Literature Review for the Applicability of Water Footprints in South Africa

Report to the
Water Research Commission

by

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This is a preliminary report on the project *Adapting Water Footprints for South Africa and Exploring the Value of Integrating Water, Carbon and Energy (Environmental) Footprints for the South African Industrial Sector (*WRC Project No. K5/2099/3).

EXECUTIVE SUMMARY

Background and Motivation

In South Africa and other water-scarce countries, tools which can inform efficiency and raise awareness and create dialogue with people not previously involved in water debates are potentially very useful. Water footprints have the potential to contribute in this way, bringing new and important decision-makers into the water debate in a way that is intuitive and cuts across sectors. Additionally, water footprints create an opportunity for companies to join a global process of disclosure, understand risk and integrate an understanding of water into planning decisions. With this potential, the concept of water footprint has gained significant traction in the past 10 years in the private and public spheres across a variety of sectors. However, water footprint as a tool is still developing and many conceptual and methodological questions remain.

To explore the applicability of water footprints in South Africa, the Water Research Commission has commissioned this project number K5/2099. The purpose of the project is to understand how water footprints may contribute to sustainable management of water in South Africa primarily in the industrial sector, and to explore linkages between water and energy and the concept of water offsetting. As the first step in this study, this document reviews the international experience and methods for water footprint, and explores linkages with carbon, energy and offsetting. It also summarises the purposes for which water footprints are being explored in the industrial sector, and highlights questions that must be addressed to use water footprint as a reliable and meaningful indicator.

Water Footprint Methodology and Case Studies

A 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. A water footprint also considers the origin of the water used, and considers both water quantity and water quality impacts by differentiating between blue, green and grey water. The Water Footprint Assessment Manual provides the basic and commonly used water footprint methodology. However, alternative methodologies, such as the life cycle assessment approach which would assign a weighting factor based on water scarcity, are being explored.

Water footprint studies have been completed for a variety of entities, including countries, products, commodities and river basins. The country and river basin footprints focus on informing policy, whereas the product and commodity water footprints focus on understanding supply chain risks. Different potential uses and challenges exist for each type of study.

- ***Country*** – The first water footprint studies focussed on illustrating water flows between countries through trade of industrial and agricultural products. These studies are useful in illustrating virtual water flows into and out of countries. However, the local context of water use must be included to understand the impacts, and challenges arise in framing the water footprint as only one of many environmental, social and economic indicators that must be considered in the context of trade.

- ***Basin*** – Basin-level water footprints have gained focus in recent years, and have been completed for basins including the Nile Basin, the Breede-Overberg River Basin, and several river basins in Spain. Basin water footprints are largely directed to the public sector, with the intent to foster strategic dialogue, inform sector policy and development planning, or inform water allocation. It has, however, proven difficult to sufficiently contextualise the water footprint and to integrate a water footprint with the wide spectrum of public interests or the complex political decision-making processes. Basin-level water footprints have been a useful communication tool for fostering dialogue between diverse sectors.

- ***Product*** – Following country-level water footprints, companies began using water footprints to help understand the footprint of products such as a bottle of Coca-Cola or a cosmetics product. The international review shows that water footprint has different levels of traction for different industries. The food and beverage and textiles sectors are most active with water footprint, as the tool helps to understand significant upstream supply chain risks. Consumer products and the cosmetics, which have significant downstream water implications, are increasingly becoming interested. The chemicals and mining industries have been least active with water footprints. In the studies completed, water footprint is perceived as being useful for understanding supply chain water risk, and for benchmarking and communication. However, there is concern as to whether the grey water footprint is an appropriate representation of water quality. Additionally, understanding the local context of water use, as well as the social, economic and environmental considerations, is critical and difficult task.

- ***Commodity*** – Water footprints have also been studied for global commodities and markets, such as wheat, cotton or biofuels. Commodity water footprints are useful for illustrating virtual water flows through trade between countries, and can help companies understand supply chain risks and make informed decisions. Additionally, commodity water footprints can create transparency and provide information which allows the public to hold companies accountable for supply chain decisions. Again, understanding the local context, including economic and social factors, is critical to understand impacts.

Key Uses and Challenges in the Private Sector

As this project is focussed on the applicability of water footprint to the industrial sector, it is important to understand the key potential uses of water footprint in the private sector and how they may apply in South Africa. Three broad purposes emerge, each having a different level of complexity:

- ***Disclosure and Reporting*** – Using a water footprint as a disclosure and reporting tool, similar to a carbon footprint, is the simplest use of a water footprint because it does not require a full understanding of impacts. The volume of water use is sufficient, without the context of that water use. Water footprint as a disclosure and reporting mechanism is valuable because it presents a more complete picture by considering water use in the supply chain, in addition to direct water use. Reporting can also be used in for benchmarking and measuring progress.

- ***Risk Filter*** – Water footprints may be used as a risk filter by understanding supply chain dependencies, and the origin of water used in the supply chain. Using a water footprint as a risk filter is more complex because the impact of water use and the local context of water use must be better understood.

- ***Planning and Decision-Making*** – Water footprints may be able to inform planning, such as decisions regarding where to source supplies or where to build a new manufacturing facility. This is the most complex potential use of water footprints as it requires a full understanding of the environmental, economic and social impacts of a water footprint, and an understanding of opportunity costs and trade-offs.

While water footprints have significant potential to contribute to corporate water management and to integrate water into decision-making, significant questions must still be addressed in order for water footprints to be a reliable and meaningful indicator. Key questions include:

- ***Understanding Impact*** – A water footprint must be rooted in a local context and its local impact understood in order for the water footprint to inform decisions. A meaningful approach to understand impact has not yet been developed, and is a key challenge for the applicability of water footprint.

- ***Water Quality*** – Significant question exists regarding whether representing water quality as a volume of water is meaningful or appropriate. The nature of the water quality impact is lost, as is information which could inform potential responses. Based on the experiences of companies which have explored the use of the grey water component of the footprint, it must be further developed or reconsidered to be useful.

- ***Integrating Complexity and Nuance*** – A water footprint is a number which represents a single consideration. However, the decisions a water footprint is meant to inform are extremely complex and must considering a range of economic, social and environmental considerations. In order for a water footprint to play a role in complex decisions, it must be integrated with the broader context and linked with other considerations.

Offsetting, Carbon and Energy

The differing nature of carbon and water introduces complexities when exploring the potential of water offsetting. Most importantly, it is assumed that carbon emissions have a global impact and may be offset at a global level. Conversely, water is a local resource and must be offset at the local level. Thus, any offsetting effort must track the geographical location of water use through the supply chain and to a point of sale, and must offset in the same geographical location as water use.

While a few water offsetting projects have been initiated, they are still in exploratory stages and many questions arise in these projects. For example, how can geographically-specific offsetting be facilitated, what measures or technologies will be used for offsetting, and what will be the benefit of offsetting? On this last question, a company may offset for good corporate stewardship, or may seek a regulatory benefit such as higher-priority access to water in times of drought.

Finally, water and energy are linked as each is required to provide the other. Additionally, there are often trade-offs between water and energy, where becoming more efficient with one leads to less efficient use of the other. As carbon footprints can represent implications of energy use, carbon footprints and water footprints may be helpful in illustrating and clarifying the connection between water and energy, and understanding trade-offs.

Next Steps

The key potential uses and questions regarding water footprints and offsetting as they apply to the South African industrial sector are framed in this review. A series of case studies on South African companies will be completed to understand the potential of water footprint to contribute to sustainable water resources management, and to explore the challenges and questions that must be addressed for water footprints to be a meaningful tool in South Africa.

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1.1 Project background

The Water Research Commission has commissioned an exploratory study to understand the applicability of water footprints to South Africa. The purpose of the study is to contribute to the understanding of water footprints and water accounting in South Africa, as well as explore the concept and relevance of water neutrality. The study is intended to inform the industrial sector and to contribute to the sustainable management of water resources.

This literature review is the first deliverable of the project, and is intended to review the international experience and methods for water footprint, as well as explore linkages with carbon footprints and neutrality. This literature review will help to scope the potential contribution of water footprint to government and industry, and will highlight important issues and assumptions that must be engaged with through the project. A preliminary framework putting forth recommended water footprint case studies in South Africa, and the approach and methodology for the case studies, will follow this review.

1.1.1 Historical development of water footprint

Ecological footprints, energy and carbon footprints and water footprints are all members of a family of footprint concepts. Although the various footprint concepts are related, significant differences in origin exist between the ecological and carbon footprint as versus the water footprint. These differences in origin have implications for the applicability of each type of footprint. Thus, understanding the origins and development of each type of footprint can help to inform a discussion on the appropriate use of each type of footprint and opportunities or challenges for linking the different footprint concepts.

1.1.2 Life Cycle Assessment

Life Cycle Assessment (LCA) is an early framework 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. Although it is not a footprint, LCA has informed the development of footprints 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.

The concept of LCA originated in the 1960s among growing concerns regarding limitations of raw materials and energy resources, with one of the first studies aimed at calculating the cumulative energy required for the production of chemicals. In 1969, an internal study done for The Coca-Cola Company investigated the environmental impacts from the raw materials and energy required to manufacture different types of beverage containers. This study laid the groundwork for current methods of life cycle analysis in industrial processes, and became known as Resource and Environmental Profile Analysis (REPA) in the United States or Ecobalance in Europe. These analyses became increasingly important with the oil shortages in the 1970s.

Although efforts to standardise and improve methodologies continued through various efforts from the 1980s, concerns with the use of LCA arose in 1991 over broad marketing claims made by product manufacturers. Following this, LCA methodologies were made into standards included in the International Standards Organisation (ISO) 14000 series.

More recently, in 2002 the United Nations Environment Programme (UNEP) and the Society of Environmental Toxicology and Chemistry (SETAC) launched the Life Cycle Initiative as an international partnership to improve the LCA tool and put it into practice.

Figure 1.1 Example Life Cycle Assessment Steps considered for a Cellular Phone (UNEP/SETAC 2009)

With its "cradle-to-grave" approach, LCA created the conceptual framework for thinking about environmental impacts through the life cycle of a product, rather than just looking at the manufacturing stage. LCA addresses different types of environmental impacts, including atmospheric emissions, energy consumption, water pollution and solid waste. However, LCA has not historically addressed the water needed to produce a product or service throughout the life cycle of a product. Efforts are currently underway to try to use water footprint to fill this gap and will be discussed in Chapter 2.

1.1.3 Ecological Footprint

The concept of ecological footprint was the first in the footprint family, developed in 1992 by Mathis Wackernagel under William Rees's supervision at the University of British Columbia. An ecological footprint represents the amount of biologically productive land and sea required to supply the resources consumed by human population and to absorb waste.

An ecological footprint considers human consumption in terms of carbon, food, housing and goods and services, and then indicates the amount of cropland, grazing land, fishing grounds, forest, built-up area and land for carbon absorption would be required to support the population. Similar to the LCA approach, the ecological footprint looks at the requirements throughout a product's entire life cycle, for example considering the carbon emissions in manufacturing, transporting, using and disposing of a product (Kitzes et al. 2007).

As application of the ecological footprint concept grew, a standard was developed and first released in 2006 to ensure consistency in methodology, and sustainability as a trusted metric. The standards is updated periodically and released by the Global Footprint Network.

The ecological footprint has been used in a public awareness sense, for example by calculating the global ecological footprint to be 1.5 planet earths in 2007, meaning that global demand is exceeding sustainable production. Ecological footprints have also been used by corporations or groups of consumers to understand ecological footprint at a more local scale. While the ecological footprint is viewed as useful for assessing progress and for communication, certain aspects of methodology and data improvements are seen as necessary.

Similar to a LCA, ecological footprint has not historically addressed water use in a comprehensive manner. While the ecological footprint considers the amount of fishing grounds required for food consumption, it does not consider the amount of freshwater required for producing the goods consumed.

1.1.4 Carbon Footprints

One view of a carbon footprint is as a subset of the ecological footprint, and thus stemming directly from the ecological footprint concept. In this case, a carbon footprint refers to the amount of productive land and sea required to sequester carbon dioxide emissions which result from human activities.

Commonly, however, a carbon footprint refers to the tonnes of carbon emitted by a certain activity or entity, such as carbon emitted to produce a product, rather than representing an amount of productive land. With increasing attention to climate change, carbon footprints have gained significant attention. In response, companies have begun to report on carbon emissions, take steps to increase efficiency to minimise carbon emissions, as well as to offset carbon emissions. As with the ecological footprint, a life cycle assessment approach which considers supply chain can be used.

