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Water footprinting in life cycle assessment

State of the science and framework to assess impacts of water use in life cycle assessment

Quantis

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Context

Good quality freshwater water is a scarce resource, and becoming more rare in some regions of the world due to increased usage and pollution. Scarcity of freshwater generates significant problems for human health, social/political stability and ecosystems *(Ceres, CEO Water Mandate)*.

Corporate involvement is a fundamental solution, but methodologies to identify effective actions are severely lacking *(Koehler et al.*[1]*)*. The need to measure, act and communicate on the impact and improvements in corporate water footprint is increasing.

Several methods are being developed to address potential impacts related to water use.

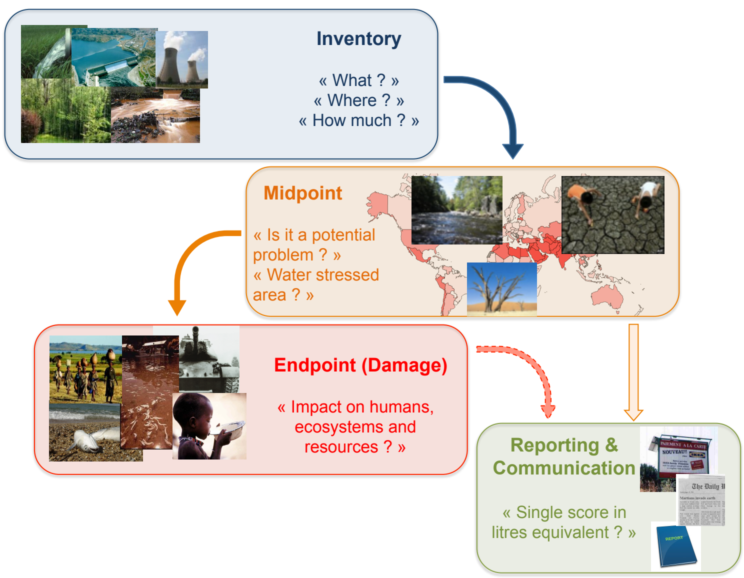
Within this context the UNEP-SETAC[2] and ISO[3] have launched two respective projects to define a consistent framework to evaluate water in life cycle assessment (LCA), based respectively on a scientific review of available methods and an international agreement.

"The need to measure, act and communicate on the impact and improvements in corporate water footprint is increasing"

Cause-effect chain to assess impacts associated with water use

The cause-effect chain to evaluate potential impact associated with water use is based on the principles of the LCA framework defined by the ISO standards 14040-44 (Figure 1).

Figure 1: Cause-effect chain to assess water is life cycle assessment



The ***inventory*** step (also referred as water accounting) evaluates the type and quantity of water used (e.g., m^3 of groundwater) as well as its geographic location (e.g., country or watershed) and in some cases its quality (e.g., level of pollution).

In life cycle assessment, two distinct steps are identified along the cause-effect chain linking water use to damages on, e.g., humans or ecosystems *(Jolliet et al., Udo de Haes et al.)*.

[1] Complete list of references available by contacting Quantis
[2] United Nation Environment Program and Society for Environmental Toxicology and Chemistry – Life Cycle Initiative, project entitled "The review of methods addressing water" (Kounina et al. 2009). Publication of the results is planned for spring 2010.
[3] International Organization for Standardization

In the ***midpoint impact assessment*** step, located at an intermediary level between water use and damages, the amount of water use is typically characterized with the local water stress level and/or local level of development. For example, potential negative effects on human health and welfare are higher in areas with higher water scarcity and lower socioeconomical development. The relation between local conditions and resulting damage can be based on cause-effect modeling or on historical data describing relationships between water scarcity and socioeconomic issues and health outcomes. The ***damage or endpoint impact assessment*** step models the ultimate potential consequences up to human health (e.g., increase in malnutrition caused by a reduction of water availability for irrigation), ecosystem quality (e.g., reduction of local freshwater biodiversity caused by release of water warmer than the receiving body), or resource availability (e.g., reduction of groundwater). This third step is performed in a consistent way as in life cycle impact assessment methods such as IMPACT 2002+ *(Jolliet et al.)* or ReCiPe *(Goedkoop et al.)*.

"The cause-effect chain can lead from inventory, through midpoint and endpoint impact assessment, and finally to a single score"

Finally, once the amount and type of water use is known and the associated impacts are identified, the resulting information can be used to support ***reporting and communication*** around the water footprint. This step might cover several purposes, including communication to interested parties (e.g., in corporate social responsibility reports), scientific communication midpoint or damage indicators (e.g., human health and ecosystem quality), or customer-oriented communication, based on a single aggregated value, expressed in an equivalent volume of water used or consumed. Grouping the damage categories in one single value is performed using a normalization and a weighting step[4].

