conditions should be treated
- Address the communication issues linked to water footprinting (based on ISO 14020 series on environmental labels and declarations)
- Be compatible with the rest of the ISO 14000 family of environmental management standards.

It is not being proposed currently that the standard should offer a methodology for calculating off-sets or compensation, but it would address only direct positive aspects, such as the benefits of decreasing the water footprint.

Life Cycle inventory by Owens 2001

Owens proposes a set of indicators that allows for distinctions among different types of freshwater uses in terms of water quantity and quality. Although Owens' definitions establish an appropriate basis on which to assess the water balance in the LCI phase, environmental mechanisms and related impact pathways caused by freshwater use remain unaddressed.

Impact Assessment of Freshwater Consumption According to Pfister and Colleagues (Pfister et al. 2009)

The method developed by Pfister and colleagues (Pfister et al. 2009) enables a comprehensive impact assessment of freshwater consumption on both midpoint and endpoint level. The method only accounts for blue water consumption, i.e. the consumption of ground and surface water. On midpoint level a regional water stress index (WSI) is introduced which serves as a characterization factor for the proposed impact category water deprivation. The WSI according to Pfister et al. 2009 relies on the ratio of total annual freshwater withdrawals to hydrological availability (WTA). The WTA ratio expresses the regional water stress and is provided for more than 10,000 watersheds by the global WaterGAP2 model (Nemani et al 2003). However, the regional hydrologic situation might vary throughout the year due to seasonal precipitation differences. This seasonal variation might cause additional water stress if the wet seasons cannot fully compensate for the dry seasons due to lacking storage capacities of the individual watershed or additional evaporation of stored water. By introducing a variation factor (VF) such effects are taken into account and are included in the modified WTA ratio WTA*. In order to achieve continuous characterization factors between 0.01 and 1, the WSI is calculated according to a logistic function. All amounts of blue water consumption can then be multiplied by their specific regional WSI to obtain characterized results, which can be aggregated in the midpoint impact category water deprivation. Next to this midpoint indicator, the method also comprises three endpoint impact categories enabling damage assessment according to the Eco-indicator 99 framework (Pfister et al. 2009) in the areas-of-protection human health, ecosystem quality, and resources.

Mila I Canals and colleagues (2009)

This method attempts to differentiate between different types of water use in LCI and provides two midpoint impact categories for LCIA.

In terms of LCI modelling, Mila i Canals and colleagues propose differentiating between inputs of green water, blue water, fossil blue water, and water use due to land use changes. Next to differentiating the input of freshwater into a product system, the use of water should be categorized as well into evaporative and non-evaporative use. Additionally, procedures for calculating different types of water consumption are provided. Furthermore, the method discusses the following impact pathways resulting from water use:

- Water use leading to insufficient freshwater availability causing impacts on human health

- Fossil and aquifer groundwater use above renewability rate leading to reduced availability of freshwater as a resource for future generations – freshwater depletion (FD)
- Water use leading to insufficient freshwater availability causing effects on ecosystem quality – freshwater ecosystem impacts (FEI)
- Land use changes leading to changes in freshwater availability causing effects on ecosystem quality – freshwater ecosystem impacts (FEI)

While no method is provided to describe the impacts to human health, Mila i Canals and colleagues propose ways of quantifying the impacts of water use to freshwater depletion (FD) and freshwater ecosystem impacts (FEI).

2.6. Results of the preliminary comparison

The evaluation is done on the level of the named sub-criteria; the criteria are used for grouping only. The overview of the evaluation of the methods is reported in Table 2. The qualitative ranking assessment has been performed to avoid mis-interpretation of result and/or summing up the individual scores. From this review, some common points and needs have emerged as follows:

- All methods are based on the same principle water type concept according to Hoekstra et al. (2009). This volumetric water type logic provides a potentially useful methodology for inventorying water use for LCI, though further differentiation is needed for impact assessment.
- Only green water is not normally considered in LCA and blue water may need to be subdivided into many classes according to its occurrence (e.g. surface water/ groundwater) or quality.
- Grey water is not considered in LCI and the impacts associated with pollution are dealt with elsewhere, and for good reasons.
- Consistent and generally accepted metrics for water-related inventory parameters are missing
- There is no generally agreed methodology. These ISO developments on water footprinting however, cannot be expected to bring the necessary methodological detail for an operational inventory and impact assessment method.
- Moreover, the additional reduction of freshwater availability as a consequence of deteriorated quality of freshwater reservoirs has not been addressed so far, accordingly an evaluation of impacts resulting from this cause–effect chain is neglected.

Table 2. Overview of the methods for water assessment in LCIA and their evaluation

	Acceptance		Suitability							Practicality			Scientific soundness					
Method	**AG**	**AI**	**SA**	**SL**	**SC**	**SQ**	**SR**	**SS**	**SD**	**PD**	**PT**	**PL**	**SSR**	**SSA**	**SST**	**SSU**	**SC**	**SSM**
1.1 Water footprint by Hoekstra (Chapagain and Hoekstra 2004)	A	C	C	C	A	C	A	C	C	A	A	C/C	A	A	A	D	C	D
2.1 Stress weighted approach by Brent (Brent 2004)	B	C	B	A	A	C	A	C	A	B	C	A/C	A	C	C	C	C	B
2.2 Swiss Ecological Scarcity Method (Frischknecht et al 2008)	B	C	B	A	B	C	A	C	A	B	B	A/C	A	C	B	B	C	B
3.1 ISO 14046 (draft 2012)	A	A	D	A	#	#	#	#	#	#	#	#	#	#	#	#	C	D
3.2 Life Cycle Inventory by Owens 2001	A	C	C	A	B	C	A	D	A	B	A	D	A	D	D	D	C	D
3.3 Impact Assessment of Freshwater Consumption According to Pfister et al 2009	B	C	B	A	B	B	B	C	A	B	B	A/A	A	B	B	B	C	B
3.4 Mila i Canals et al 2009	B	C	B	A	B	B	A	C	A	C	C	A/A	A	B	B	B	C	B

# ISO took decision in 2012 to re-discuss ISO 14046, therefore no information available
D= Not applicable
Acceptance: AG: General acceptance by stakeholders, AI: International stakeholder development process
Suitability: SA: Appropriate for policy needs, SL: Life cycle based approach, SC: Coverage of water types, SQ: Quality of water considered, SR: Applicable for broad range of products and services, SS: Social aspects considered, SD: Spatial differentiation
Practicality: PD: Data availability, PT: Tool availability; PL: Connects to midpoint and/or endpoint (AOP) in LCA
Scientific soundness: SSR: Reproducibility, SSA: Absence of (or: limited) subjectivity, SST: Transparency, SSU: Un-biasedness, SC: Considers cause–effect chain, SSM: Robustness of modeling if any modeling

2.7. Recommendation on water footprint methodologies

The water footprinting methodology should be a consistent integral part of the LCA framework. The product water footprint is an indicator of freshwater use that considers the direct and indirect water required to produce a product, measured over the full supply chain, use and end-of-life of products. The volumetric Water footprint approach provides a potentially useful starting point to come to a suitable methodology for quantifying water use for Life Cycle Inventory. The product water footprint should consider the origin of the water used, and water quantity and water quality impacts by differentiating between blue, (potentially) green and grey water as well as subtypes as needed. The current water footprint methods are not well suited to be used as comprehensive and robust recommended method by the European Commission but rather to use as a starting point for gaining initial experience as contribution to further method development. Indeed, even the actual ILCD recommendation (EC-JRC, 2011), indicated Frischknecht et al 2008 as the recommended methods but with a level III (recommended but to be applied with caution)

In principle, freshwater flows are non-exhaustible, but as they provide a life-supporting element to the biosphere, unsustainable withdrawal of freshwater has substantial adverse effects on ecosystems. For freshwater resources, one can summarize that depletion takes place whenever the replenishment capacity is exceeded by extensive withdrawal, or freshwater flows are cut down by a reduced regeneration rate having implications for the future resource availability (see also Bauer and Zapp 2005). When coupled with information on the basic water source (e.g. river, ground water aquifer), the aforementioned differentiation of freshwater resource types provides a basic format for structuring the water inputs and outputs in the life cycle inventory analysis. However, there is no consistent and generally accepted metrics for water-related inventory parameters; hence, a clearly defined terminology and categorization for freshwater use are required as first step. Table 3 provides a starting point for developing such metrics.

Table 3. Proposal for water-related inventory parameters

Water use categories	Inventory flow	Water flow types/features and examples	
		Input	Output
Total water use **Degradative** water use **Consumptive** fresh water use (freshwater consumption) **In-stream** water use	Elementary flow	Groundwater, fossil groundwater, surface water (river/ lake/stream water), rainwater, sea water, brackish water	Surface water (river, lake,…), sea water (ocean), cooling water (warm)
	Product flow	Tap/ drinking water, desalinated water, cooling water (cold), irrigation water	Effluent to sewage drainage system, cooling water (warm)
	Flow property of material/ product	Water in material/ products	Water in product,

In the assessment from a product life cycle perspective, water quantity issues are strongly interrelated with water quality aspects. Quality specifications of water flows indicate the adequacy as input for a particular application and the potential for reuse of discharged water outputs, an option which mitigates the necessity to withdraw freshwater from nature (e.g. use of reclaimed water for agricultural irrigation). Water quality impairments in terms of chemical impurities of discharged (i.e. emitted) water are already broadly covered by current LCA methods (e.g. CML 2001; Eco-indicator 99; IMPACT 2002+; ReCiPe 2008; Koehler 2006). These quantify the environmental burdens of ecotoxicity, nutrifying, and acidifying waterborne emissions.

However other relevant qualitative aspects such as heat releases and microbial contaminations still remain uncharacterized, the latter one representing a major cause of human diseases in regions as Asia and Africa. Likewise, the additional reduction of freshwater availability as a consequence of deteriorated quality of freshwater reservoirs should be addressed.

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3. Water footprint: recommendations of the European Food Sustainable Consumption and Production Round Table

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3.1. Introduction

In the context of the European Food Sustainable Consumption and Production Round Table (Food RT 2013), an initiative co-chaired by the European Commission and food supply chain partners and supported by the UN Environment Programme (UNEP) and European Environment Agency, the working group 1 has been developing its harmonised methodology for the environmental assessment of food and drink products.

To come out with the draft ENVIFOOD Protocol (Bligny et al 2012), this is the name of such harmonised methodology, the following tasks were conducted (De Camillis et al 2012a): a preparatory scientific workshop (Peacock et al 2011); a detailed analysis of the existing environmental assessment methodologies for food and drink products; a data gap analysis; a second scientific workshop (De Camillis et al 2012b); and a series of discussions within working group 1. Given the importance of water for the agri-food sector, how to best assess the water footprint of foods and drinks was a key task for working group 1.