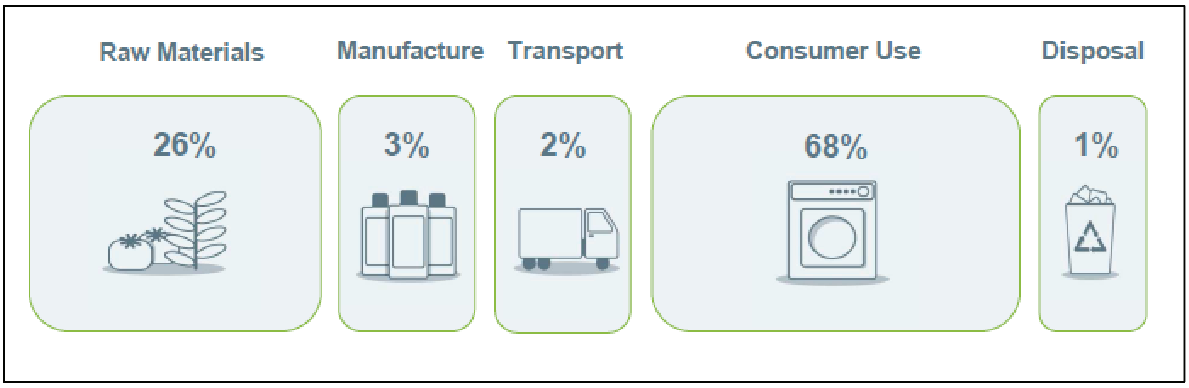


Figure 1.2 Greenhouse gas emissions distribution in the lifecycle of selected Unilever products (Unilever 2008)

An important characteristic of carbon is that its impacts are assumed to be global. An expression of a carbon footprint need not be placed into a local context. As this review will expand upon, this is in contrast to water which is a local good and must always be rooted in a local context.

1.1.5 Virtual Water and Water Footprint

1.1.5.1 Virtual Water

The concept of virtual water was introduced in the early 1990s by Professor Tony Allan, and is a concept to which water footprint is closely related (Hoekstra 2007). Virtual water means the volume of water required to produce a good or service, considering all inputs throughout the supply chain of production (Hoekstra 2007). This is in contrast to traditional water resources management, which looks primarily at direct water withdrawals for domestic, agricultural and industrial use.

The virtual water concept was developed to explore the potential of importing virtual water through goods and services as a potential way to address water scarcity in the Middle East (Hoekstra, WF of Nations 2007, 36, Allan 1993 & 1994). Thus, the virtual water concept did not originate from the LCA and ecological footprint family but rather was developed earlier to address a different problem. It was developed to address trade and water scarcity, rather than environmental impacts. The virtual water concept has been primarily used to illustrate the flow of water between countries through trading of food products, and thus is a concept which links water, food and trade in an accessible way. This can help to understand comparative advantages of production between different countries, and can inform discussions around water security.

One criticism of the virtual water term has been that it is misleading because it leads one to think that water is being traded instead of food (Merrett 2003). Virtual water is not virtual at all, rather it is real water which is used to produce crops and is therefore represented by crop water requirements. Rather than thinking of virtual water, the value of water should be captured by thinking of water as part of the value of land on which a crop is produced (Allan 2003).

1.1.5.2 Water Footprint Origins in Virtual Water and Carbon Footprint

The water footprint concept was introduced in 2002 by Arjen Hoekstra at UNESCO-IHE, and has been further developed at the University of Twente and by the Water Footprint Network. 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 (Hoekstra 2011a).

Water footprint builds on both the virtual water concept and ecological and carbon footprints, and thus has similarities and differences to both. A water footprint is conceptually similar to virtual water in that both represent the water required to make a product considering all inputs in the supply chain. A water footprint adds to virtual water in that it also describes the characteristics of the water used, including whether the water was rainwater or surface water, as well as the place of origin of the water and the time of use. Understanding the nature of the water used in a product’s supply chain is necessary to understand water dependencies and risks, as water is a resource which must be understood in its local context.

Water footprint was also introduced as an analogy to the ecological footprint and carbon footprint family (Hoekstra 2007). Where a carbon footprint is the amount of carbon emitted throughout the supply chain for the production of a product, a water footprint is the volume of water required throughout the supply chain to make a product. However, a fundamental distinction between water footprint and carbon footprint exists in that water is a local resource whereas carbon can be viewed at a global level. Carbon emissions will have similar implications regardless of where emissions occur. Conversely, water use must be understood in its local context. Use of water in a water abundant location is very different than use of water in a water scarce location, and use of rainwater in a water scarce location is also very different than use of surface water in that same location. Thus, unlike with carbon footprint, many more local and contextual issues must be understood in order to give meaning to a water footprint.

1.1.5.3 Development of Water Footprint

The first water footprint studies were conducted around nations, similar to virtual water studies, in order to understand direct and supply water requirements to support a country's consumption. Water footprints gained traction and were conducted in the private sector around products and companies, and also commodities to help companies understand the supply market. More recently, water footprints have been conducted around basins in an effort to affect policy. These different areas of focus are important because the approach and applicability of a water footprint is very different depending on the intended use. For example, the private sector is often interested in understanding water dependencies in its supply chain for its products to help understand risk, whereas the public sector would look to understand opportunities for water footprint to inform policy, strategy, planning or public sector operations. Different types of analyses and information are required to achieve these different goals.

Though the use of water footprint has gained significant traction, many questions remain unanswered. For example, it is not clear how a water footprint for a country can be used to inform policy, or what the real value or importance of a country's water footprint is. Additionally, it is unclear how a water footprint of a product helps a company understand its risks, what an appropriate response to water footprint should be, and how to communicate information gained from a water footprint without being misleading. For example, placing a label indicating the water footprint of a product has been suggested as a consumer awareness mechanism. However, a water footprint label is potentially misleading because it does not indicate the origin of the water used, and therefore does not contribute to consumer awareness. Rather, it communicates incomplete information.

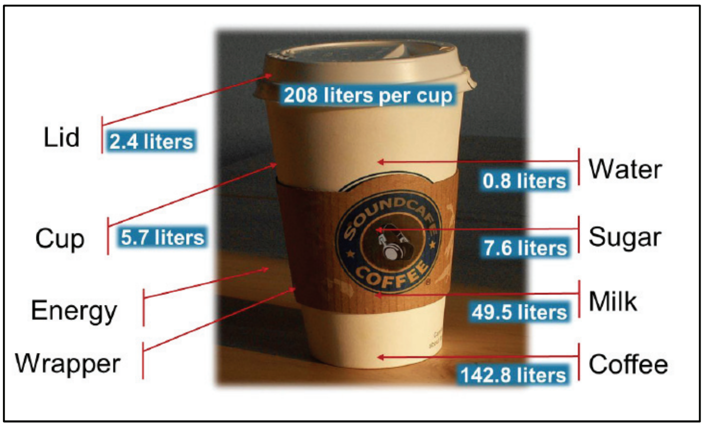


Figure 1.3 Example of a product water footprint for coffee (Chapagain 2010)

As the water footprint concept has gained significant traction, efforts have been undertaken to standardise the basic methodology, advance the concept and answer some of the questions above. The Water Footprint Network (WFN), a network of international organisations, is central in this regard. The WFN is a Dutch non-profit foundation which was founded by the University of Twente, WWF, UNESCO-IHE, the Water Neutral Foundation, WBCSD, IFC and the Netherlands Water Partnership. It was founded to coordinate efforts to develop and disseminate knowledge of water footprint concepts, methods and tools, and has contributed to much of the water footprint literature that will be reviewed in this document.

1.2 Scope of this review

Understanding of the development of LCA, ecological and carbon footprint, and virtual water and water footprint provides a basis to understand the motivations for development, and some linkages and distinctions between the various types of footprints. This background also highlights some key questions which must be explored.

WF Key Questions

- What water footprint methodologies and applications are appropriate for different types of assessments, including products, companies and commodities, and countries or basins?
- What is the true contribution of water footprint to the private and public sectors, over and above what is already understood from other water resources tools? Specifically, how can water footprint contribute to the private sector to understand water risk, and how can it be used by the public sector to inform policy, planning or discussion?
- Considering the differing nature of carbon and water footprints, what are the appropriate opportunities to link the two types of footprints? Can the concept of offsetting apply to water?
- What does the international understanding of water footprint teach us about the best opportunities to use water footprint in South Africa?

This review will seek to address the important questions regarding the applicability of water footprint in South Africa by first conducting a comprehensive review of water footprint literature to understand the conceptual framework and international case studies of water footprint. It will then explore the links to carbon footprints, offsetting and related literature.

It will proceed as follows:

- **Chapter 2** unpacks the conceptual framework of water footprint and discusses its relevance to water risk.

- **Chapter 3** examines a series of case studies which represent the international experience with water footprint. It will first focus on water footprint as applied in the private sector and supply chains, looking at manufacturing, agriculture and retail, and energy. It will then investigate the application of water footprints in the public sector, including at a multi-national level, national level, basin level, and local level. These case studies will highlight differences in methodologies, as well as some of the key benefits and challenges of water footprints.
- **Chapter 4** expands the discussion to exploring carbon and energy footprints, offsetting and disclosure. It explores potential opportunities and difficulties in linking carbon and water footprints, and how offsetting and disclosure which originated with carbon may be relevant to water footprints.
- **Chapter 5** concludes by providing guidance on the adaptation of water footprint and related tools for use in South Africa, including opportunities, challenges and remaining questions.

2 CONCEPTUAL FRAMEWORK OF WATER FOOTPRINT

The conceptual framework for water footprint assessments has undergone significant development since its conception in 2002. A basic methodology has been developed, and the mainstream approach to water footprint assessments is provided in the Water Footprint Assessment Manual. Additionally, certain key concepts and considerations have emerged. However, with the variety of applications and involvement of different organisations, certain divergences in methodology have developed. Additionally, critiques in the concept and methodology have been expressed. This chapter will introduce the basic methodology and key concepts for a water footprint, divergences in approach, and important criticisms and key challenges.

2.1 Water footprint components and methodology

The Water Footprint Assessment Manual, a product of the WFN, presents the predominant approach to conducting water footprint assessments. As the WFN is a large network of international partners, the WFN methodology has guided basic water footprint approach used by many of the organisations which have conducted water footprint assessments. While the basic concepts are largely followed, many nuances and challenges with methodology have emerged. The basic methodology is put forth below, and the nuances and challenges will be explored in case studies and in later stages of this project.

2.1.1 Components of a Water Footprint

A water footprint is a temporally and spatially explicit representation of the volume of freshwater required to produce a good or service, measured over the entire supply chain (Hoekstra 2011a).

The following concepts are central to the concept of water a footprint:

- ***Direct and Indirect Water Use:*** A water footprint represents the volume of freshwater used to produce the product, measured over the total supply chain. Thus, it looks at **direct water use**, for example at the water used in manufacturing processes when making a cotton product. It also looks at **indirect water use** throughout the supply chain, for example at the water required to grow the cotton used in manufacturing the product. Often, these indirect water requirements are far greater than the direct water requirements.

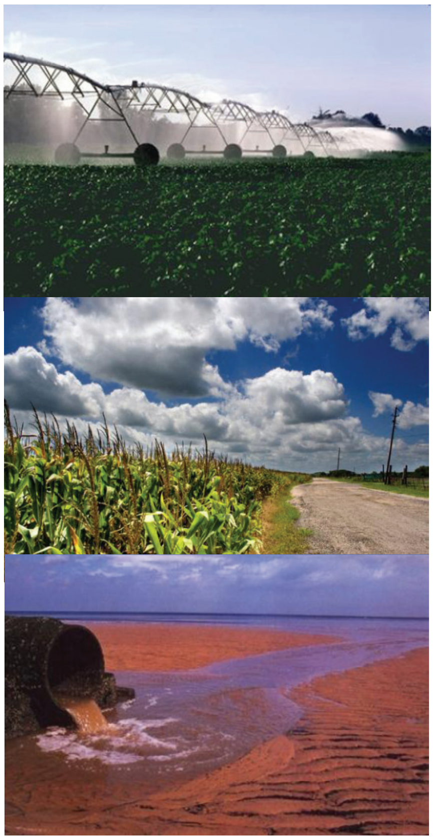
- ***Consumptive versus Non-Consumptive Water Withdrawal:*** A water footprint looks at **consumptive** water use, which is water that is evapotranspirated, incorporated into a product or returned to a different watershed from which it is extracted or returned at a different time. A water footprint excludes **non-consumptive** water use, or water which is returned to the same watershed and is available for downstream uses.