Review of methods available to assess water use

Several methods have been developed or are in development that can be used to evaluate water use in life cycle assessment (Table 1 in Annex B). Figure 2 shows how these methods fit within the framework depicted in Figure 1.

"Several methods exist that are specific to one step in the cause-effect chain"

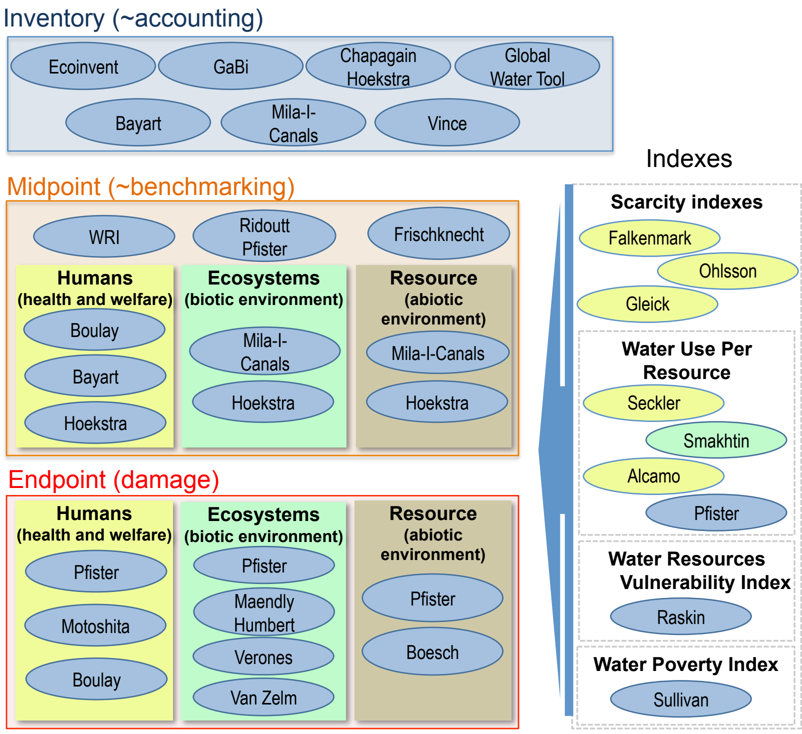


Figure 2: Situation of the methods reviewed within the life cycle framework as defined by ISO

[4] For example, by dividing the damage calculated by the damage of an average m^3 of an area of reference (such as the World)

Problematic and answer

As shown in Figure 2, some of the methods perform an inventory of water use in physical quantity, without characterizing and/or weighting the associated potential impacts. Others address the potential environmental burdens caused by specific impact pathways associated to a given water use, such as human health caused by malnutrition *(Pfister et al.)*, loss of biodiversity from groundwater extraction *(Van Zelm et al.)*, cooling water *(Verones et al.)* or hydropower *(Maendly and Humbert)*.

These approaches developed single issues, but they do not comprehensively assess the whole range of relevant pathways related to water use. To overcome this limitation a project has been launched within the UNEP-SETAC Life Cycle Initiative with the objective to perform an extensive survey of existing (and currently in development) methods, to provide a first generic assessment framework and finally provide operational characterization models and factors. This project, grouping tens of researchers from all over the world, just published the generic framework *(Bayart et al. 2010)* and is currently characterizing existing methods in order to identify the most relevant elements to be integrated in the framework that addresses both inventory and impact of water use.

"Theses approaches do not comprehensively assess the whole range of relevant pathways related to water use"

Practical framework to assess impacts of water use

Building on the work in progress within the UNEP-SETAC Life Cycle Initiative on water footprinting[5], a framework[6] has been developed by Quantis made of a state-of-the-science compilation of methods comprehensively addressing the major issues related to water use in LCA (Figure 3).

"A framework, in line with the ongoing work of UNEP-SETAC"