This chapter describes how such task has been conducted by the ad hoc task force within working group 1. In particular, the relevant terms and definitions included in the draft ENVIFOOD Protocol (Bligny et al 2012) are introduced first in this paper. This is to provide readers with a concise vocabulary to understand the recommendations of the draft ENVIFOOD Protocol (Bligny et al 2012). The importance of water use as well as the nature of water footprint relative to the broad spectrum of sustainability issues is then briefly introduced.

The state of the art in the water footprint research field is then analysed in this paper. In particular, the mainstream practices as well as the outcomes from authoritative scientific initiatives on water footprint are reported.

Finally, this paper presents the recommendations of the draft ENVIFOOD Protocol (Bligny et al 2012) on water footprint, and concludes highlighting some implications and research perspectives.

3.2. Terms and definitions

The draft ENVIFOOD Protocol contains some terms and definitions from the Water Footprint Network methodology" (Hoekstra et al 2011) developed by experts in the field of "water resource management". Nevertheless, the methodology by the Water Footprint Network (Hoekstra et al 2011) has not been endorsed by the European Food Sustainable Consumption and Production Round Table.

See in first pages of this report for the definitions of the following terms: blue, green, and grey water. Further water footprint-related terms and definitions in the Protocol are the following.

- Evapotranspiration: Evaporation from the soil and soil surface where crops are grown, including the transpiration of water that actually passes through crops (Hoekstra et al 2011).
- Water consumption: Water withdrawal minus the return flow to rivers, lakes, aquifers and sea (adjusted from Hoekstra et al 2011).
- Water stress index: The ratio of total annual freshwater withdrawals to water availability (Pfister et al 2009)
- Water withdrawal: The volume of freshwater abstraction from surface or groundwater. Part of the freshwater withdrawal will evaporate, another part will return to the catchment where it was withdrawn and yet another part may return to another catchment or the sea (Hoekstra et al 2011).

3.3. Hints on the nature of water footprint in the sustainability impact assessment framework

Water is a valuable natural resource because it both allows life to be sustained and it cannot be replaced by any other substance. Freshwater is scarce in some regions, or countries thus leading to notable resource supply problems. In addition, water-use can be substantial for producing foods, biofuels, or renewable raw materials (Dominguez-Faus et al 2009).

Water-use has major implications on the following areas of protection: human health, ecosystem quality, and resource availability (in terms of availability of freshwater to future generations).

With regards to human health, water scarcity in terms of, for example, lack of surface water and groundwater for agricultural irrigation may have major implications on malnutrition. Approximately one third of the world's population is threatened by a lack of water to meet daily needs (International Water Management Institute 2007).

Regarding ecosystem quality, water scarcity may affect biodiversity, as sensitive species may not be able to cope with reduced "environmental flow requirements". Water for irrigation and for industry competes with water for the environment. This situation has the potential to negatively impact aquatic biodiversity and the health of riparian, floodplain and estuarine ecosystems (Ridoutt and Pfister 2010).

Where surface water and groundwater resources are consumed at a rate that exceeds the regular replacement, (and where non-renewable water resources are consumed, like fossil groundwater resources), this is a form of resource depletion that limits the availability of blue water for multiple priority purposes over the time.

3.4. Water footprint and Life Cycle Assessment: state of the art and perspectives

Unlike "water resource management", on which the scientific community has begun to map and analyse water availability, water use, and water pollution, the Life Cycle Assessment (LCA) community has been dealing with water use assessment only recently.

Although a wide range of impact assessment methods for LCA have been developed (Bayart et al 2010; Berger and Finkbeiner 2010), how to properly account for and assess water use is still a challenge in the LCA community (Berger and Finkbeiner 2010). To address water use in LCA, the UNEP SETAC Life Cycle Initiative has an on-going project and results are coming underway (Bayart et al 2010). In parallel, the International Organization for Standardization (ISO) is currently developing an international standard on water footprint (ISO 2011).

Nevertheless, even if carbon footprinting and water footprinting evoke the same principle of measurement referring to a distinct impact, the water footprint approach needs further development. Unlike carbon emissions, which affect the entire planet wherever the emission occurs, the water impact is linked to the location (watershed, river, lake, etc.) where the water is sourced. In this case the local availability of water reflected across the water stress factor is key issue and must be taken into account in the definition of water-related impact assessments. Furthermore, the impact of polluted water released in the environment obeys to complex mechanisms related to the amount of pollutants, molecule type, and receptor middle. Thus, the impact of releasing polluted water must be evaluated by taking into consideration the complexity of those phenomena and not exclusively through an angle of pollutants concentration.

3.5. Recommendations of the ENVIFOOD Protocol

The draft ENVIFOOD Protocol includes recommendations on water footprint at two different levels: inventory and impact assessment.

3.5.1. Inventory

Quality and quantity over space and time are crucial aspects to be considered when accounting for blue, green, and grey water use.

- Blue water withdrawal is a possible freshwater input flow of unit processes. It can be differentiated between irrigation water for farming, and process water for factories including conversion to potable water for human use.
- Green water is a controversial aspect in water accounting. Until it becomes blue water, green water neither contributes to environmental flows which are needed for the health of freshwater ecosystems, nor is accessible for other human uses. Indeed, green water is only one of the many resources acquired through land occupation: access to solar radiation, wind and soil are others (Ridoutt and Pfister 2010). As green water dominates in current global food production and will become more important if food security for a growing world population is to be met (Rockström et al 2009), it should be considered in the context of the land use impact category elementary flows.
- Grey water is the possible freshwater input flow to dilute a certain volume of polluted water e.g. in a waste water treatment plant. As the formula to calculate grey water is not scientifically-sound enough for product environmental assessments because of double counting to some respect with blue and green water, grey water is not to be included as such in life cycle inventories. Yet, whereas diluting waste water is allowed, the actual freshwater input flow to waste water treatment unit processes is to be accounted in life cycle inventories according to its own nature (i.e. grey water will result in either blue water or green water).

Note: At present, emission flows to freshwater are generally well-incorporated in those impact assessment methods used in LCA. In particular, those emission flows to freshwater are generally captured by impact categories such as eutrophication and freshwater eco-toxicity, applying complex fate and effect models.

3.5.2. Impact assessment

While the ISO standardization process for water footprint is on-going, impacts related to water use shall be assessed according to the method by Ridoutt and Pfister (2010). According to that method, water use is to be assessed using the regionalized water stress indexes developed by Pfister et al. 2009 as characterization factors.

3.6. Conclusion

The method by Pfister et al (2009) is preferred to the Swiss Ecological Scarcity Method by Frischknecht et al (2008), which was recommended by the ILCD Handbook (EC-JRC, 2011), because the first method produces more geographically-representative and accurate results than the latter.

Green water is recommended by Ridoutt and Pfister (2010) to be considered in the context of the land use impact category. Yet, scientific consensus on how to account for the land use impact due to green water use is still missing.

The draft ENVIFOOD Protocol is currently in public consultation. A testing phase has been launched in order to check how practical and sound are the recommendations of the draft ENVIFOOD Protocol.

For these reasons, the recommendations of the final Protocol may be different from those presented in this paper. For sure, the terms and definitions related to water footprint will be updated soon throughout the Protocol. The forthcoming ISO standard on water footprint is, in fact, introducing new terms (e.g. water scarcity footprint, water degradation footprint) and definitions. These are due to be endorsed in the short run to fulfil the Guiding Principles of the Food Round Table

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4. Mapping water withdrawal and consumption in Europe

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4.1. Introduction

An important step towards the sustainable management of water resources in Europe is related to understanding the spatial and temporal trends in water use. Although there have been significant improvements in water use efficiency over the last few decades, and per capita withdrawal is actually decreasing in several countries, there is still a need to assess and monitor the withdrawal and consumption of water resources.

In this chapter we describe a methodology being developed to map water withdrawals and consumption in Europe for the public, industrial, and agricultural sectors. So far, we only take into account the usage of “blue water”, that is we look only at withdrawal of water from freshwater sources, both from surface and groundwater bodies. As yet we do not take into account the additional use of “green water”, and consider “grey water” only as being water which is ‘consumed’, or used for the varying sectorial purposes, and therefore having a degraded quality, and therefore requiring treatment before being returned to the environment. We also assume that water is withdrawn within the same region that it is used, and therefore do not take into account the concept of virtual water.

Water withdrawals and consumption are mapped for the following sectors:

- Public
    - Domestic
- Industry
    - Manufacturing
    - Electricity Production
- Agriculture
    - Irrigation
    - Livestock

The main approach is to disaggregate actual water withdrawal statistics spatially by linking them to the appropriate land use classes and the relevant proxy data. The methodology differs, however, depending on the specific sector mapped. The model uses the reference year 2006, for which the most complete statistics are available, and attempts to forecast future trends to 2030. While industrial and energy withdrawals were assumed to remain constant throughout the year, we could compute monthly public water withdrawal maps, and daily agricultural withdrawal maps.

The diagram below (Figure 3) gives an overview of the terminology (based on the 3rd UN WWDR, 2009) and approach used to assess sectorial water flows. **Water withdrawal** is the gross amount of water extracted from any source in the natural environment for human purposes. If supply is unconstrained, water demand therefore equals withdrawal. **Water consumption** refers to the part of the processed water that is evaporated, transpired, incorporated into products or crops, consumed by humans or livestock, so heavily polluted that it is no longer suitable for use (what we consider to be 'grey water'), or otherwise removed from the immediate water environment. For the time being we map water withdrawals based on disaggregation of the available statistics, and water consumption as a sector-specific percentage of these total water withdrawals. At this stage of development of the model we assume that there are no limitations due to water availability, and that water consumption equals water withdrawal minus the leakages and water returned directly to the environment without having been used.