- ***Blue, Green and Grey Water:*** A water footprint distinguishes between blue, green and grey water consumption.

- A **blue water footprint** refers to the volume of surface and ground water required for the production of a good or service, and is the freshwater traditionally thought of when considering water resources.

- A **green water footprint** refers to the volume of rainwater used to produce a product which does not run off or recharge groundwater, but is stored in or temporarily on top of the soil.

- A **grey water footprint** addresses pollution, and represents the volume of freshwater that is required to dilute or assimilate the load of pollutants based on existing ambient water quality standards. Together, the blue, green and grey components of a footprint form the overall footprint for the product.



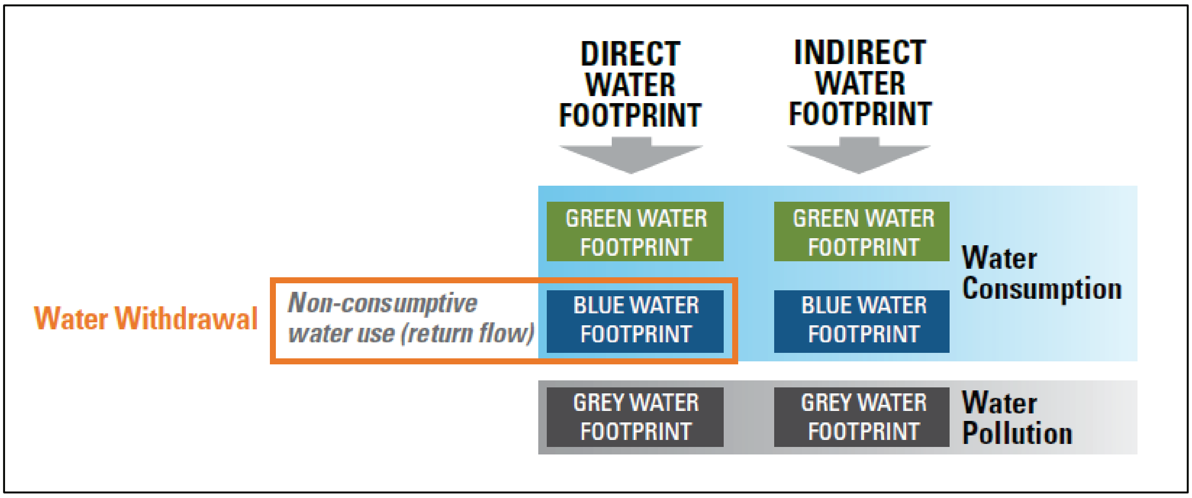


Figure 2.1 Components of a water footprint (The Coca-Cola Company (2010), based on the Water Footprint Assessment Manual)

2.1.2 Steps in a water footprint assessment

A full methodology will be developed in later stages of this project. The overview of water footprint assessments provided here is to indicate the general steps, and introduce some of the key concepts that come into a water footprint assessment.

The Water Footprint Assessment Manual describes 4 phases of a water footprint assessment. The first phase is setting the goals and scope of the assessment, as this is required in order to determine how to approach and structure the analysis. The second phase is that of water footprint accounting, which is conducting the calculations for a particular process, producer, producer or consumer in a specified geographical area. The third phase is a sustainability assessment, which seeks to understand the environmental, social and economic sustainability of the water footprint which has been calculated. Finally, the fourth phase of formulating response strategies is aimed at making the water footprint more sustainable (Hoekstra et al., 2011).

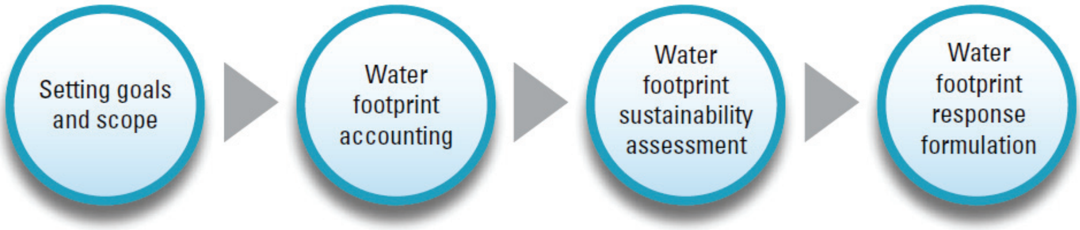


Figure 2.2 Steps in a water footprint assessment (The Coca-Cola Company (2010), based on the Water Footprint Assessment Manual)

An important point to take away from the description of these four phases is that a water footprint is more than a numerical calculation done in isolation. While phase 2 is focussed on the numerical calculations, the other phases help to understand the purpose of the footprint assessment, how to place the footprint into a local context in terms of sustainability, and how to respond to insights gained from the water footprint. Still, in terms of developing the water footprint concept, phase 2 around water footprint accounting has received significant attention in case studies and discussion. Therefore, water footprint accounting is more developed in methodology and practice than the other phases. In particular, both the sustainability assessment and the response formulation phases are in need of further development and understanding.

2.1.2.1 Phase 1 – Setting goals and scope

It is important to first clarify the goal of a water footprint assessment, as the approach and methodology will change depending on the goal and context. The entity around which a water footprint will be completed will be determined by the goal of the study. For example, if a water footprint is aimed at understanding a nation's reliance on virtual water imports through trade, a footprint on country-level will likely be relevant. If a water footprint is aimed at understanding supply chain risks for a business, a footprint around a particular product or business will be most helpful. Common entities around which water footprints are conducted include:

- Process steps
- Products
- Commodities or markets
- Consumer or group of consumers
- Geographically delineated area – Multi-national, National, Provincial, Basin or Catchment, or Municipal

Once the entity has been identified, additional questions regarding the scope and focus of the assessment must be answered, including:

❖ **Blue, green and/or grey water** – Whether to include blue, green and grey water in the study, or whether to focus on only one or two components. Blue water is usually scarcer and has high opportunity costs than green water, and thus is typically the focus of analysis and of traditional water resources tools. However, green water may be of interest because it often plays a significant role in agricultural production and has not been included in traditional types of analysis. Grey water will be interesting when water pollution is a concern.

❖ **Truncation of supply chain** – Where to truncate the analysis when looking at the supply chain. The general rule expressed in the Water Footprint Assessment Manual is to include all water use in the supply chain that 'significantly' contributes to the footprint, although exact guidelines have not been developed. The water footprint of labour in the supply chain, including the food, clothing, and other consumption of workers in the process, is generally excluded in a water footprint. This is because it would result in a never-ending analysis and double-counting.

❖ **Period of time** – Water availability and demand varies within a year, and from year to year. The water footprint will also vary depending on the time period chosen. For example, a blue water footprint will be higher in a dry year than a year with significant rainfall. Thus, an assessment must specify whether it is looking at a particular year, a number of years, or an average.

❖ **Production or consumption** – A water footprint can be conducted from a consumption perspective, a production perspective or both. Some of the above entities around which footprints are completed are clearly either consumption or production-focussed. For example, a footprint for a product will focus on the freshwater required throughout the supply chain for the production of that product. A footprint for a consumer will determine the freshwater required for the products consumed according to that consumers habits. However, for a geographically-delineated area such as a country, either production or consumption water footprints may be of interest and should be clarified for the assessment.

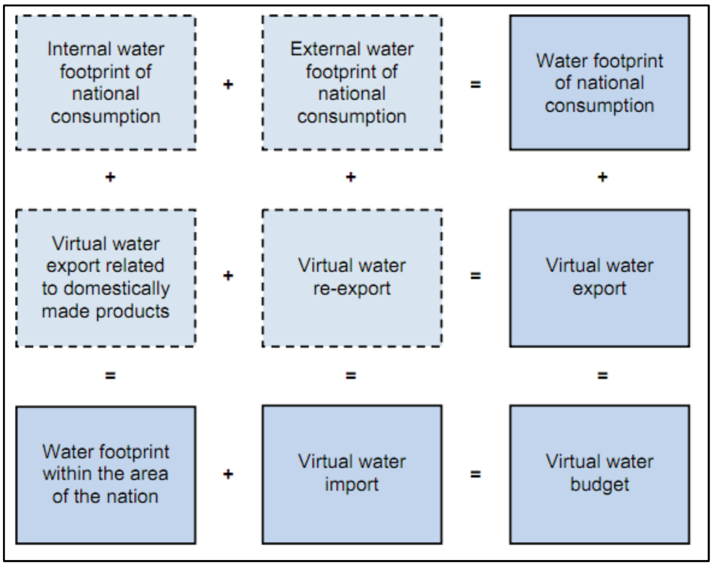


Figure 2.3 Internal and external components of a consumption water footprint (Mekonnen and Hoekstra 2011)

❖ **Internal or external –** Distinguishing between internal and external water footprints is most relevant when discussing the footprint of a geographically delineated area, such as a country. An **internal water footprint** refers to the domestic freshwater used to produce the goods and services consumed by the population of a particular country or area, whereas an **external water footprint** refers to the freshwater used in other countries to produce goods and services which are then imported and consumed the country of interest. This concept becomes important because an external water footprint implies reliance on foreign countries to meet freshwater needs, and thus is relevant to discussions on using trade to address water scarcity and also discussions on food and water security.

2.1.2.2 Phase 2 – Water footprint accounting

Water footprint accounting is the step of calculating the water footprint. As indicated above, a water footprint can be calculated for many different entities. The discussion below provides the methodology for some of the most common types of calculations, including the blue and green water footprint of a crop, and the grey water footprint of a point source of pollution which is relevant to industrial processes. The general approach to calculating the footprint of a product is then reviewed. The Water Footprint Assessment Manual provides more detailed methodology and additional examples. The various methodologies will be further explored in the next step of this project of developing a framework for methodology and case studies (Hoekstra 2011a).

Green and Blue Water Footprint of a Crop

The virtual water demand (use) of a primary crop is calculated as the ratio of the volume of water requirement for crop c production in exporting country e, *CWR[e,c]*, to the yield of crop c, *CY[e,c]*, in exporting country e.

$$CWD[e,c] = \frac{CWU[e,c]}{CY[e,c]}$$

The volume of water use for crop production, CWU[e,c], is composed of three components:

$$CWU[e,c] = CWU_{green}[e,c] + CWU_{blue}[e,c] + CWU_{grey}[e,c]$$

Here, $CWU_{green}[e,c]$ (m^3/ha) is the evaporation of rainfall from crop land (green water use), $CWU_{blue}[e,c]$ (m^3/ha) is the evaporation of irrigation water from crop land (blue water use) and $CWU_{grey}[e,c]$ (m^3/ha) is the polluted volume of water resources resulting from leached fertilisers, chemicals or pesticides from agricultural land (grey water consumption). The first two components, $CWU_{green}[e,c]$ and $CWU_{blue}[e,c]$, will be the components subject to further analysis here.

The components of blue and green water use are both evaporative and are no longer immediately available in the local hydrological cycle. They depend on the specific crop evaporation present and soil moisture availability in the field.

Crop evaporation

The crop evaporation requirement for a crop c, ET_c [t]mm/day, is calculated using the crop coefficient, K_c [t], for the respective growth period and reference crop evaporation ET_0 [t] mm/day, at that particular location and time.

$$ET_c[t] = K_c[t] \times ET_0[t]$$

This is illustrated below. Evaporation of water (mm/day) can be expressed in terms of volume per hectare (m^3/ha/day) by multiplying the above by a factor of 10.