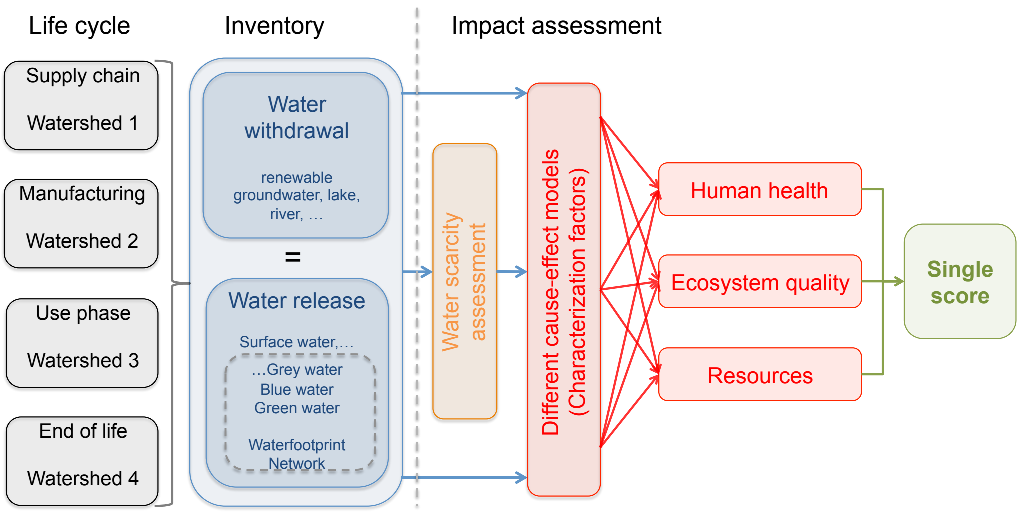


Figure 3: General scheme used to characterize impacts of water use including the baseline approach

" Water inventory built in line with Water Footprint Network method"

The **water inventory** is built for each life cycle stages considering withdrawal and release of water. This inventory is fully compatible with the Water Footprint Network method. Each flow is associated with characterization factors addressing the different issues modeled, leading to a midpoint or endpoint indicator.

A **water scarcity assessment**, sometimes referred as simplified impact assessment, midpoint indicator, baseline evaluation or screening assessment, has been developed using a water stress index (WSI, Figure 4) to provide companies the ability to assess the potential environment impact of water use in a rapid, easy and consistent way. Applications for such a simplified assessment include risk assessment, benchmarking, and labeling of high number of products (such as the French environmental product declaration).

[5] By water footprint, we mean the impact assessment of water use and not the water footprint definition of the Water Footprint Network
[6] An up-to-date and exhaustive scheme can be sent upon request, including all inventories flows, characterization factors methods, etc.

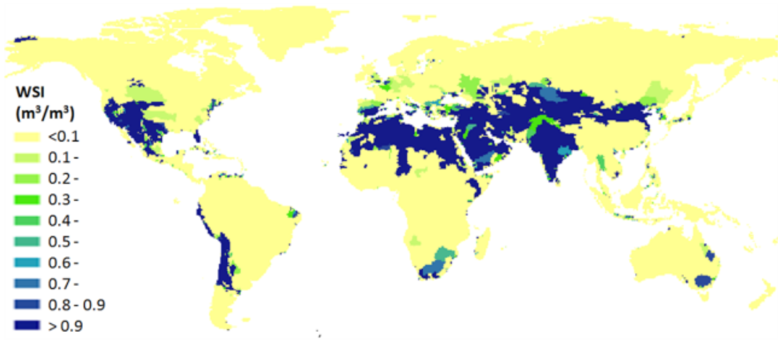


Figure 4: WSI of Pfister (2009) at a watershed level (also available at a country level)

"Purposes for water scarcity assessment include risk assessment, benchmarking, and labeling"

The result is a **weighted inventory** (or water footprint), in volume-equivalent water use (i.e., m^3_{eq}), that can be mapped as in Figure 3 *(Ridoutt and Pfister)*, *(Pfister and Hellweg)*.

For **endpoints** indicators state-of-the-science methods are taken to address, for example, thermally polluted water *(Verones et al.)*, blue water "consumed" *(Pfister et al.),* renewable groundwater withdrawal *(Van Zelm et al.)*, non-renewable groundwater withdrawal *(Pfister et al.)*, turbined water *(Maendly and Humbert)*, and chemically polluted water *(Humbert et al.)* (Annex A). The resulting damage indicators are quantified on human health (in DALY), ecosystem quality (in PDF·m^2·y) and resources (in MJ).

Finally, an optional weighting step can be performed to support communication. The **single value** result might be expressed as $\text{liters}_{\text{equivalent}}$ or $\text{person·year}_{\text{equivalents}}$.

"This framework allows to quantify offsetting measures"

This simplified approach and the damage impact assessment allow the quantification of benefits from **offsetting measures** (**compensation** or **responsible actions**), a major concern for some companies. This quantification can be performed consistently between negative and positive actions.[7]

Source of data and supply chain

Considering that we place the water footprint assessment in a life cycle perspective, well-regarded life cycle databases (e.g., the ecoinvent database) are used to provide information on the amount of water potentially used along the life cycle of more than 4000 products and processes. Water inventory along the supply chain can therefore be quantified. Direct water use can also be quantified using generic inventory databases, but refinement of the data using primary data (i.e., collected directly at the company level) is advised for robust results and communication.