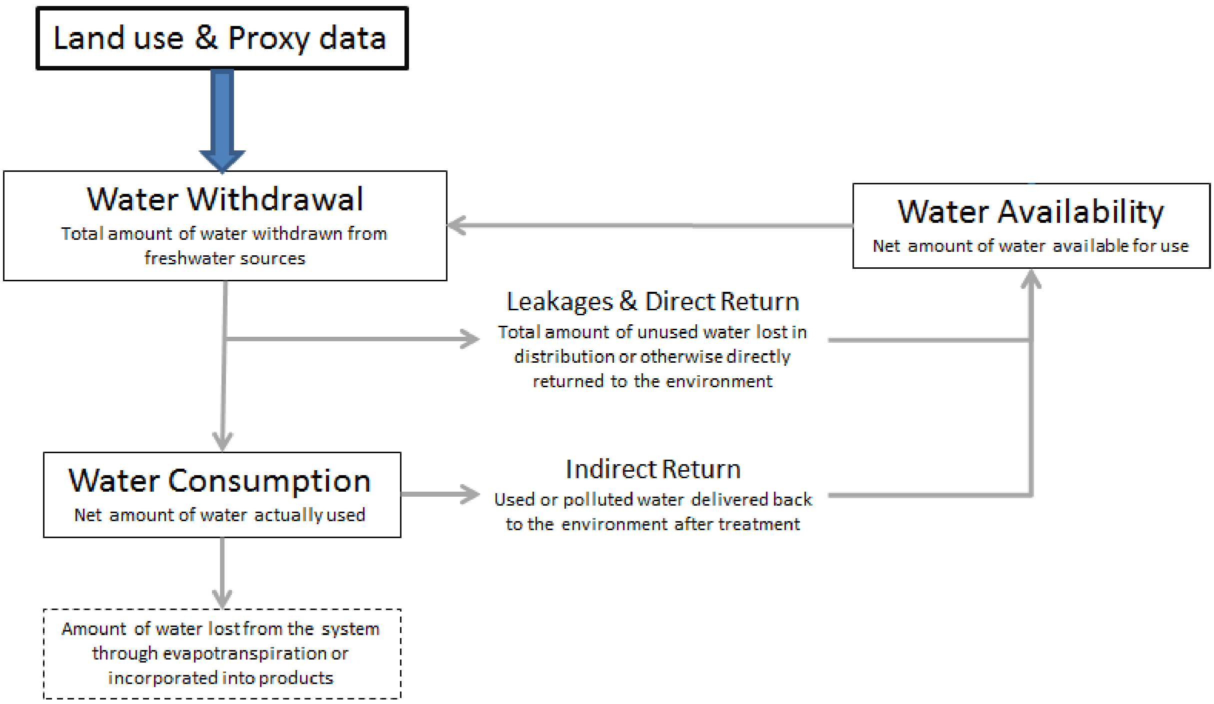

Figure 3. Diagram clarifying the adopted definitions, and showing the dynamics in the water accounts model under development.

4.2. Methodology

The modelling approach differs depending on the data availability and quality for each sector. For this reason, each sector is further described individually. Domestic, manufacturing, and irrigation water withdrawals are modelled with a direct linkage to the respective land use and proxy parameters. All 3 sectors were modelled by disaggregation of country-level water withdrawal data. Livestock withdrawals, however, were modelled in a bottom-up approach, without directly taking land use into account, and since there is no differentiable land use class for energy, an alternative methodology has also been used there.

4.2.1. Data availability

The OECD/EUROSTAT Joint Questionnaire on Inland Water provides country-level statistics on sectorial freshwater supply and abstraction (Nagy et al, 2007; EUROSTAT, 2011). The questionnaire covers the EU27 countries plus some data on Iceland, Norway, Switzerland, Croatia, the Former Yugoslav Republic of Macedonia, Turkey, Bosnia and Herzegovina, Serbia, and within the UK, Scotland, Northern Ireland, England and Wales. We used the annual average sectorial water withdrawals for the period 2005-7, which we assume to be representative for the year 2006, while excluding any extreme values. The year 2006 was chosen as the reference year since it was the year for which the most complete and consistent data was available. Where this dataset was incomplete or missing values we used the 2003-2007 average annual withdrawal from FAO – AQUASTAT (2011). Where there was still data missing we used the normalized European value (in a sector-specific way, i.e. for the domestic sector where data was missing we used the European average withdrawal per capita).

In order to supplement the country-level data provided by Eurostat, we collected regional statistics (at NUTS2, NUTS3 or basin-level) from each country’s National Statistical Institute. Since we do not, as yet, have a complete regional dataset for all EU27 countries, further analysis has been carried out on the country-level data. Where available, the country-level statistics were verified with the regional totals. Since detailed and verified NUTS3 level data was available for France (SOeS, 2012), however, this country was used as a test case to find and verify correlations between sectorial water withdrawals and proxy parameters where needed.

Figure 4 gives an overview of the data availability per country for the public, industrial, and energy sectors. All withdrawals have been normalized by the country area to allow comparison of values.

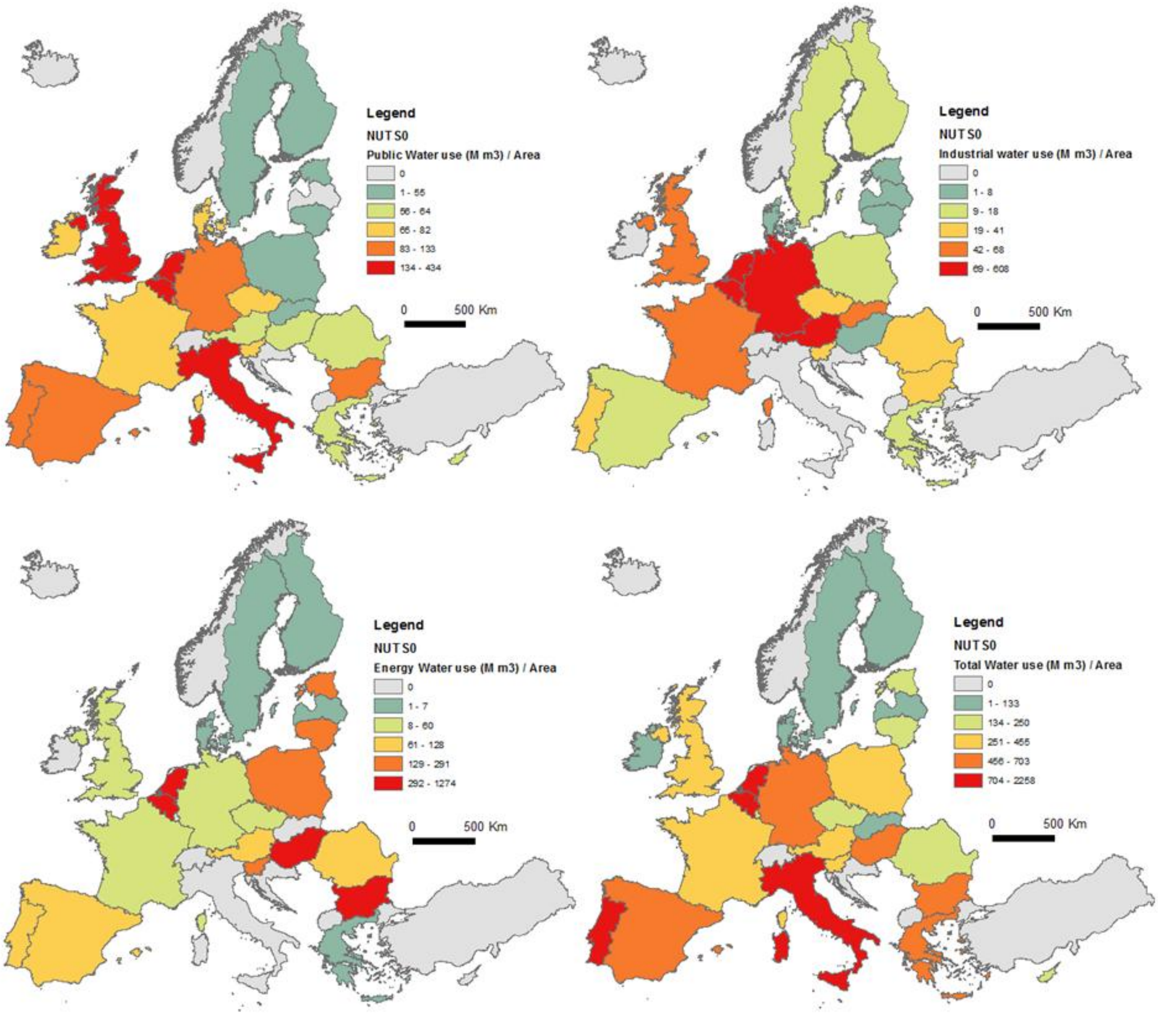

Figure 4. Representation of the country sectorial water withdrawal data available from EUROSTAT.

Figure 5 shows the relative proportions of water withdrawals attributed to the major water-using sectors. Notable is that public water withdrawals make up more than 60% of the total in Northern countries such as the UK, Luxemburg, and Denmark, while agricultural withdrawals make up the majority of the total withdrawal in the Mediterranean countries Portugal, Greece, and Spain. Energy withdrawals (used as cooling water in thermal power plants) are especially important in both the western and central/eastern European countries, whereas they account for only some 5% of withdrawals in Northern Europe, probably due to a focus on non-thermal energy sources in that region.

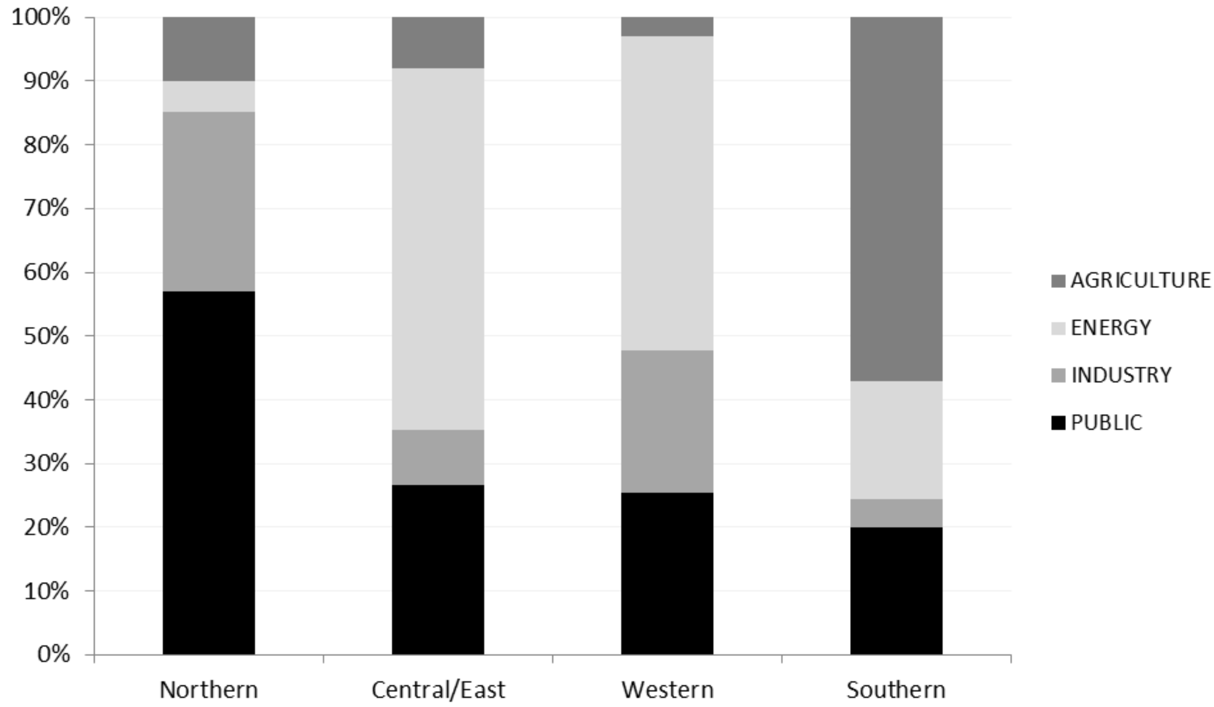

Figure 5. Country sectorial water withdrawals as a percentage of the total for 2006.