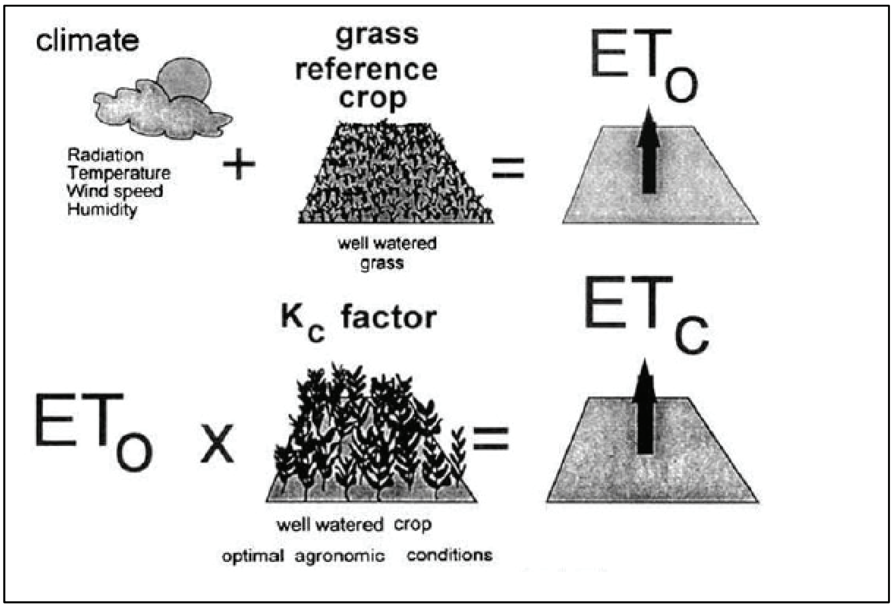


Figure 2.4 An illustration of the calculation ETc (Allen et al. 1998)

The CROPWAT model (www.fao.org) is a useful resource which employs the classic Penman-Monteith equation to estimate evaporation ET_0. The ET_0 (reference crop evaporation – the reference crop is grass) is only affected by climatic parameters. It expresses the evaporation power of the atmosphere at a specific location at the time of the year and does not consider crop characteristics or soil factors. The crop evaporation, ET_c, differs from the reference evaporation ET_0, as ground cover, canopy properties and aerodynamic resistance of the crop are different from grass (the reference crop).

The effects and characteristics that distinguish field crops from grass are integrated into the crop coefficient K_c. The major factors determining K_c are crop variety, climate and crop growth stage.

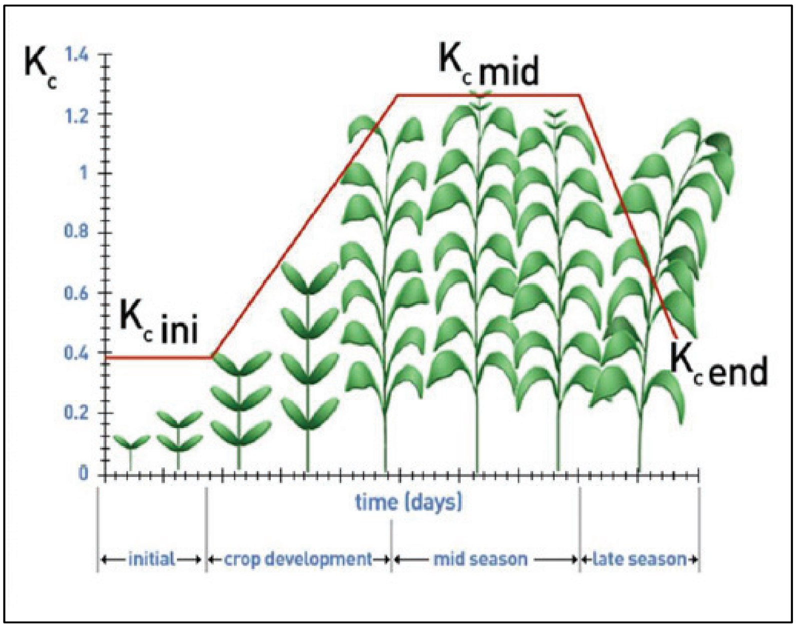


Figure 2.5 An illustration of the variation in the crop coefficient Kc (based on Allen et al. 1998)

There are differences in evaporation during the various growth stages, as a result, the K_c for a given crop will vary over the growing period (from planting to harvesting). For perennial crops, the planting dates can be assumed to be the green-up date for the calculation of crop water requirements.

Soil Moisture

Soil moisture is maintained either by effective rainfall or by irrigation water supply. The CROPWAT model has a few inbuilt options to estimate effective rainfall (effective rainfall, as compared to actual rainfall, is the amount of precipitation that is added and stored in the soil rather than becomes run off).

Green Water Use

The green water use, $CWU_{green}[e,c]$, is equal to the minimum effective rainfall (precipitation), $p_{eff}[t]$, and crop water evaporation requirement at that time step (t).

$$CWU_{green}[e,c,t] = \min\left(ET_c[t], p_{eff}[t]\right)$$

The total green water use $CWU_{green}[e,c]$ for crop c production in country e is calculated by summing up green water use for each time-step over the entire length of the crop period, T.

$$CWU_{green}[e,c,t] = 10 \times \sum_{t=0}^{T} CWU_{green}[e,c,t]$$

Green water is independent of irrigation water supply and solely depends upon the effective rainfall and crop evaporation requirements. Evaporation of water (mm/day) is expressed in terms of volume per hectare (m^3/ha/day) by multiplying the above by a factor of 10.

Blue water use

Blue water use, in contrast to green water use, depends on crop evaporation requirement, green water availability and irrigation water supply. The first two variables, $ET_c[t]$ and $CWU_{green}[e,c,t]$ define the third, the irrigation requirement $I_r[t]$ which is calculated as:

$$I_r[t] = ET_c[t] - CWU_{green}[e,c,t]$$

The blue water use, $CWU_{blue}[e,c,t]$, is the minimum irrigation requirement, $I_r[t]$, and the effective irrigation water supply $I_{eff}[t]$. The effective irrigation supply is the part of the irrigation water supply that is stored in the soil moisture and available for crop evaporation (similar to effective rainfall).

$$CWU_{blue}[e,c,t] = \min(I_r[t], I_{eff}[t])$$

It is useful to note, if there is no irrigation, the effective irrigation is equal to zero (and blue water use is none).

The total blue water use, $CWU_{blue}[e,c,]$, in crop production is calculated by summing up blue water use for each time-step over the entire length of the crop period, T.

$$CWU_{blue}[e,c,t] = 10 \times \sum_{t=0}^{T} CWU_{blue}[e,c,t]$$

Evaporation of water (mm/day) is expressed in terms of volume per hectare (m^3/ha/day) by multiplying the above by a factor of 10.

Grey Water Footprint of a Point Source of Pollution

The grey water footprint is the volume of freshwater that is required to assimilate the load of pollutants based on natural background concentrations and existing ambient water quality standards. In general terms, it is calculated by dividing the pollutant load, *L*, by the difference between ambient water quality standard for that pollutant (the maximum acceptable concentration c_{max}, in mass/volume) and its natural concentration in the receiving water body (c_{nat}, in mass/volume).

$$WF_{proc,grey} = \frac{L}{c_{max} - c_{nat}} \left[\frac{volume}{time}\right]$$

For human-made substances that do not naturally occur in water, c_{nat}= 0. If the natural concentration is unknown, it can be assumed to be 0, although this will underestimate the grey water footprint if the natural concentration is not in fact 0.

For a point source of water pollution, such as chemicals being released from a manufacturing facility into a surface water body in the form of wastewater, the load, *L*, is calculated as the effluent volume times the pollutant concentration in the effluent minus the abstraction volume times the pollutant concentration in the intake water. This represents the amount of pollutant which is contributed by the analysed process.

$$WF_{proc,grey} = \frac{L}{c_{max} - c_{nat}} \left[\frac{volume}{time}\right] = \frac{Effl \times c_{effl} - Abstr \times c_{abstr}}{c_{max} - c_{nat}}$$

Water Footprint of a Product

The water footprint of a product is defined as the total volume of fresh water that is used directly or indirectly to produce the product. It is estimated by considering water consumption and pollution in all steps of the production chain.

In order to estimate the water footprint of a product, one will have to start by conceptualising the way a product is produced. For that reason, one will have to identify the 'production system'. A production system consists of sequential 'process steps'. A simplified example of the production system of a cotton shirt is: cotton growth, harvesting, ginning, carding, knitting, bleaching, dying, printing, finishing. Given the fact that many products require multiple inputs, it often happens that multiple process steps precede one next process step. In such a case we will not have a linear chain of process steps, but rather a 'product tree'.

For estimating the water footprint of a product, one will have to schematize the production system into a limited number of linked process steps. In the case of many processed goods, this might involve tracing the origin of the inputs of the product in different countries and determining the associated water footprint there.

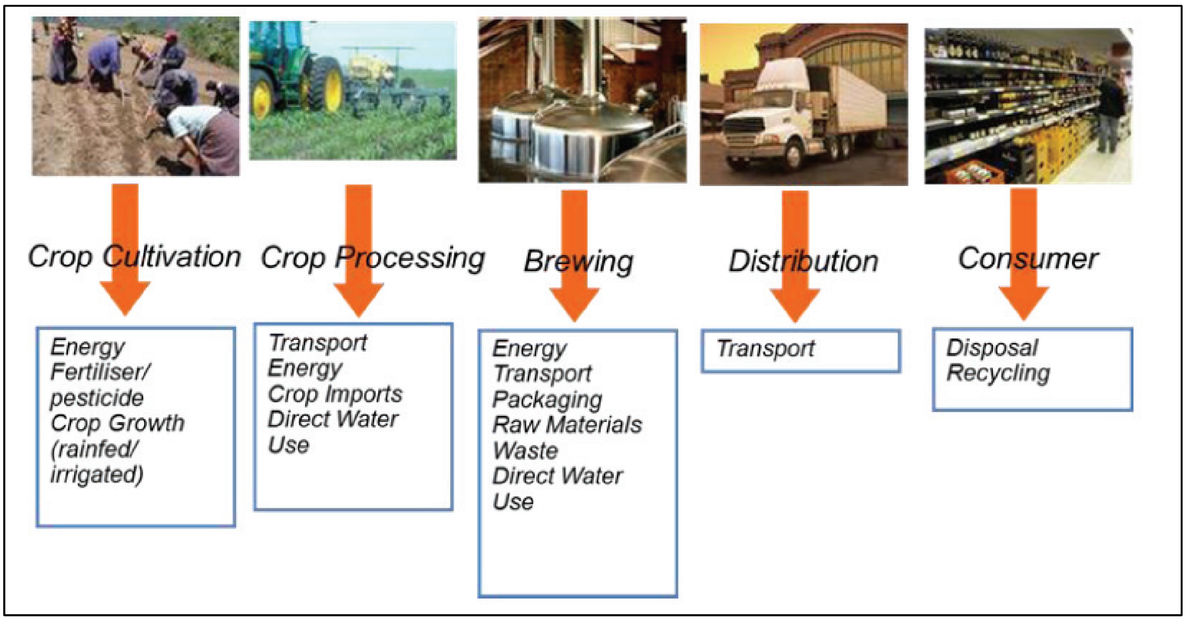


Figure 2.6 Example schematic of water use in the production supply chain of beer (based on SABMiller 2009)

Broadly, there are two approaches to calculating a water footprint of a product:

- **The chain-summation approach**: this approach is the simplest, but can be applied only in the case where a production system produces one output product (e.g. the supply chain from growing hops to making beer). In this particular case, the water footprints that can be associated with the various process steps in the production system can all be fully attributed to the product that results from the system. In this simple production system, the water footprint of the product is equal to the sum of the relevant process water footprints divided by the production quantity of product.

- **The stepwise accumulative approach**: this approach is a generic way of calculating the water footprint of a product based on the water footprints of the input products. Suppose we have a number of input products when making one output product. In this case we can get the water footprint of the output product by simply summing the water footprints of the input products and adding the process water footprint. Suppose another case where we have one input product and a number of output products. In this case, one needs to distribute the water footprint of the input product to its separate products. This can be done proportionally according to the value of the output products or it could also be done proportionally to the weight of the products (although this would be less meaningful).

A practical example of the calculation of the water footprint of a crop product is given in the Water Footprint Assessment Manual (Hoekstra 2011a) in Appendix III.

2.1.2.3 Phase 3 – Sustainability assessment

The sustainability assessment step compares the water footprint found in the accounting step to available freshwater resources for the relevant time and place. A sustainability assessment may include environmental, social and economic sustainability, as well as primary and secondary impacts. Additionally, a sustainability assessment will differ based on whether the assessment is regarding a product, or whether the assessment is regarding a geographic area. Some guidance on sustainability assessments has been developed, but this step evolved after the accounting step and thus is less developed.

The three components of sustainability considered are environmental, social and economic. If a blue, green or grey water footprint prevents any of the below from being satisfied, then the footprint is considered unsustainable.