"Connecting with the development the next ecoinvent database"

However, gathering or calculating these data is often a resource intensive and difficult part of a water footprint assessment and databases such as ecoinvent are still incomplete (e.g., consider only withdrawal) with a too low level of confidence to support robust communication, especially in public comparative claims (e.g., identifying products that has the lower water footprint).

Discussions are ongoing to improve the inventory of water use in the ecoinvent database (withdrawal per type of water, release quantity, etc). Quantis is supporting the development of the next ecoinvent database and aims at developing high quality data on water for more than 4000 processes used in life cycle assessment and water footprinting in a consistent way with other impact categories such greenhouse gas emissions for carbon footprinting.

About the authors

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[7] A detailed list of examples can be obtained by contacting Quantis.

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Annex A - Methods used to asses impacts associated with water use

Pfister et al. (2009): Impact on human health caused by malnutrition.


Boulay et al. (2010): Impact on human health caused by malnutrition and compensation scenarios.


Pfister et al. (2009): Impact on ecosystem quality caused by water quantity reduction.


Verones et al. (2010): Impacts on aquatic biodiversity, mainly from a reduction in dissolved oxygen, caused by release of cooling water warmer than the receiving environment.


Van Zelm et al. (2010): Impacts on terrestrial plants caused by reduction of ground water level.


Maendly and Humbert (2010): Impacts on aquatic biodiversity from dams.


Pfister et al. (2009): Impact on future availability of water from non-renewable ground water abstraction.


Annex B – Methods addressing water

Table 1: Methods identified to address water at the inventory level (both in terms of data structure and content), at the index level, and at the impact level (midpoint and damage levels). Complete description (Kounina et al. 2009) can be obtained by contacting Quantis

Category	Methods addressing water
Framework	• Bayart et al. (2009): The UNEP-SETAC Life Cycle Initiative framework
Inventory databases	• Ecoinvent (2009): Simple water inventory (withdrawal and turbined) • GaBi (2009): Simple water inventory (withdrawal and turbined)
Inventory methods	• Global Water Tool from the World Business Council for Sustainable Development (2007) • Chapagain and Hoekstra (2008), Hoekstra et al. (2009): Water footprint method (green/bleu/grey water) from the Water Footprint Network (WFN) (a limited amount of data is available on the WFN website) • Vince (2007): Water quality and electricity required to achieve an upper quality level • Bayart (2008): Assessing water in LCA • Boulay et al. (2010): Freshwater use impacts on human health, Compensation measures • Milà I Canals et al. (2008): Assessing freshwater use impacts in LCA
Indexes	• Gleick (1996): Basic Water Requirement (BWR) • Falkenmark (1989): Water Resource Per Capita (WRPC) • Ohlsson (1998, 1999): Social Water stress index (SWSI) • Alcamo et al. (1997, 2000): Criticality ratio • Seckler et al. (1998): Index of Relative Water Scarcity (IRWS) • Smakhtin et al. (2004): Environmental Water Requirement (EWR) • Pfister and al. (2009): Environmental impacts of freshwater consumption in LCA, Water Stress Index (WSI) • Alcamo et al. (1997, 2000): Criticality Index (CI) • Raskin et al. (1997): Water Resources Vulnerability Index (WRVI) • Sullivan et al. (2003): Water Poverty Index (WPI)
Impact assessment, at midpoint level	• World Resource Institute's water risk index (WRI) • Hoekstra et al. (2009): Water scarcity indexes for green, bleu, and grey water • Frischknecht et al. (2006, 2008): Swiss ecological scarcity method • Pfister and al. (2009): Environmental impacts of freshwater consumption in LCA using WSI • Milà I Canals et al. (2008): Assessing freshwater use impacts in LCA • Bayart (2008): Assessing water in LCA • Boulay et al. (2010): LCA characterization of freshwater use impacts on Human Health, Compensation
Impact assessment, at damage level (also referred as endpoint level)	• Pfister and al. (2009): Environmental impacts of freshwater consumption in LCA (human health in DALY/m^3, ecosystem quality in PDF-m^2-y/m^3, and resources in MJ) • Motoshita et al. (2008): Damage to human heath (in DALY/m^3) from Infectious diseases arising from domestic water consumption and undernourishment related to agricultural water scarcity • Boulay et al. (2010): Freshwater use impacts on human health, Compensation (in DALY/m^3) • Van Zelm et al. (2009): Disappearance of plant species due to groundwater extraction (in PDF-m^2-y/m^3) • Verones et al. (2010): Impacts on aquatic biodiversity from cooling water (in PDF-m^2-y/m^3) • Maendly and Humbert (2010): Aquatic biodiversity damages of hydropower water use (in PDF-m^2-y/m^3) • Bösch et al. (2007): Cumulative exergy demand (resources in MJ)