A large part of the spatial disaggregation of data is based on the assignment of withdrawal sectors to land use classes (Table 4). The linkage of sectorial water withdrawals, for which statistics are available, to a land use class proxy allows the prediction of temporal and spatial trends in water withdrawals based on projected land use/cover maps. These land use maps were computed for the period 2006 to 2030 using EUClueScanner (Lavalle, 2011). The Corine Land Cover map (EEA, 2009) for 2006 was used as the reference year, and a baseline scenario was used to model the 2030 land cover for the EU27 countries. The land use model exogenously takes into account the latest economic and social trends available through the integration of data from sector-specific models.

Table 4.The correspondence of the Corine Land use classes to their water use categories.

CLC CODE	CLC Category	Description	WATER USE CATEGORY
111, 112, 113	Urban fabric	Built-up	Public
141, 142	Artificial, non-agricultural vegetated areas	Green urban areas; Sport and leisure facilities	Public
121	Industrial, commercial and transport units	Industrial or commercial units	Industry
123, 124	Industrial, commercial and transport units	Port areas; Airports	Industry
131	Mine, dump and construction sites	Mineral extraction sites	Industry
212, 213	Arable land	Permanently irrigated land; Rice fields	Irrigation
221, 222, 223	Permanent crops	Vineyards; Fruit trees; Olive groves	Irrigation
231	Pastures	Pastures	Livestock
211	Arable land	Non-irrigated arable land	Livestock

4.2.2. Public water withdrawal

EUROSTAT provides data on "Public water supply", which is defined in the metadata (Nagy et al., Data Collection Manual) as: "water supplied by economic units engaged in collection, purification and distribution of water". If actual residential (household) water use is to be differentiated, then the category has to be further defined. Indeed, on average, some 18% of public water goes to uses in industry, and 4% for use in agriculture. For the time being, however, the public water withdrawal is assumed to be the total water withdrawn in urban areas. This sector is therefore attributed to the urban land use classes (as in Table 4). Although some commercial/service areas may be included in the land use class, the use is assumed to be mostly domestic. Since tourism has a large impact in some of the most water scarce areas, we have taken the influence of additional tourist presence into account.

Public water withdrawals were assumed to be those made by residents and tourists in urban areas, so that the spatial distribution of the withdrawals was assumed to be directly related to the combined population and tourist density. Indeed, an initial analysis of possible contributing factors to public withdrawals at both country and regional level gave high R^2 correlations for public water withdrawal with total population (0.92) and number of nights spent by non-residents (0.82), which is a good indicator for tourism.

Since tourists tend to have a higher water-use than residents, the tourist density maps were given a greater weight when assigning the water withdrawals – we used a ratio of 300/160 (Gössling et al 2012). Population density maps were available for 2006 at 100m resolution (Batista e Silva et al., in press). Tourist density maps were created using the regional number of nights spent by non-residents, and the number of bedplaces (EUROSTAT). The monthly distribution of tourism was calculated using the country-level percentage of nights spent per month (EUROSTAT). The total number of tourists per month at regional level for each country was disaggregated to the appropriate Corine Land Cover classes (urban fabric, green urban areas, and sport and leisure facilities). The number of nights spent abroad by residents per quarter year was also calculated and subtracted from the population density maps.

The final map, to which the country-level public water withdrawal statistics were disaggregated, was then calculated as:

*Weighted number of "users" per pixel = Population density map 2006 – outbound tourism map (quarterly) + 300/160*inbound tourism density map (monthly)*

A population density map for 2030 was computed using population projections from EUROSTAT, and projected land use maps for 2030 from the EUClueScanner model. The tourism density was increased according to the tourism growth forecasts (at country level) from the Europe vision 2020 report (WTO, 2000). In this, we assume the growth rate for the period 2006-2030 to be that predicted for 2010-2020 in the report.

The temporal (monthly) and spatial distribution of tourism was kept constant. The public water withdrawal per capita was also kept constant, so that the total public water withdrawals for 2030 directly reflect the projected population and tourism densities.

Figure 6 shows the public water withdrawals for 2006. Especially high withdrawals are seen in the most densely populated areas, such as Belgium, the Netherlands, and Northern Italy. There are also high withdrawals along the Mediterranean coastlines, due to the high tourism density in those areas. Major cities such as London, Paris, and Madrid also show very high withdrawals.

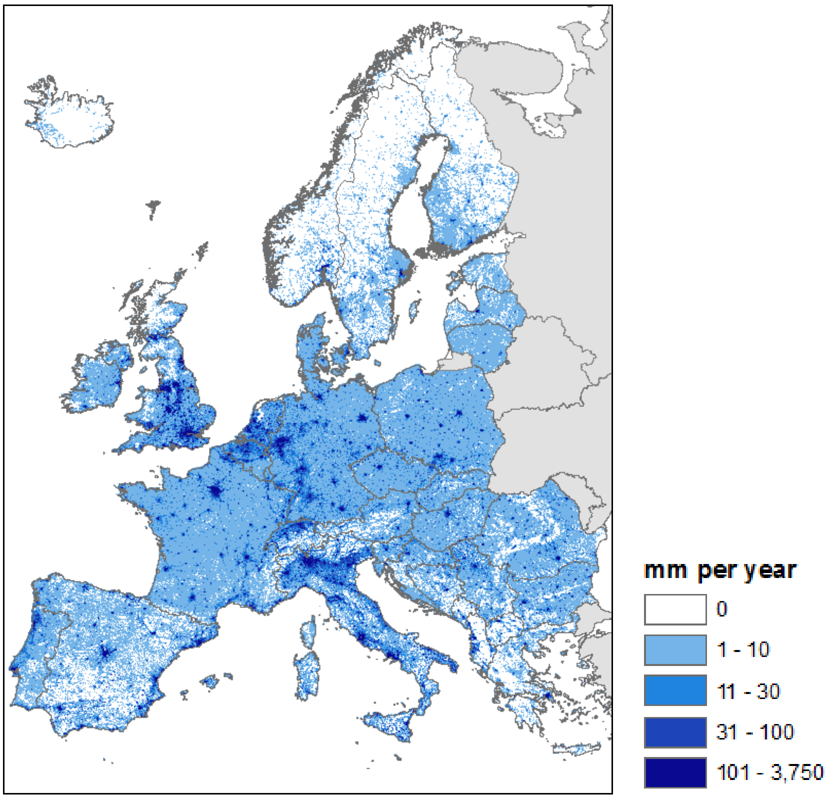

Figure 6. Public water withdrawal at 5km x 5km resolution for 2006, shown in millimetres per annum.

Figure 7 shows the change in water withdrawals between 2006, our reference year, and the modelled withdrawals for 2030. Most countries show a moderate increase in withdrawals, most notably in Iceland, the UK, Ireland, Norway, and Serbia. Latvia, Lithuania and Bulgaria actually show decreasing trends in water withdrawals, linked to the forecasted decreasing trend in population growth for those countries. Changes range from a decrease in withdrawals of 4% in Latvia, to increases of up to 37 and 53% in Luxembourg and Ireland respectively.

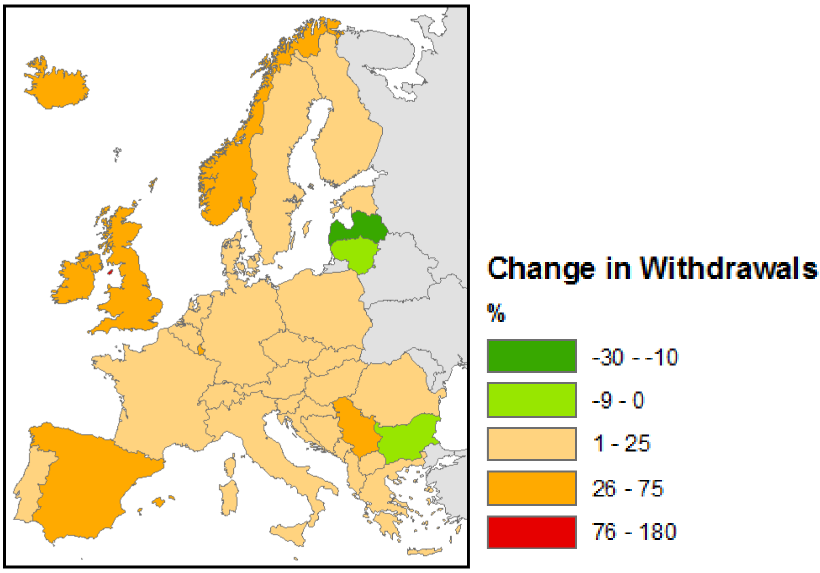

Figure 7. Change in sectorial water withdrawals for the period 2006 – 2030 for the public sector.

4.2.3. Industrial water withdrawal (manufacturing)

All water used for manufacturing purposes was assumed to be withdrawn within industrial areas. Water withdrawals at country level for use in the manufacturing industry (EUROSTAT) were disaggregated directly to the relevant industrial land use classes. As a base map for 2006 we used the refined Corine land cover dataset available at the JRC (Batista et al 2011). Within the assorted classes related to industry, class 121, industrial or commercial units, and class 131, mineral extraction sites are the most represented classes, accounting for 77% of 'industrial' pixels (Table 5). Withdrawals were assigned to the classes 121, 123, 124, 131, and 133. Classes 122, road and rail networks, 132, dump sites were assumed not to have any significant withdrawals associated, and class 133, construction sites, was not taken into account because we see it as a transitional class.

Table 5. Industrial Corine land cover categories and their respective representation for the 2006 map

CLC CODE	**Description**	Number of pixels	Share of total (%)	WATER USE CATEGORY
121	**Industrial or commercial units**	3353776	63.7	Industry
122	*Road and rail networks and associated land*	353714	6.7	-
123	Port areas	134690	2.6	Industry
124	Airports	329781	6.3	Industry
131	**Mineral extraction sites**	701355	13.3	Industry
132	*Dump sites*	92377	1.8	-
133	*Construction sites*	297412	5.7	-

In order to calculate water withdrawals for 2030, we first computed a "change factor" per country. We assumed the driving force for water withdrawals in time to be the Gross Value Added (GVA) for industry; the R2 correlation between industrial withdrawals and GVA for industry was 0.74. In using this parameter we assume a direct linear relationship: the higher the production level or industrial output, the higher will be the water abstraction, and consequently consumption, for industry.