- ❖ **Environmental sustainability** – This has a quantity and a quality dimension. Environmental flow requirements must be met in order to sustain ecosystems, groundwater flows must remain within certain limits, and water quality must remain within specified limits.
- ❖ **Social sustainability** – A minimum amount of freshwater at a certain quality must be allocated to basic human needs, including drinking, washing, and cooking within a catchment or river basin. Additionally, a minimum amount of freshwater must be available for the secure production of food supply, though this consideration can look beyond the catchment or basin due to trade. If a blue, green or grey water footprint prevents the minimum amounts from being met, then the footprint is not sustainable.
- ❖ **Economic sustainability** – Water should be allocated in an economically efficient way, meaning that the benefits of the footprint should outweigh the full costs, including opportunity costs and externalities.

When considering the water footprint of production for a basin or catchment, the above can be investigated for the specified area of production. If considering the sustainability of a water footprint for a product, then the geographic origin of water inputs to that product must be identified, and a sustainability assessment must be undertaken for each geographic area.

The identified steps for the sustainability assessment are:

1. Identification of the environmental, social and economic sustainability criteria
2. Identification of hotspots, including particular catchments and times of the year
3. Identification and quantification of the primary, or direct, impacts in the hotspots
4. Identification and quantification of the secondary, or indirect, impacts in the hotspots

A "hotspot" is a catchment where the total water footprint is unsustainable for a period of the year according to the environmental, social and economic criteria identified. Thus, a sustainability assessment seeks to identify the location at a catchment-level where water use or pollution exceeds that which is deemed acceptable to meet environmental, social and economic standards. It then quantifies the impact in that catchment.

While the sustainability assessment step is intended to understand the local context of water use, the practical challenges of this task are great. The most relevant environmental, social and economic criteria to use are not identified, and what the criteria should be and how to quantify impacts is unclear. Efforts to provide more detail in this step are currently underway.

2.1.2.4 Phase 4 – Response options

The final step in a water footprint assessment in the Water Footprint Assessment Manual is to form a response to the water footprint. In theory, if a water footprint is deemed not sustainable, action should be taken to reduce the water footprint and make it sustainable.

The suite of responses possible will depend on the entity or group responding. The entity which will be responding should be identified in the goal-setting phase of the water footprint, and may include consumers, companies, investors or government.

What constitutes an appropriate response or suite of responses is in the very early stages of development. Many ideas for responses have been suggested for consumers, companies, government and investors. For example, farmers and agricultural policy can seek to support efficient farming practices, and retailers or food and beverage companies can engage with their supply chains to encourage efficient practices. Still, these suggestions are very simplified. It is unclear how a water footprint should actually inform the choice of which response is most appropriate, and what makes these responses different from generally good water management practices. Efforts are underway to develop the understanding of response options.

2.2 Divergence in water footprint methodologies

While the above overview of methodology represents a general approach to water footprint, divergences in methodologies are now arising from organisations with different areas of focus.

2.2.1 Water Footprint Network approach

The WFN approach is represented by the methodology explained above. In this approach, actual volumetric water requirements are represented and thus reflect the physical reality. This approach is consistent with the concept of virtual water, which indicates water flows through the trade of products. This is the approach being developed by the WFN and the University of Twente, among others. Most water footprint studies to-date follow this approach.

2.2.2 Life Cycle Assessment approach

An alternative approach is being developed for inclusion of water footprint in LCA. The LCA approach includes a weighting factor to understand impact based on water scarcity. In addition to LCA, the International Standards Organisation (ISO) is developing a standard for water footprint assessments which utilises this weighting approach. The LCA approach is earlier in its development than the WFN approach, and has not been utilised in practice as much as the WFN methodology.

The purpose of LCA is to understand aggregate environmental impacts. With this emphasis on understanding impacts, a volumetric representation of water does not provide sufficient information about the impact of that water use. As water is a local resource, the impact of water use can only be understood by comparing the water footprint to available water resources in the area. Thus, LCA approach includes a weighting factor based on a water scarcity index. The result is that instead of representing a real-world physical quantity, the LCA approach represents a weighted indicator.

The advantage of this weighting approach is that it has potential to indicate the impact of water use in a particular location and time, whereas a volumetric footprint cannot represent impact without specifying the local context. However, weighting based on water scarcity causes a water footprint to lose real-world significance and physical meaning. Additionally, weighting based on a water scarcity index is simplistic in that it only considers one factor, rather than the spectrum of environmental, social and economic factors that are required to truly understand impact.

2.3 Perspectives of water footprint

In addition to the scoping and goal-setting above, two additional considerations related to the approach to a water footprint merit discussion, and should be thought of at the beginning of a water footprint assessment as they will have implications for the methodology and expected contribution of a water footprint assessment:

- ***Private sector or public sector:*** It is important to consider whether a water footprint is intended to inform a private company or the public sector, as this will have implications for the approach, methodology and potential actions which can be taken. A private company may be interested in understanding supply chain risks, whereas a government may be interested in understanding trade opportunities or food security. This means that a water footprint relevant to a private company would likely focus on a product or group of products, whereas a water footprint relevant to the public sector would focus on a commodity and look at imports and exports for a geographic area. Additionally, the spectrum of response opportunities differs by sector. A private company will likely have clear goals and a decision-making process, and will be able to engage directly with its supply chain around water use. In contrast, public sector institutions have a wider range of considerations and decision-making processes, introducing significant complexity in the response strategy phase.

- ***Water footprint as a metric, metaphor and method:*** Water footprint can be understood as a ***metric***, ***metaphor*** or ***method***, depending on the intent of the study. Water footprint is most often seen as an accounting metric for water use, conveying the virtual water of a product, or the virtual water contained in the production or consumption of a country. When viewing water footprint as a metric, arriving at an accurate number is critical in understanding both water use and impact. The metric approach is most relevant where direct control over one's water use exists, such as with a private company, and action can be taken to change water use and track progress. Alternatively, water footprint can be approached as a metaphor which enables one to broadly represent the flow of water through the economy. When viewing water footprint as a metaphor, the value of the footprint is that it helps to tell a story which has water dimensions, as well as economic and social dimensions. Thinking of water footprint as a metaphor is more relevant in a policy environment where creating a general understanding and illustration of water flow in through the economy is valuable, but direct response to the accounting metric is difficult. Third, water footprint can also be viewed as a method, or process, which raises critical questions and leads to strategic dialogue. Fostering dialogue through process may be relevant to both the private and public sectors.

2.4 Critiques of water footprint concept and methodology

A water footprint is a fundamentally different approach to understanding the role of water than traditional water resources planning and management. This is sometimes forgotten, and attempts are made to use water footprint as other water resources management tools may be used. It is also not intended to be a tool which tells an entire story or serves all purposes. The Water Footprint Assessment Manual recognises and emphasises that water footprint is an indicator which presents one part of a story, and that a water footprint must be used in combination with environmental, social, institutional or economic indicators and insights to consider trade-offs and inform decisions (Hoekstra 2011a).

In addition to the acknowledged limitations, challenges around the concept and potential contribution of the footprint, as well as questions around methodology have arisen. Among these challenges and questions are:

- **Contribution of water footprint** – One of the most important challenges to water footprint asks what the true value of water footprint is, and whether a footprint is able to contribute to tools already available. Wichelns (2011) argues for water management and ensuring food security, a water footprint will not be valuable. This is because a water footprint does not describe environmental, social or economic impacts, and therefore does not link water to any of these considerations. A water footprint is also not specific enough to provide information that allows action, either in terms of understanding the local impact of water use or to identify opportunities to use water more efficiently or effectively. Wichelns contends that any useful information provided by a water footprint is already available with other water resources management tools. Although these comments are most directly applicable when considering water management from a policy perspective, similar concerns exist relevant to understanding supply chains.

- ***Local context of a WF*** – As water is a local resource, the local context must be understood in order to give a water footprint meaning. However, how to properly root a water footprint in a local context is a difficult task that is still being grappled with. This must include consideration of hydrological, environmental, social and economic indicators, and must leave space for a conversation of trade-offs. At present, WF assessments are often presented as a number representing water content and an indication of where that water came from. However, the broader story relevant to the source of water is not presented. For example, a water footprint of a product may look harmful if water was used from a water-scarce area. However, it may be that livelihoods depend on the production of that product, and that the social and economic benefits of production are high.

- **Potential to be misleading** – A water footprint can be misleading because it presents an appealing and convenient illustration of the water required to produce a good, but does not provide sufficient context regarding the water used. A consumer may be quick to see the numerical water footprint, and assume that a large footprint is bad and a small footprint is good. However, a numerical water footprint without understanding the local context of that water lacks meaning. A large footprint from water originating in a water-abundant area may have acceptable impacts, particularly if significant social and economic benefits are derived from that production.

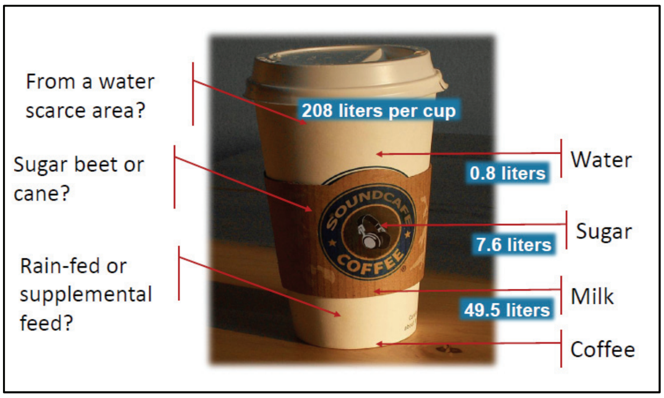


Figure 2.7 Contextual questions for a product water footprint (Chapagain 2010)

- **Opportunity costs and non-water inputs** – A water footprint portrays only a volume of water, and does not give any additional information regarding the opportunity costs of that water. In order to inform water resources decisions, particularly from a planning or policy perspective, the opportunity costs of water use must be understood (Wichelns 2010). Additionally, other inputs such as labour and the opportunity cost of those inputs should be considered. In conveying only a volume of water, a water footprint is too narrow in scope to assist with complex decisions and trade-offs.

- **Grey water footprint** – Representing the impacts of water pollution by transforming water quality into water quantity has been criticised as losing important information and distinctions without providing any useful information in return. Some see the grey water footprint component as simply being a meaningless, but convenient, calculation (Wichelns 2011). Turning a water quality measure into a water quantity loses information about what harm a constituent may actually cause, and it is not possible to understand environmental impacts. It does not consider factors such as ecotoxicity, biodegradability or water treatment. Expressed as a quantity of water, a grey water footprint does not provide information upon which policies or interventions can be taken. How to revise the grey water footprint calculation for a more meaningful representation is unclear.

- **Sustainability assessment and response options** – The sustainability assessment and response options parts of a water footprint assessment require significantly more development to make these steps useful. As currently described in the Water Footprint Assessment manual, most green, blue and grey water footprints will be classified as unsustainable. A water footprint is classified as unsustainable if it uses water from a catchment or river basin in which the overall water footprint is unsustainable, or if water footprint can be reduced or avoided at an acceptable societal cost. This definition is both vague and extremely broad, as "acceptable societal cost" is not defined and most water footprints can likely be reduced. Additionally, response options are often simplistic, and in many cases are no more than simply good water management practices. For example, a water footprint is not required to know that efficient irrigation practices in a water-scarce setting will help to use water more efficiently.

- **Gross versus net treatment of evaporation** – A water footprint allocates the gross, or total, evaporation or evapotranspiration to the water footprint of a product or process. An alternative would be to use a net approach, which would compare the evaporation or evapotranspiration resulting from a product to what would have happened in a natural reference state. Certain examples of water footprint assessments, such as hydropower or biofuels, argue that a net instead of gross approach would better reflect the impact of water use.

- **Practical complexities with data** – Completing a water footprint assessment in practice can be difficult due to data availability and reliability, and the number of product inputs that must be considered for more complex products or organisations. While agricultural and water input data is available through databases such as CROPWAT or FAOSTAT, the data are averages and may not be according to the time or geographical boundaries desired in a study. In this case, data must be adapted to fit the circumstance which introduces errors and uncertainty. For complex products or organisations, hundreds or thousands of inputs from locations all over the world must be considered, introducing many opportunities for errors and gaps in data. After these complexities, drawing comparisons between water footprints of two products or two countries, other than at a high level, has questionable value as many assumptions must have been made during the process.