Looking at historical data (1990-2010), there is a trend towards more efficient water use in industry due to technological improvements, and therefore, on average, a decreasing water use per unit in Europe. The average (decreasing) trend in total industrial water withdrawals for 2000-2006 for DE, ES, FR & UK, was taken as an “efficiency factor” (-1.33 %/year) to correct for this observation. This factor was subtracted from the (increasing) trends given by the GVA (%increase/year, for EU25, from GEM-E3) for each country. The EU average trend in GVA was used to fill in for any missing values.

Country change factor (%/yr) = Δ GVA for industry (%/yr) – efficiency factor (%/yr)

Each country’s total water withdrawal for 2006 was first multiplied by the country-specific change factor (x24 years) to give the 2030 values. These values were then disaggregated to the new industrial land for 2030 – computed by combining the modelled industrial area for 2030 (using EUClueScanner, Lavalle et al 2011) with the infrastructure which is not modelled from the 2006 map (ie. the mineral extraction sites, port areas and airports).

Figure 8 shows the resulting map of industrial water withdrawals for the reference year 2006. Again, the major towns and most densely populated areas have the highest withdrawals. Especially Benelux, Germany and Northern Italy stand out.

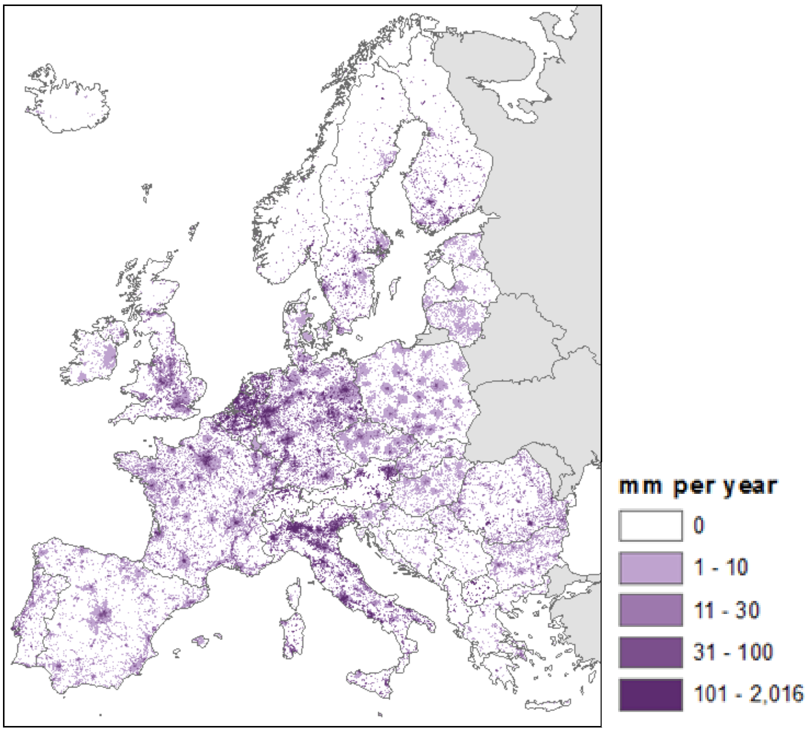

Figure 8. Industrial Water withdrawal at 5km x 5km resolution for 2006, shown in millimetres per annum.

Figure 9 shows the change in industrial water withdrawals per country for the period 2006 to 2030. Withdrawals are expected to increase in all countries; the high percentage changes reflect the highly optimistic forecasted GVA for industry.

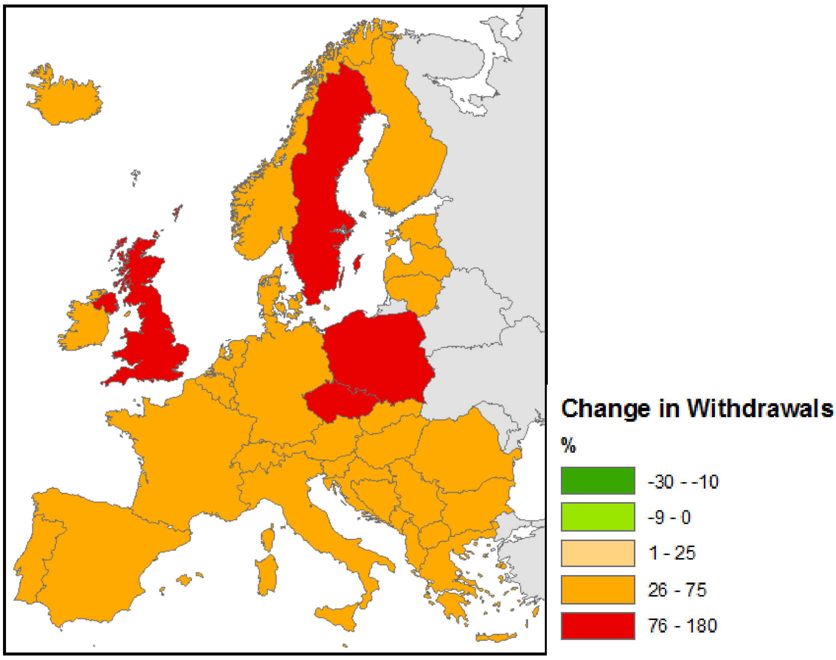

Figure 9. Change in sectorial water withdrawals for the period 2006 – 2030 for the industrial sector.

4.2.4. Water withdrawal for electricity production

Statistics are available on water withdrawals for the energy sector at country level (EUROSTAT). Since energy water withdrawals were assumed to be completely used for cooling during electricity production we attributed this withdrawal to thermal power stations, assuming the amount of cooling water for alternative methods to be minimal. The country-level water withdrawals for use in the energy sector were therefore disaggregated directly to the thermal power stations as extracted from the European Pollutant Release and Transfer Register data base, E-PRTR (thermal stations >50MB and related facilities). This dataset was seen as a good proxy since there is as yet no differentiated land use class for energy production, and it offers a reasonably complete localization of the major power plants, which should account for the largest part of these withdrawals.

In the forecasting of energy withdrawals, for the time being the location of thermal stations were assumed to be static and the water demand is assumed to be driven by energy consumption (as forecasted by the POLES energy model). There is a strong correlation (an R2 value of 0.88) between energy consumption and the volume of water withdrawn for electricity production.

The average trend in water use 2000-2006 for DE, ES, FR, UK & PL was taken as an “efficiency factor” (-1.69 %/year), which was subtracted from the trends given by energy consumption (POLES, 2012; as

% increase/year) for each country. The EU average trend in energy consumption was used to fill in for any missing values.

Country change factor (%/yr) = Δ energy consumption (%/yr) – efficiency factor (%/yr)

The 2006 energy withdrawals map was multiplied directly by this change factor (x24 years) to compute the 2030 energy water withdrawals. Figure 10 shows the resulting map of energy water withdrawals for 2006.

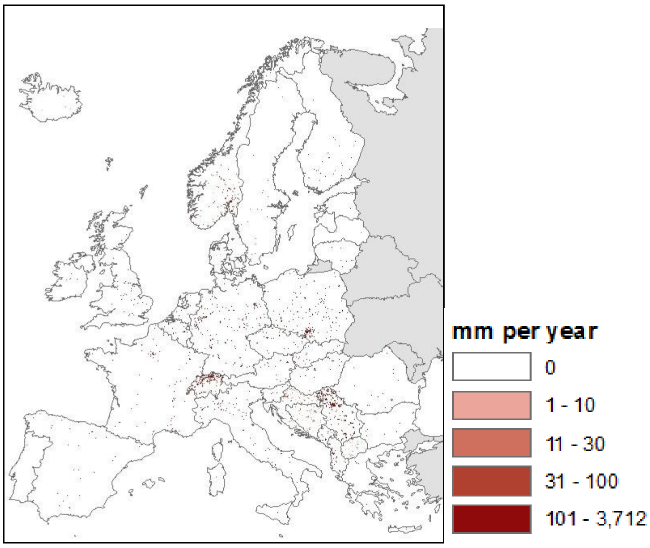

Figure 10 Water withdrawals for electricity production at 5 km resolution, in M m^3.

Figure 11 shows the change in water withdrawals for electricity production between 2006 and 2030. Large increases are seen in the Eastern European countries especially, whereas most Scandinavian countries such decreasing trends, probably reflecting a move away from conventional thermal power plants to more alternative and renewable sources.

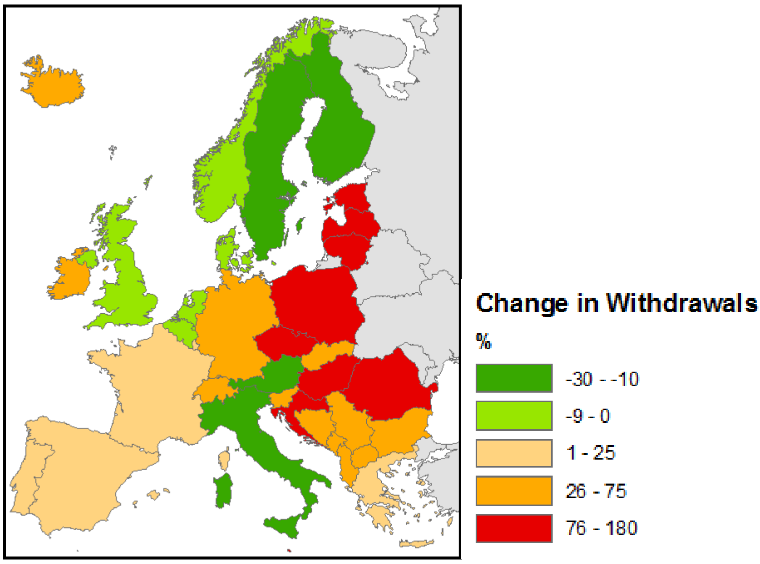

Figure 11. Change in sectorial water withdrawals for the period 2006 – 2030 for the energy sector.

4.2.5. Livestock water withdrawal

Daily maps of livestock water withdrawals were calculated based on the specific water requirements and spatial distribution of each type of livestock. The livestock water requirement map series is based upon the Food and Agriculture Organization of the United Nations (FAO) livestock density maps (FAO, 2012) for 2005 (described in Robinson et al 2007). Actual livestock figures for 2005 as given by the Complete and Consistent database (Witzke et al, 2011) made available through the Common Agricultural Policy Regionalized Impact Modelling System (CAPRI, 2012) are used to refine the livestock density maps. A series of water requirements per livestock type data is taken from the literature in order to compute water requirements per livestock type on a daily basis. No projection of this map has been made as yet, but would be possible based on the output of CAPRI for the year 2030. Figure 12 shows the resulting map of livestock water withdrawals for 2006. The highest withdrawals are in Denmark, Belgium, the Netherlands, Northern Italy, and the northeast of Spain.

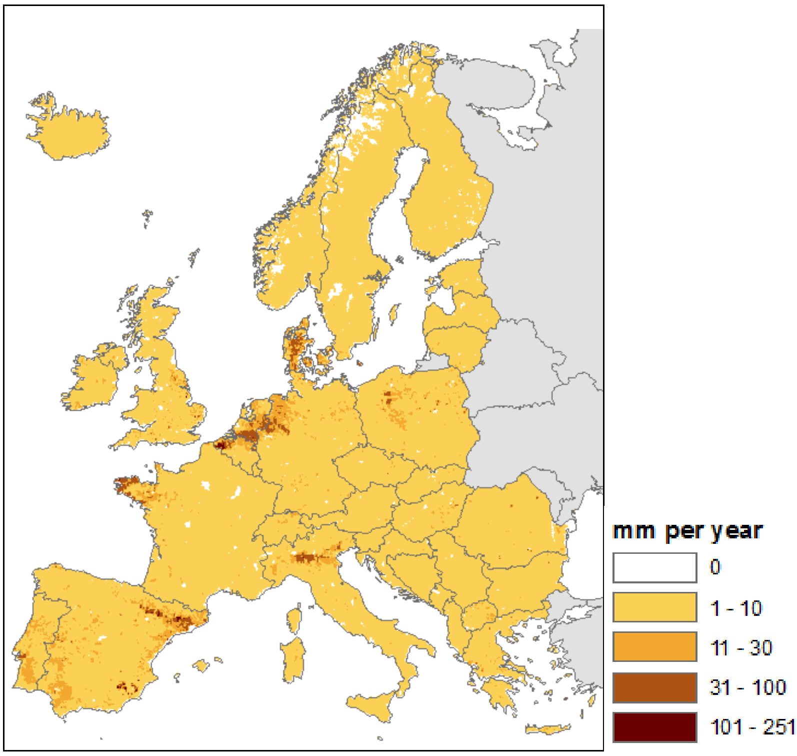

Figure 12. Annual average livestock water withdrawals.

4.2.6. Irrigation water withdrawal

Irrigation requirements were estimated based on Wriedt et al. 2008. The generation of the irrigation map followed a two-step procedure. First, irrigated area was distributed to crop categories at sub-regional level based on statistical information and distribution rules. Next, the regional information was disaggregated to a high resolution dataset based on the crop distribution and a global irrigation dataset (Siebert et al., 2005). Based on crop growth, soil water and the EPIC nutrient model, irrigation water requirements were estimated on a daily basis at a 10 x 10 km grid scale assuming unlimited irrigation. For 2030, the irrigation water withdrawal map was updated using the projected land use map computed by EUClueScanner.

Figure 13 shows the irrigation water withdrawals for 2006. The highest withdrawals are in southern Europe, as well as Denmark, Belgium, the Netherlands, and some parts of Eastern Europe.

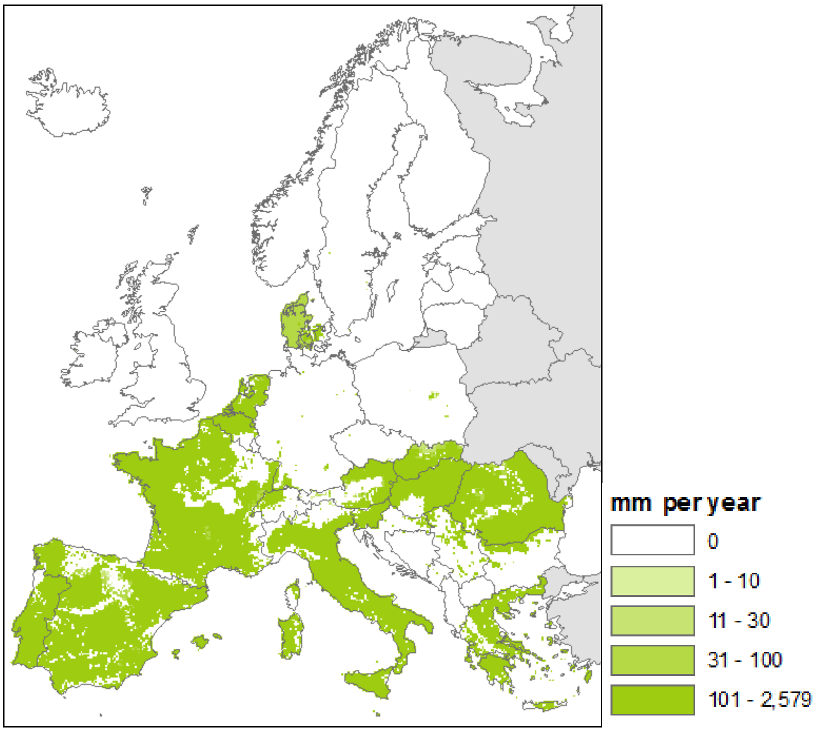

Figure 13. Annual average irrigation water withdrawals.

4.2.7. Sectorial water consumption

Of the total water withdrawn for each sector, a portion is 'consumed', that is to say removed from the direct environment through evapotranspiration, conversion into a product or otherwise. The remaining water is returned to the environment either directly, or after use, so having an altered quality level. For each sector we assumed a percentage of the total withdrawals to be fully consumed. The table 6 shows these figures, originating from available literature (UN WWDR, 2009) and expert opinion. These average values were then used to compute maps of water consumption (by multiplying this sector-specific value with the water withdrawal maps).

Table 6.Actual estimated sectorial consumption of water.

Water withdrawal sector	Water consumption from literature (%)	Assumed water consumption (%)
Public	10-20	*20.0*
Industry	5-10	*15.0*
Energy	1-2	*2.5*
Irrigation	50-60 (surface); 90 (localised)	*75.0*
Livestock	-	*15.0*

4.2.8. Summary of the methodologies adopted for estimating water withdrawals

Table 7 gives an overview of the methodologies and data involved in the water use module to date. It is possible to map both water withdrawals and water consumption (calculated as a percentage of the withdrawals, taken from literature, which varies across the sectors) for 2006 and 2030.

Table 7. Summary of the methodologies and data used to model the water withdrawals

Sector	Method	Water use	2006 demand proxy	Time series	*2030 demand proxy*
Public	Disaggregation	EUROSTAT	Population density Tourism density	Monthly	*Population (GEM-E3)* *Tourism growth rates (WTO)*
Industry	Disaggregation	EUROSTAT	GVA industry, industrial land use	Yearly	*GVA industry (GEM-E3)* *Industrial land use (EUClueScanner)*
Energy	Disaggregation	EUROSTAT	Thermal power stations EPRTR	Yearly	*Energy consumption (POLES)*
Livestock	Aggregation	Specific water requirements	Livestock density (FAO/CAPRI)	Daily	*CAPRI forecasts*
Irrigation	EPIC-EAGLE model	Specific crop irrigation requirements	Irrigated area map of Europe	Daily	*CAPRI forecasts*

4.3. Discussion

As mentioned in the introduction, we attempt to map only the direct freshwater withdrawals (the so-called 'blue water'). The module is currently being further developed and we are looking at expanding the approach to quantify water exploitation and better map the consumed water, especially the part which is in fact 'grey water', and which can be returned to the environment after treatment. Several areas of improvement are mentioned in the following paragraphs.

Water abstractions have been allocated to the same location where the water is actually used. In fact, water may be withdrawn a substantial distance from its destination, especially in the case of public water withdrawals. An idea of the point locations of withdrawals and returns would be a great improvement.

We should also be able to differentiate withdrawals into those originating from surface and groundwater sources. Existing data (EUROSTAT, Table 8) does make this differentiation, which differ significantly between countries and sectors. Where water is actually withdrawn is highly dependent on the amount and location of exploitable water resources and also on the technologies employed and infrastructure used to distribute them.

The availability of water will, in turn, affect the amount actually withdrawn, especially where there are water shortages, or water sources are not easily exploitable. It would be useful in the future to include a parameter to vary withdrawals with water price, which should be related to availability.

The losses due to leakages in the distribution network need to be taken into account. Bulgaria (24%), Greece (16%), Malta (19%), and the UK (13%), for example, all show losses much higher than the average of 7.7%, which in itself is already a significant loss.

Table 8. Estimated European average percentages of water withdrawals by source per sector

Water use sector	Surface water (%)	Groundwater (%)
Public	40	60
Industry	72	28
Energy	93	7
Agriculture	60	40
Total	69	31

Although for the time being we assume the whole population to be connected to the public water supply, the average EU-27 connectivity is only 91% for 2006, and countries such as Romania and Estonia have connectivities as low as 49% and 73% respectively. This means that there is a large amount of water being withdrawn directly from a source or through boreholes, and that the public withdrawals registered should be attributed to a smaller percentage of the population.

A differentiation should also be made of the type of cooling system used in thermal power stations, since this greatly affects the amount of water consumed and returned. With once-through systems, for example, almost all water is returned, but at a higher temperature, in cooling towers there is more loss by evaporation but a lower temperature difference after use

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5. Consumer's behaviour and water footprint: the relevance of water awareness campaign

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5.1. Water footprint and lifestyles

It is widely documented that humanity is now consuming more resources than our planet is able to produce and regenerate. Whilst human consumption is increasing, water availability is becoming more variable due to climate change and is forecast to decrease in many regions in the future (IPCC, 2001; Inman and Jeffrey, 2006). Among the numerous indicators and methodologies for sustainability assessment, Ecological footprint (EF) is one of the indicators developed to track and to communicate this gap between need and availability of resources (Wackernagel and Rees, 1996; WWF, 2010). Water footprint, as for the methodology of the Water footprint network, applies a similar concept of EF (Hoekstra and Mekonnen, 2011) focusing only on water resources. It accounts for the use of rainwater (green WF) and ground and surface water (blue WF) and volumes of water polluted (grey WF), giving emphasis not only to water consumption but also to water quality and the need of a more efficient direct and indirect (e.g. though food consumption and production) use of this life-sustaining resource. Therefore, the activities of education, information and the awareness campaign should aim at covering both the direct and indirect consumption.