3 WATER FOOTPRINT CASE STUDIES

A water footprint can be completed around a variety of entities, including countries, products and companies, commodities and markets, and river basins. The following case studies will review examples of water footprint assessments conducted around these different types of entities, and will draw out key insights regarding the relevance of water footprints and remaining challenges or questions.

3.1 Country level footprints

Similar to virtual water studies, the first water footprint assessments focussed on a single or several countries, and the trade patterns between them. The first case reviewed studied the water footprint of all nations in the world and presents an overview of international virtual water flows. The second case focuses on the Netherlands and Morocco, and shows how water footprint can show the relationship between two countries. The third study looks at the UK, and explores possibilities for thinking about understanding impacts and responses.

3.1.1 National Water Footprint Accounts

The National Water Footprint Accounts report presents a global perspective on water footprint by country, and illustrates the virtual water flows at a global level (Mekonnen and Hoekstra 2011). The study calculates the blue and green water footprint of production and consumption for each country in the world from 1996 to 2005. The footprints for production are shown in

Figure 3.1. It also estimates the grey water footprint from agriculture during this time. China, India and the United States had the largest total water footprints and 74% of the production footprint was green water.

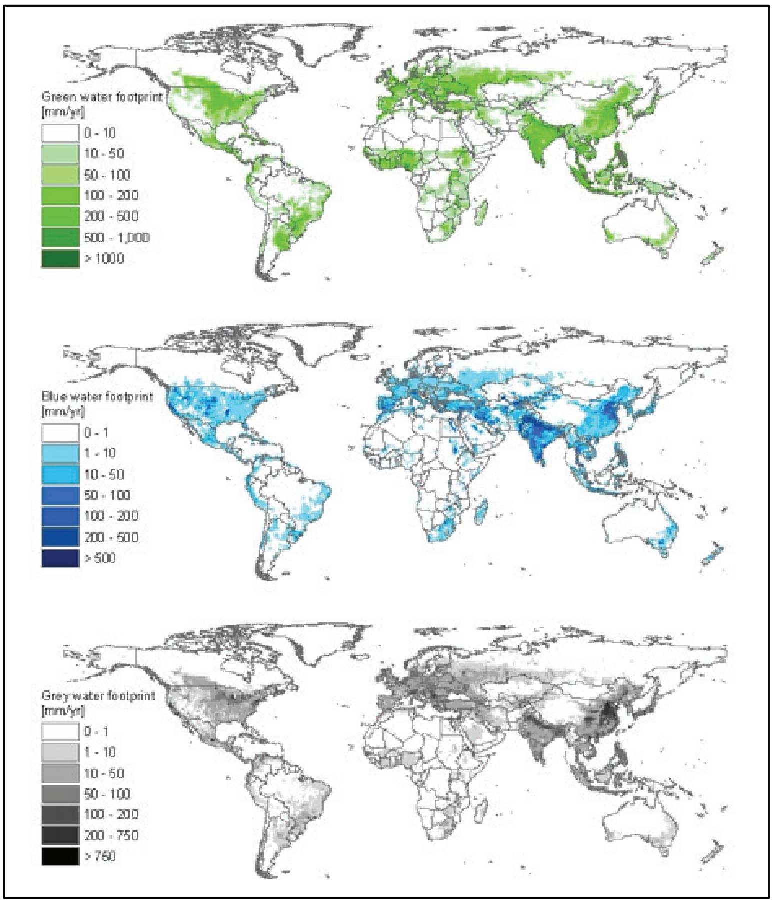


Figure 3.1 Global water footprints for production of agricultural and industrial products (Mekonnen and Hoekstra 2011)

This global water footprint and virtual water study builds on two earlier studies, and represents an increasingly complex and granular understanding of the water footprints of countries. Many databases and information sources were used to find data on domestic water consumption, agricultural and industrial production, and trade.

The study distinguishes between the water footprint from goods produced with domestic water resources and consumed within the nation (internal water footprint), goods produced elsewhere in the world and imported for consumption (external water footprint), and goods produced using a nation's domestic water resources which are then exported. As illustrated in Figure 3.2, it can be seen whether each country is a net importer or exporter of virtual water, and the virtual water flow patterns that occur through trade.

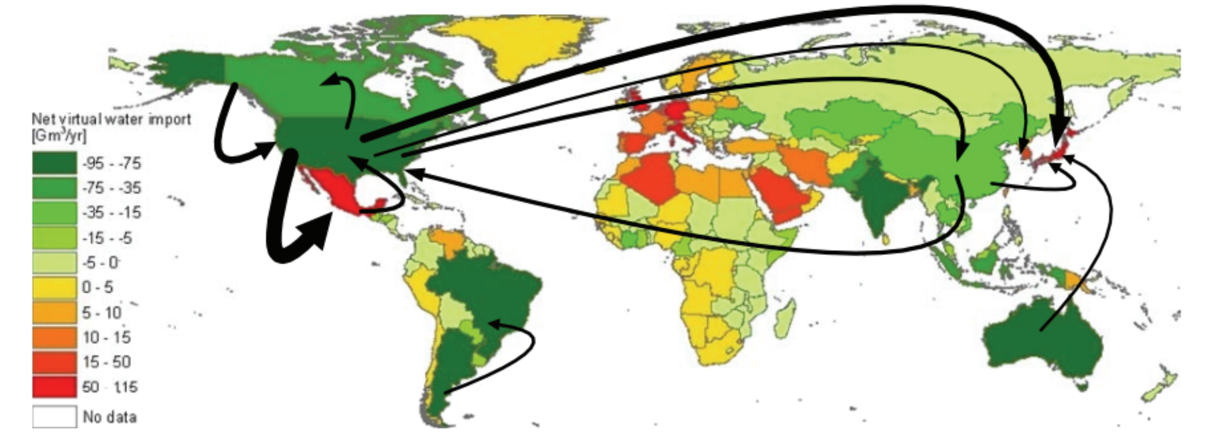


Figure 4. Virtual water balance per country and direction of gross virtual water flows related to trade in agricultural and industrial products over the period 1996-2005. Only the biggest gross flows (> 15 Gm^3/yr) are shown; the fatter the arrow, the bigger the virtual water flow.

Figure 3.2 Virtual water balance and virtual water flows from agricultural and industrial trade (Mekonnen and Hoekstra 2011)

This global picture has been mainly used for discussion on issues such as virtual water flows through trade, water dependencies, and to understand the green and blue footprints of national production and consumption. It also contributes to the further development of the water footprint concept, methodology and data availability as complex questions must be addressed to create this picture.

3.1.2 The Netherlands and Morocco

A study was undertaken to understand the agricultural water footprints of the Netherlands, a humid country, and Morocco, a semi-arid/arid country (Hoekstra and Chapagain 2006). For both countries, an internal and external water footprint was calculated for the period of 1997 to 2001. The internal water footprint is the footprint of goods produced and consumed within the country, whereas the external water footprint is the footprint of goods produced outside of the country and imported for consumption.

The study found that both the Netherlands and Morocco import more virtual water than they export, making them both dependent on water use outside of the country. Comparing the import and export of virtual water between the two countries also demonstrates that the Netherlands imports a significant amount of virtual water, processes the goods such as coffee or cocoa, and re-exports the virtual water. Most of the virtual water exported from the Netherlands in the form of goods originated from outside of the Netherlands. This is indicative of the agricultural through-trade economy in the Netherlands. Conversely, Morocco uses a significant amount of domestic water for agricultural production rather than relying on a trade-through economy.

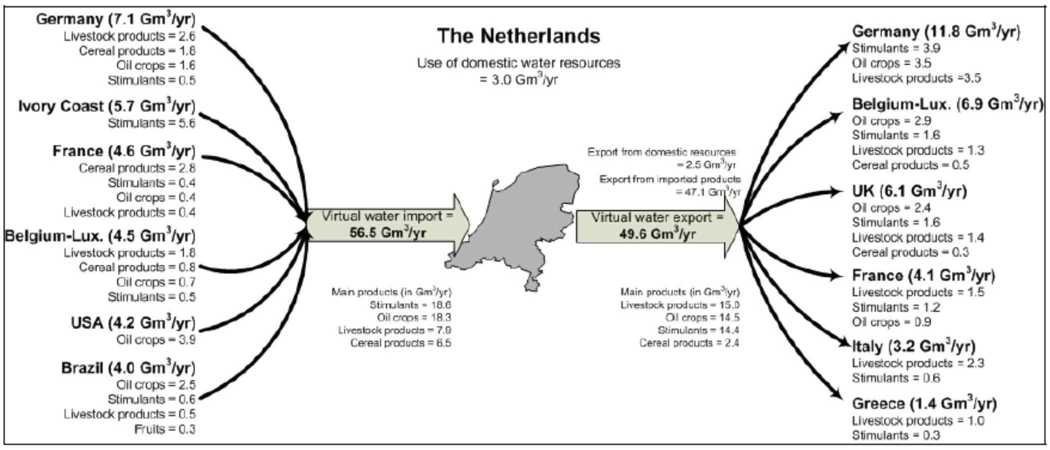


Figure 3.3 Virtual water flows from agricultural trade in the Netherlands (Hoekstra and Chapagain 2006)

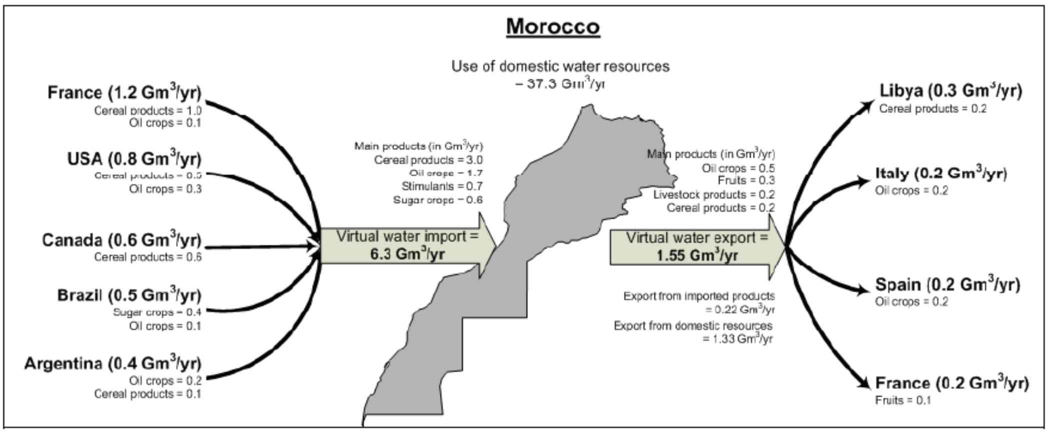


Figure 3.4 Virtual water flows from agricultural trade in Morocco (Hoekstra and Chapagain 2006)

This study also investigates the virtual water trade between the Netherlands and Morocco, and illustrates the concept of water savings. Morocco uses 50 million m3/year for producing agricultural goods which it exports to the Netherlands, whereas the virtual water flow from the Netherlands to Morocco is 140 million m^3/year. The study indicates that if Morocco had to domestically produce the goods which were imported from the Netherlands, it would require 780 million m^3/year. In contrast, these goods were produced in the Netherlands with 140 million m^3/year. This difference is due to greater evaporative demands and lower agricultural yields in Morocco. The "water savings" is thus calculated to be 640 million m^3/year. It is not suggested that this trade pattern developed because of water considerations, but that trade patterns can have significant implications for water use and allocation within a country.

3.1.3 The UK

In 2008, WWF published a report on the water footprint of food and fibre consumption within the UK (Chapagain 2008). The purpose of this study was mainly to raise awareness of water issues around trade and production, and to create a space for dialogue between civil society, corporates and government agencies. The internal and external water footprints for crops and livestock products consumed within the UK were calculated.

This report had important implications for understanding the impact of a water footprint, and thinking about responses to a water footprint. Importantly, this was one of the first studies to bring the concept of an impact or sustainability assessment into discussions of water footprint assessments. The study investigated water impacts of UK agricultural and fibre consumption by identifying the countries from which the UK imports the greatest amount of virtual water and which have high water stress indices. These countries are shown in the upper right-hand corner of the graph in Figure 3.5, and include Egypt, Pakistan, India, and Uzbekistan.