Amongst different drivers of water uses, domestic use, especially in cities is increasingly expanding and the growing demand for water increases the strain on local supply sources. The traditional response to this demand is to increase water availability by developing new surface and groundwater abstractions, constructing or expanding storage reservoirs and transferring bulk supplies from regions where water is less scarce. However, this approach is increasingly being questioned as natural limitations, environmental concerns and the impacts of climate change reduce the availability of existing resources and prevent the development of new ones to match the demand of growing populations

Rather than increasing supply to meet demand, an alternative way of addressing water scarcity is to manage consumption. This approach follows the guidance principles of the most recent European strategies, which put reduction as the first priority in environmental policies (e.g. Waste Framework Directive, 2008/98/EC). Indeed the increasingly complex challenges of making water management more sustainable require a critical and detailed understanding of the social organization of water

(Moss et al, 2009). As any sustainability policy or action plan, also the sustainable use of water, apart from a technical approach, needs a socio economic approach to understand better the interactions between different actors (users, water companies, public institutions) in order to establish the adequate policy instruments (Lallana et al, 2001; McKay 2005).

Common-pool resources (CPRs or simply ‘commons’) are natural or man-made resources shared among different users. This produces competition that often (although not necessarily) leads to their degradation or even to destruction. Many natural resources are CPR and water is one of them.

As pointed out by Ison and colleagues (2007), giving economic value to common resources is not sufficient to prevent their exploitation: “rational economic behaviour was shown to cause the destruction of a common pool resource such an open access grazing land” (Ison et al 2007) and market strategies failed in facing global environmental problems like climate change (Stern 2006).

Besides, with specific reference to water resource, there is a growing debate about privatization and marketization of the supply management of the resource, opposite to the anti-privatization campaigns claiming the “human right to water”.

However we should not forget that the main driving force in natural resource use is consume, i.e. the demand of natural resources arising from the current consumption patterns of citizens (Baiocchi et al, 2010). Therefore as mentioned before, another aspect to be considered in addressing the problem of resource scarcity is obviously the need to rethink lifestyles and consumption behaviour in order to make a more rational end efficient use of resources (Scott, 2009, European Commission, 2011).

Research about CPRs management (North 2005; Ostrom 2006; Bravo 2011) considers that people can hold beliefs and mental models of the world, which influence their choices. Beliefs and mental models are formed and updated using two sources of information: the feedback received from the external environment and the shared belief systems. Therefore a change in human behaviour about water use is strongly needed.

5.1.1. European and water-related impacts

According to a recent European survey (Eurobarometer, 2012), Europeans feel less informed about problems facing groundwater, lakes, rivers and coastal waters in their country than they did in 2009. A majority (69%) believe that water quality and quantity problems are serious; 44% of respondents believe that the quality of surface and groundwater has deteriorated over the past ten years; 85% consider that household water consumption may impact status of quality and quantity of water; 84% show concern for chemical-related water pollution, 46% for scarcity-related impacts and only 30% for hydrological change-related impacts. Additionally, two-thirds of Europeans believe that more information about the environmental consequences of water use is the most effective way of tackling water problems.

5.2. Lifestyles and consumption awareness campaigns

There are two main types of actions that can be made by individuals in order to reduce the environmental impact of their consumption: on the one hand, the reduction of consumption itself, in absolute terms, e.g. avoiding activities that imply unnecessary consumptions; on the other hand, buying more sustainable and eco-innovative products. The first option implies a change in behaviour and lifestyle, arising from a higher awareness and knowledge of the impacts that different consumption choices can generate. The second option usually involves the need to be informed about the criteria consumption and willingness to support an initial economic cost (due, for example the purchase of new products and technologies - such as plants for the production of energy from renewable sources or car power - or at least products cost more than traditional ones), but often provides savings in the medium to long term. In the case of water footprint, i.e. of the awareness about the amount of water embodied in the products/services that are bought or used, the information could be effectively delivered through labels. A “water footprint label”, which reports the embodied water in a way similar to carbon footprint labels, could help consumers in making more conscious consumption choices. Similarly to what happens in the industrial sector, even sociological research has dealt to identify what are the factors that may affect consumer choices and the factors affecting the ability or desire to change their lifestyle to make it more sustainable. Also in this case it is possible to identify external factors, related to the society as a whole, and internal, relating to the personality and to the values of the individual (Jansson et al 2010).

Stern (2000) has identified four categories of drivers for sustainable consumption behaviours:

<u>Characteristics of the society context</u>: it is an external factor, which influences the other three (internal) factors related to the individual itself

<u>Attitudinal factors</u>: include values, beliefs and personal rules (such as moral norms that the individual considers to adopt) that affect the individual's general predisposition to behaviours and lifestyles more or less sustainable.

<u>Habits</u>: habits influence the intentions and willingness to change behaviour and to transform attitudinal factors into actual behaviour. Consequently, the more the habits of an individual are close to or compatible with sustainable behaviour, the greater the possibility of a change in this direction.

<u>Personal skills</u>: they include the knowledge and skills needed to adopt sustainable lifestyles (e.g., knowledge of the different viable options and methods to achieve them), the availability of time to

realize this desire for action, in addition to more general capacities and knowledge such as education, disposable income, social status and power.

Starting from the Sustainable development summit of Johannesburg (in 2002) and coming to the present days (through the recent Rio+20 summit), there is an emerging demand of concrete actions (Schrader and Thögersen, 2011) and stronger implementation of the existing policies and international resolutions to meet the targets for sustainable development set in the last decades (AA.VV.,2011). This shift from awareness rising to a call to action requires proper education to citizens, policy makers and enterprises about sustainable consumption and production and sustainable lifestyles.

UNEP (2010) states that “Education for Sustainable Consumption (ESC) is essential to empower individuals and social groups with appropriate information on the impacts of their daily choices as consumers, as well as for workable solutions and alternatives”. Awareness raising campaigns are widely diffused in sustainability actions worldwide. Nevertheless their tangible outcomes in terms of environmental benefits from behaviour changes could be difficult to be assessed, mainly because their effects could be seen only in the long term and partly because they are not directly focused on producing a real effective change but rather to diffuse knowledge about the topic. To fulfil the need of a quick and effective response to global environmental problems, interventions are needed not just to inform and raise awareness about the environmental consequences of consumption behaviours but to generate concrete actions that will result in more sustainable living and consumption styles.

5.3. The Italian context: reason for a case study on sustainable lifestyles’ education and water footprint reduction campaigns

Water consumption in Italy (considering both the amount withdrawn and the amount effectively distributed) is higher than in other European countries. In addition, Italy has the one of the highest consumption of bottled water in the world, which was about 194 litres per person per year in 2008, corresponding to more than double the average in Europe and the United States. The bottling and distribution of bottled water lead to the production, transport and disposal of 5 billion plastic bottles (over 77% of the water is bottled and sold in plastic bottles).

Considering the per capita consumption in the 27 European Union countries for the period 1996-2007, Italy shows values higher than average European (85 m^3 per capita per year) and relatively stable over time (Figure 14, elaborated from ISTAT, 2012). In particular, comparing the phenomenon in the period considered in some large countries in the EU, the average consumption in Italy is lower than the Spain (100 m^3) and the United Kingdom (110 m^3), and is higher than in the Netherlands (73 m^3) and in Germany (57 m^3) (ISTAT, 2011).

This high amount of water used consists totally of high quality water (drinking water), because in Italy systems for the collection and reuse of grey water are almost non-existent and therefore drinking water is provided for any use of water (including, for instance, to flush the toilets and to wash cars).

However, the diffidence in drinking tap water appears elevated among people: in 2011, in 30.0% of households one or more components declare not to be trusted to drink it (ISTAT, 2011). In 2010, 61.8% of Italian households have purchased mineral water and this percentage is only slightly lower than in previous years.

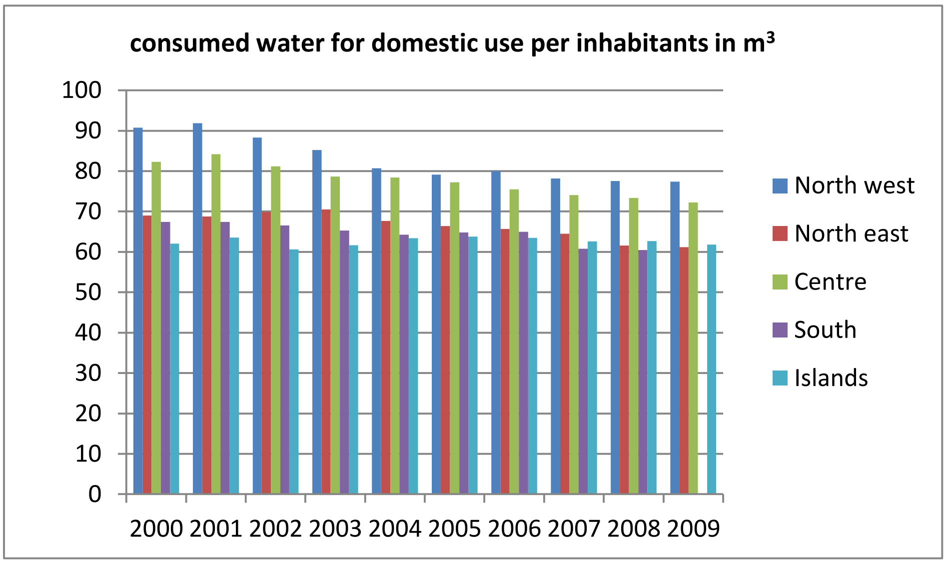

Figure 14. Annual average consumption of water in Italy for domestic use 2000-2009

Diffidence in drinking tap water arises partly from wrong information (e.g. most of people are not aware that the water from the aqueduct is strictly and more frequently tested by public health agencies than bottled water) and partly from the fact that the taste of tap water in houses sometimes is not very good, due to the fact that the last part of the water pipes (e.g. the portion from the public grid to the single apartments) can be very old and poorly maintained, i.e. can release particles that affect the quality of the water pouring from the taps into the houses. For this reason, some families prefer to take water from public water houses, where the quality of water is frequently tested directly at the tap.

Indeed the reasons of the high level of consumption lie both in the infrastructure system and in the consumers' habits: on the one hand, citizens need to understand the importance of saving water and to be more aware of the environmental impacts related to the consumption of bottled water;

on the other hand, in some cases, grids and pipes need to be more efficiently maintained, to ensure higher quality of water not only at the aqueduct level but also at the final tap.

Therefore, what is needed with respect to water use in terms of sustainability education is:

1. to increase the awareness of the overall consumption of water, considering not only the direct consumption but also the embodied water due to product and goods (as in water footprint)

2. to increase awareness of environmental impacts associated to consumption choices (e.g. the use of bottled vs. tap water)

The present chapter focuses on this last aspect of awareness rising and presents a case study of a sustainability education campaign about the value of water as a common good. Aim of the study is to investigate the most relevant issues that influence water consumption habits and to verify the effectiveness of awareness raising campaigns in term of changes in citizens' behaviour.