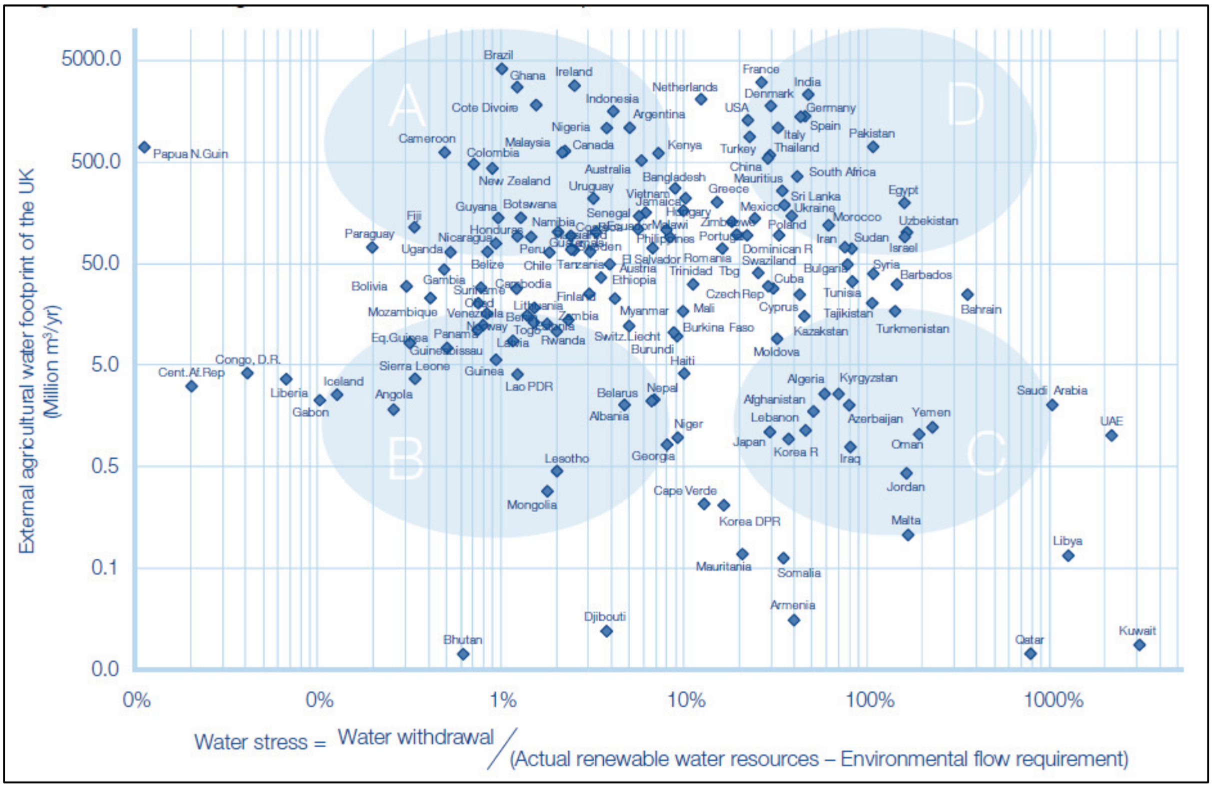


Figure 3.5 Water footprint and water stress for UK agricultural imports (Chapagain and Orr 2008)

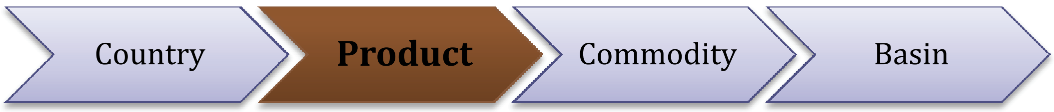
Additionally, this report generated interest from a variety of groups. First, although consumers were not a target audience, the report received considerable interest from news media and NGOs on issues of food and equity. Second, there was concern expressed from the development community that water footprint studies were prescriptive in terms of where consumers should buy from or where growers should grow. This could potentially be dangerous to poverty alleviation efforts if interpretation of numbers drove investment away from areas of high impact. Interest was also generated in the public sector around development and agricultural policy, and in the business community to open water discussions with retailers.

3.1.4 Insights from country-level water footprints

The water footprint of a country provides an interesting illustration of virtual water flows into and out of a country through trade. The key question which emerges is what does a water footprint actually mean, and how should the information be used?

Some insights can be gained from the cases above. Impacts differ significantly if a country has a large water footprint but the water used is from an area which is water-abundant, as versus if the water originates in an area which is water-scarce. Thus, the origin of the water and the local circumstances must be understood. Even then, as highlighted in the UK case study, water is only one of many considerations. It may be beneficial from an economic development or poverty alleviation standpoint to increase water use and export in a water-scarce area. A water footprint must be one of many factors considered when making decisions.

3.2 Product or company water footprints



Following the introduction of water footprints in relation to countries, companies began using the water footprint concept to understand the footprint of particular products.

The reason companies are interested in water footprint is that it can help to understand supply chain risks and dependencies. Additionally, it can be relevant from a reputational and disclosure perspective.

Much of the corporate water risk literature discusses that because corporates use water in operations, they may face water risk in terms of physical limitations, reputational risks, social risks or regulatory risks. Water footprint adds a dimension to this in that it highlights the importance of supply chain water risk, as it indicates not only direct water use but also indirect water use such as that required for raw materials. Companies are now beginning to understand that the most significant water risks may fall outside of their internal operations and instead be located in their supply chains.

Table 3.1 Company and product footprint studies and key points shows some of the companies which have conducted a water footprint assessment, and indicates some of the key learning points, insights or challenges. Each case is discussed in more detail below.

Table 3.1 Company and product footprint studies and key points

Case	Industry Sector	Key Points on Contribution and Challenges with WF
Coca-Cola	Food & Beverage	• Useful to understand green/blue/grey water use • Highlights importance of engaging directly with agricultural suppliers • Important to understand context of WF and communicate appropriately
SAB Miller	Food & Beverage	• Highlights importance of agricultural water use,

Case	Industry Sector	Key Points on Contribution and Challenges with WF
		and significant differences based on location • Water footprint can be used for benchmarking and monitoring progress • Helpful for strategic assessment of water risk, and knowledge tool for senior managers • Methodological and impact assessment challenges remain
Natura Cosméticos	Cosmetics	• Grey water in consumer use phase most important • WF helpful for consistent way to assess products, and for freshwater strategy • Methodological challenges with grey water footprint
Unilever	Consumer Goods	• Example of attempting a water footprint across many (1600) products • Water footprint methodology was not likely clear for first study
Levi & Strauss	Textiles	• LCA approach highlighted water use in upstream cotton production and downstream consumer washing
Lafarge	Cement	• Direct water use in operations was largest component of water footprint • Difficulties with consistent definitions and grey water calculations

3.2.1 Coca-Cola

The Coca-Cola Company and The Nature Conservancy conducted several product-focussed water footprint assessments. These assessments were done in an effort to understand the applicability of using water footprints to address freshwater challenges from a corporate perspective and to support corporate water stewardship.

The study included a water footprint assessment on three products – a 0.5 litre PET bottle of Coca-Cola, beet root sugar supplied to European plants, and two orange juice products made in the United States.

The analysis on the 0.5 litre PET bottle of Coca-Cola presents a clear example of a water footprint assessment for a product, the result of which is shown in Figure 3.6. The water footprint assessment includes the direct and indirect water required to make the packaging, the Coca-Cola drink, and the direct water requirements for the bottling process. The green water footprint was 15 litres, the blue water footprint was 8 litres, and the grey water footprint was 12 litres. The majority of the green and blue water footprints are associated with sugar beet production, whereas the grey water footprint was associated with both nitrogen fertiliser used in beet root production and with cooling water used in making the PET packaging. The direct water requirements from operations of the bottling plant represent only about 1% of the overall water footprint of the product. Thus, the indirect water footprint from the supply chain is the most significant component.

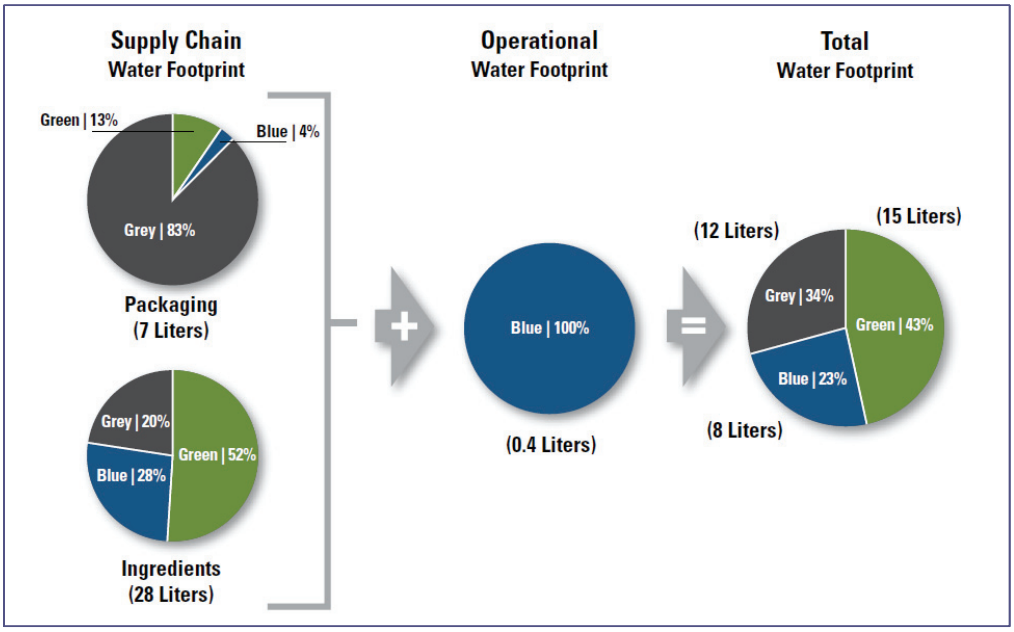


Figure 3.6 Water footprint of a 0.5 litre bottle of Coca-Cola (Coca-Cola Company and The Nature Conservancy 2010)

The water footprint assessment of beet sugar presents a good example of a slightly different type of assessment as it focussed on the production of an agricultural product input from a variety of geographical locations. Beet root was studied in more depth because it constituted the majority of the water footprint for a Coca-Cola drink. As represented in Figure 3.7, the average green water footprint to be 375 litres/kg of sugar, the average blue water footprint to be 54 litres/kg of sugar, and the average grey water footprint to be 128 litres/kg of sugar. However, the components of the water footprint vary significantly by region and can vary by more than threefold, as is the case in France as versus Greece.

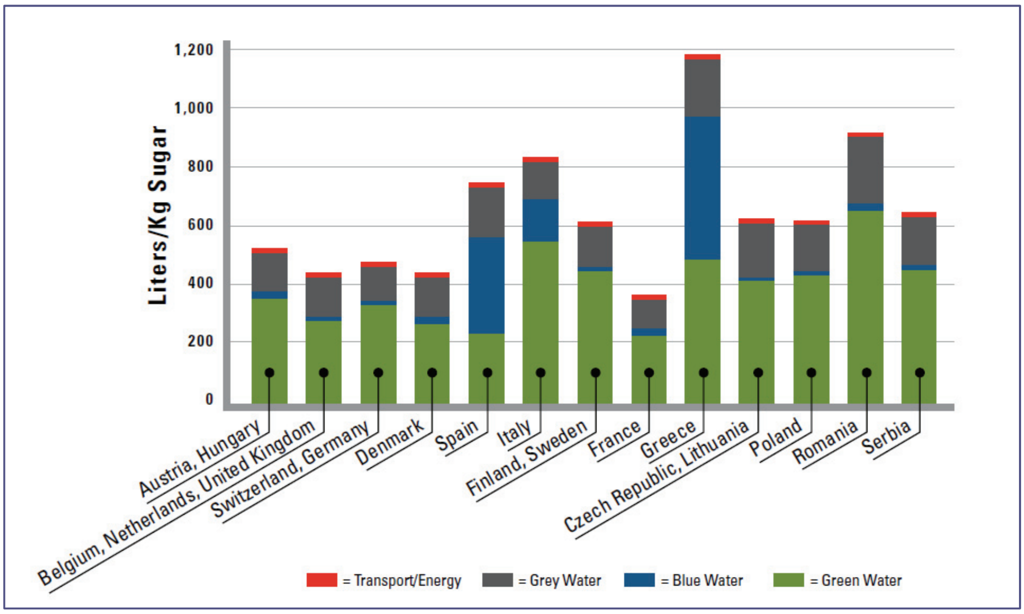


Figure 3.7 Water footprint of beetroot for use in Coca-Cola products by country of production (Coca-Cola Company and The Nature Conservancy 2010)

Key observations made by Coca-Cola regarding the applicability of water footprints included:

- The perceived value of water footprints is the ability to disaggregate water use by component. This includes distinguishing between blue, green and grey water, and distinguishing between direct operational and indirect supply chain water requirements. Understanding each of these components in the context of a local watershed allows impacts to be assessed at a local level.
- Agricultural supplies, including beet sugar, constitute the largest portion of the water footprint of Coca-Cola products. This motivates strongly for direct engagement with agricultural supplies for sustainable water use.
- The direct water requirements from manufacturing processes were a minor component of the water footprint.
- To understand the impact of water use, the water consumption must be considered within the context of the cumulative effect of water use as a shared resource. This includes understanding changing impacts throughout a year.
- Care must be taken when communicating with water footprints, as numeric labels do not provide sufficient information to make informed choices.
- Water footprints can be highly sensitive to a few input parameters.