The research is structured upon two main areas: the use of participatory methodologies (e.g. survey to citizens and workshops) and monitoring methods to track changes in consumption patterns (e.g. measure of the quantity of water distributed by public distributors of micro filtrated water in substitution of bottled water before and after the campaign). This method enable researcher and policy maker to quantify the environmental benefit gained through the awareness campaign and to identify consumer' patterns (and reasons behind them) among the citizens.

5.4. Case study description: Sesto San Giovanni, a municipality in Northern Italy

The present case study has been developed in partnership with an ONG (Comitato mondiale contratto mondiale sull'acqua - Committee for the World Water Contract) and in close collaboration with a municipality: Sesto San Giovanni. This is one of the municipalities of the metropolitan area of Milan belt to use more water in proportion to its surface. According to data collected by the operator Amiacque, consumption per capita per day in Sesto San Giovanni are around 337 litres, while the cubic meters of water are paid annually 9,963,915 for a resident population of 80,886 people.

Although there have been problems pollution of groundwater in the past, due mainly to the presence of industrial areas, in the recent years the water quality in Sesto is greatly improved. The risk of pollution to the water for drinking purposes have been eliminated and the quality is considered "fair" in accordance with legal parameters defined by Legislative Decree no. 31/2001 on the implementation of the European Directive 98/83/EC.

For these reasons and in order to strengthen the diffusion of sustainable consumption patterns, the Italian Committee for the World Water Contract with the Municipality of Sesto and other organizations and associations launched a project to inform and to raise awareness with respect to consumption of water and relative changes in behaviour, seeking greater involvement of citizens and other stakeholders (Storni et al 2012).

The project aimed primarily to verify the representativeness of national statistics about water consumption through sample surveys in a specific area and at the same time to stimulate the area a new "culture of responsibility" with respect to the use of water as a common public good, through the direct involvement of local institutions and individuals that use the water service. The project was also aimed at promoting tap water through the creation and dissemination of an awareness campaign, aimed at reducing daily use and at promoting one of the public places related to drinking water most frequented by citizens: the Public Water Houses.

5.4.1. Survey methodology

To obtain the data needed to detect the perceptions and behaviour semi-structured questionnaires were used, with questions about the habits of water use by citizens and their perceptions about the quality of tap water, the use of bottled water and of Public Water House services.

The questionnaires were designed in two different versions and subjected to two types of respondents: residents of apartment buildings involved in the project and visitors of public parks and Water Houses. The two questionnaires differed in the number of questions to respondents: 27 for apartments' residents and 18 for those who frequent the parks and Water Houses. The questions included in the questionnaire for those who frequent the parks were designed only to detect the daily consumption of water, the cost and type of water consumed. This choice was made to facilitate the compilation reducing the number of questions, based on the fact that the people in parks and at the house of water had less time to respond.

The first part of both surveys included some questions about the demographic characteristics of respondents in order to better classify the types of users of the services that have been analysed. The second part aimed at collecting information on water consumption habits of citizens and the use of tap water and of Water Houses, asking also to provide any useful suggestions and impressions for the improvement of the service.

5.4.2. Main findings from the surveys

Condominiums questionnaires

150 questionnaires were distributed in three condominiums in Sesto San Giovanni and 91 were completed and returned. The composition of the family with a higher representation was given by the couple with child(ren) (n =36) and couples without child(ren) (n = 23). Regarding gender, 54% of respondents were men. 48% of respondents had an average level of education with college degree, while 20% have middle school and 19% are graduated. Regarding the profession about 30%

of respondents were retired, followed by employees and students. This confirms the population estimates at Sesto San Giovanni municipality with much higher percentages of seniors than young people. 36% of the 91 respondents said they consume 30-60 litres of water per day and 35% reported consumption about 1 to 30 litres of water a day. Only 4% said they used over 150 litres a day. This figure shows how people did not realize the amount of water they use in their daily habits, such as that just to take a bath in the tub requires about 100 litres of water.

As for the cost of water services, only 7 out of 91 respondents said they know how much they pay for the bill water. As a first observation it is noted that, even today, many people do not actually know what it spends and how much water costs to the family.

In Italy the water costs 1.25 euros per cubic meter, while France has already arrived at 2 euros and Berlin even pay 4 euros per cubic meter (Federconsumatori, 2012). Perhaps in Italy, as the costs it is not too high; there is a lack of perception of the value of the water.

52% of respondents reported drinking bottled water purchased at the supermarket, while a 47% said they always or often drink tap water. Among those who consume bottled water, 40% reported drinking 4 to 6 bottles of 1.5 litres per week and for the question "how often you drink tap water" 29% of respondents answered "never". The main reason was because "is not safe" (61%). Bottled water has become a habit for many people because it is perceived as safer, healthier and of better quality due to advertising (Ferrier, 2001; Kunze, 2008, Botto et al, 2011).

.In terms of savings or environmental protection 47 of 91 respondents said they had applied a reduction of flow in the bathroom or in the kitchen. .98% of the respondents who use bottled water make waste collection (recycling). Respondents still say they do not throw a lot of bottles, 64% say less than 10 bottles a week.

It is also important to note that, in condominiums, although minimal, a more radical group of citizens do not have confidence in the quality of the delivered water from the aqueduct: 18 of 91 respondents said they use the bottled water for cooking, which indicates that there is a strong distrust. This finding confirms one of the motivations behind the project: the citizens still believe that the water supplied is not of good quality and do not think about environmental issues when decide to buy bottled water.

Individual choice of drinking water may have big consequences in terms of greenhouse gases (GHG) emissions. The Italian market is one of the most mature bottled-water markets in the world. In 2009, Italians were the second consumers of bottled water, at 192 L per capita (IBWA, 2009). In 1980, before creation of a real national bottled-water market, per capita consumption was 47 L (IBWA, 2008). This means that Italians changed their drinking habits from tap water to bottled water in less than 30 years.

Botto et al (2011), studying the carbon footprint of bottled water in Italy showed that drinking 1.5 L of tap water instead of PET-bottled water saves 0.34 kg CO2eq. Thus, a PET-bottled water consumer (2 L per day) who changes to tap water may prevent 163.50 kg CO2eq of greenhouse gas emissions per year. In monetary terms, this translates into a tradable annual verified emission reduction (VER) between US$ 0.20 and 7.67per drinker. Indeed, consumer's choice has consequences for climate change. Growing public awareness about climate change may help consumers to perceive tap water and bottled water as substitutes

Parks and Water House users' questionnaires

150 questionnaires were distributed in some parks and at the house of water and 118 were returned completed. The family composition with a greater representation is given by couples with child (ren) and couples without child (ren). In third place amounted the singles. Regarding gender, 59% of respondents were men. Also for this type of questionnaire, the majority of respondents are retired. 34% of respondents reported drinking water from the water house, while 24% reported consuming tap water. About this sample it is important considered that the people interviewed were more sensitive to the issue as they already use the water house service.

47% of those surveyed say they go to the water house at least 2 times a week, taking in most cases up to 6 bottles. 16% takes up to 12 litres.

From the point of view of environmental protection, from the questionnaires emerges that the majority of respondents use glass bottles (36%) to withdraw the water. 20% of the respondents use plastic bottles previously used. With reference to citizens' satisfaction with the service of the water house, 25% expressed "very good" and 40% said "good." We can therefore say that more than half of the respondents found the house of water a useful and well organized.

There is a tendency to use more water from the aqueduct network among the users of parks and water house, with respect to this distrust in condominiums. Only 24% of the respondents reported the use of bottled water (in the condominiums the percentage was 52%). About the motivations underlying the consumption of bottled water, the majority of the respondents highlight the "safety" as the main reason for the choice. It follows, therefore, the discussion on the topic 4.1 about the need of a growing public awareness.

5.5. Conclusions

The analysis of the questionnaires has highlighted some critical issues about the knowledge of water system and of water use by citizens, especially at the level of primary use (alimentary) but also about the relationship between citizens and territory, that is, with the water house and other civic uses. Regarding the level of information and awareness for the use of the resource and the daily behaviour, emerges a lack of awareness of the amount of water used daily. The majority of respondents in the condominiums declared to consume a small amount of water, therefore the problem of high level of consumption is not acknowledged by citizens.

The survey confirmed the opinion, rather widespread, that the water network is not good as bottled water is: yet many people think that tap water is less safe than bottled one despite the many active campaigns about tap water quality has been promoted in recent years in Italy.

It emerged strongly that citizens do not know how much water costs. For this reason, many of the educational activities laid down in the project were addressed to young people and citizens to explain the value of this resource, and show the cost associated with maintaining of water system and water quality.

People interviewed in public parks and at the water house seemed more aware of good quality of tap water. Nevertheless also in this case citizens state that they take water from public water houses instead of using tap water because in their opinion the first is better than the other, even if it originally comes from the same source (i.e. the public water system). The explanation for this answer probably lies in the quality and maintenance status of the water system and especially of pipes that bring water from the public system to the single apartment, as explained before.

The analysis and discussion of the result of surveys is extremely relevant for defining tailored policy for resource efficiency at local scale.

The presented case study highlights that it is still extremely necessary to raise awareness about the value of water as a resource and the importance of a proper use of it (UNESCAP, 2001) because many people are not yet able to understand its value and its importance for human life. So far, the study reported here is limited to direct consumption and could be widened in order to explore awareness about water embodied in product and services.

Besides, community involvement adds value to a water conservation promotion program by building local perspectives, values and expectations into decision-making. It also encourages long-term commitment of the community to program ownership and a desire for its success. It is anticipated public awareness campaigns for rational water use could result in significant water savings (UNESCAP, 2001).

Educating children and students inculcates a future society with a water conservation culture (UNESCAP, 2001). It also helps to educate present society when children return home and show their families what they have learned. Raising awareness of water issues at all levels is deemed critical in the successful implementation of water conservation programs and activities.

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Abstract

Sustainability science explores the interactions between human activities on the Earth's life support systems. Unless we understand these interactions, we will not be able to design a path towards sustainable development. In this report we focus our attention on water as key resource for human health and ecosystem health and as archetypal resource for which sustainability assessment is needed in order to preserve quality and quantity of the resource for present and future generations. A holistic approach to sustainability assessment of water requires different methodologies able to capture the magnitude of socio-economic drivers related to water consumption: both from production sectors (such as industries and agriculture) and from consumers (domestic use, consumption pattern). The present report aims at presenting different methodologies for depicting sustainability of water use in a life cycle thinking perspective.

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