3.2.2 SABMiller

SABMiller worked with WWF to conduct a water footprint for beer produced in two countries: South Africa and the Czech Republic. The purpose of the study was to understand and compare water used in SABMiller's supply chain in these two different countries, to understand how water footprint can help the company make decisions, and how a footprint can be contextualised into specific water catchments. SABMiller recognises that the majority of its water footprint will be in the agricultural cultivation phase, and sees it as a priority to understand which agricultural areas face the highest water risk and to work with farmers in those areas to use water efficiently.

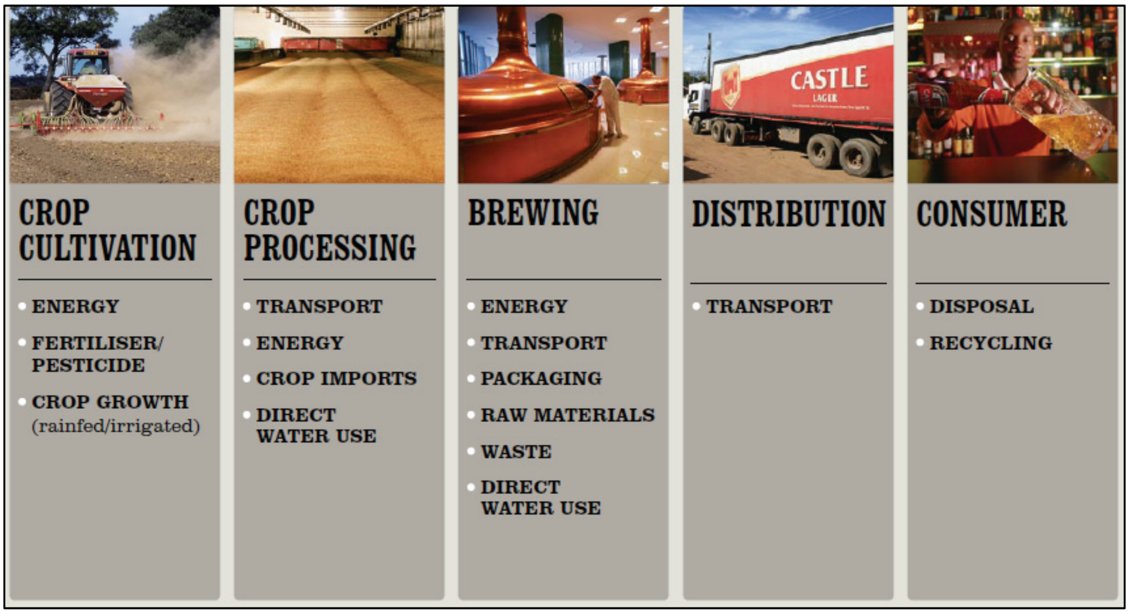


Figure 3.8 Value chain for beer production (SABMiller and WWF-UK 2009)

In its water footprint study for one litre of beer produced in South Africa and one litre of beer produced in the Czech Republic, SABMiller looked at crop cultivation, crop processing, brewing, transport and consumer use and disposal. In both South Africa and the Czech Republic, agricultural cultivation accounted for more than 90% of the overall water footprint, thus highlighting the importance of its upstream supply chain.

In addition, the study showed that the water footprint of beer made in South Africa had a footprint of 155 litres of water per litre of beer, as versus 45 litres of water per litre of beer for production in the Czech Republic. The reasons for this difference related to crop production, including increase evaporative demand in South Africa and a higher blue water component due to higher reliance on irrigation in South Africa.

Importantly, these numbers must be reviewed with caution. One footprint being larger than another does not necessarily mean it is "worse" as the degree of impact cannot be determined without a full understanding of the local context. Thus, at present the water footprint for each place of production is more useful for benchmarking than for assessing impact.

SABMiller found three main value-adds from the water footprint exercise:

- As an overview of water use in the supply chain, including the quantity and location of such use.
- As a source of strategic information to assess water risk, both in terms of water availability and in terms of regulation, allocation and pricing.
- As a tool for senior managers to provide them with knowledge regarding the broad issues of water management, and enable them to engage with stakeholders and establish partnerships.

Finally, the SABMiller study also highlighted areas in need of improvement for performing water footprint assessments. The methodological improvements needed include a better way to assess the grey water footprint, and whether green water use should be calculated compared to what natural evapotranspiration would have been as opposed to in a gross manner. In determining impacts, the SABMiller study indicates the need for more guidance on how to analyse water impacts given that water is a local resource.

3.2.3 NATURA COSMÉTICOS

Natura Cosméticos is a large cosmetics company in Brazil. In an effort to better understand the applicability of water footprint to its freshwater sustainability strategy, Natura conducted a pilot water footprint study on two of its products – a perfume and a body oil. Natura looked at the green, blue and grey water footprints throughout the supply chain of these products, which include a raw materials and processing phase for the product and its packaging, an operational phase, and a use phase. This example is relevant to consumer products companies where significant water footprints may result from downstream consumer use of the product.

Interesting insights can be gained by Natura's analysis of its body oil, as this is one of the few case studies which looks at grey water at a local level from consumer user of a product. The study found 98% of the body oil's footprint to result from grey water and 96% of this was during the use phase, as the product is washed off the body and increases the pollutant load in waste water. Natura went on to understand the importance of locality in terms of treatment of water. If waste water is treated, then many of the pollutants are removed so the relative impact is lower. If waste water is not treated, as is the reality in Brazil, then the relative impact is higher. Still the absolute grey water footprint was found to be largest in urban centres, despite water treatment facilities, due to the volume of product use. The response question that emerged from this analysis is to understand who is responsible for water sanitation and how corporations can contribute to increase sustainability.

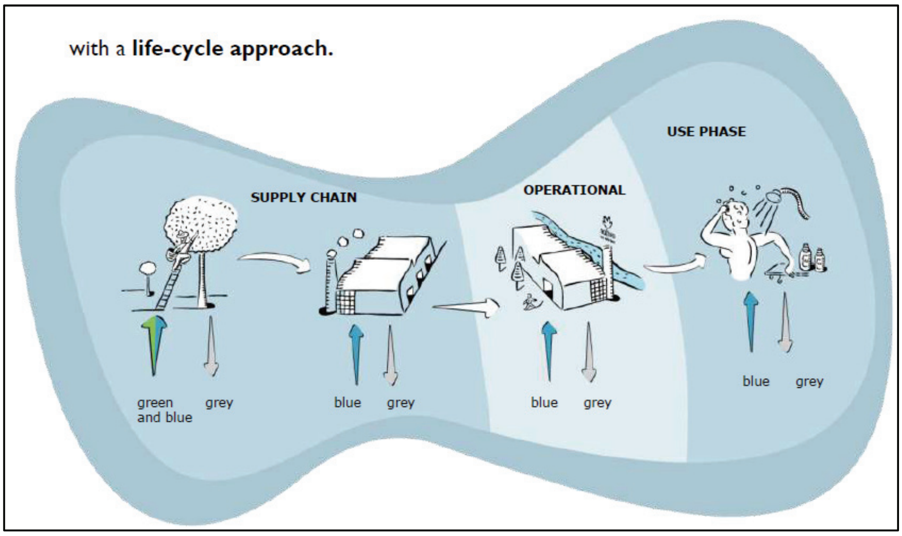


Figure 3.9 Life cycle view of water use in cosmetic products (Franke 2011).

Natura found the following key insights regarding the value and challenges of water footprint:

- A water footprint assessment across products can build a consistent understanding of freshwater impacts for the corporate portfolio.
- Water footprint can be used as a tool to establish a water sustainability strategy, and there is thought to be potential to combine it with offsetting initiatives.
- Assessing the grey water footprint came with challenges, including the need to have access to sanitation and water quality data, and how to consider ecotoxicity and biodegradability factors.

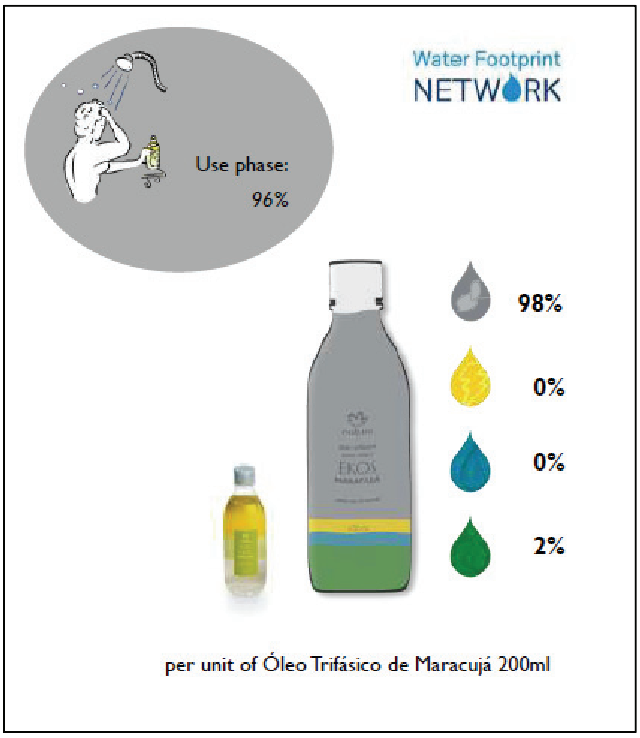


Figure 3.10 Water footprint of a Natura body oil, illustrating the grey water footprint of the use phase (Franke 2011).

3.2.4 UNILEVER

Most of the companies conducting water footprint studies have focussed on one or a few important products. This is because conducting a water footprint requires understanding the upstream and downstream water use for a product, and requires knowing the origins of all inputs to each product. The information-gathering stage can be complicated for even a single product produced in a single location, so gathering this information for all products requires significant effort.

Unilever represents an example of a company which has attempted a water footprint for most of its business, rather than focussing on a specific product. Unilever conducted a water footprint assessment across 1600 of its products in 14 countries, which together represent more than 70% of the sales volume. The types of products investigated included mostly personal hygiene and household cleaning products.

Figure 3.11 shows the overall distribution of the footprint in terms of the water required to produce the raw materials used, the water added during operations, and the downstream water used by consumers. The footprint indicates that approximately 50% of the water footprint is upstream raw material water requirements, and 50% is from downstream consumer use of the product.

While this was an early and ambitious study for its time in 2008, it appears that the methodology used differed somewhat from a normal water footprint approach and may be missing a few key pieces of information. First, Unilever chose to exclude water used during operations as they have a different metric which covers operational water use. Second, it is not clear that the upstream or downstream water use takes into account pollution in terms of the grey water.

Figure 3.11 Distribution of water footprint for selected Unilever products (Unilever 2008)

The Unilever study also showed the water footprint contribution of each category of product studied, as shown in Figure 3.12. Unilever has made strides to reduce its water footprint in response to information learned. For example, nearly 40% of the water footprint in the study was caused by laundry detergents, particularly downstream consumer washing. Unilever introduced new washing products which require two-thirds less water in the washing cycle. However, while this effort is well-intended, lacking information about the water quality implications of the detergent leaves a question as to whether the most significant impacts are due to the volume of water used by the consumer, or the implications of the chemical pollutants resulting from product use.

Unilever has remained interested in water footprints, and has undertaken pilot projects to apply water footprint assessments to its food products now, including a butter spread and tea. It is undertaking this study with a methodology more aligned with other water footprint studies, for example by including blue, green and grey water footprints. Additionally, it is looking at impact assessments and hotspots.

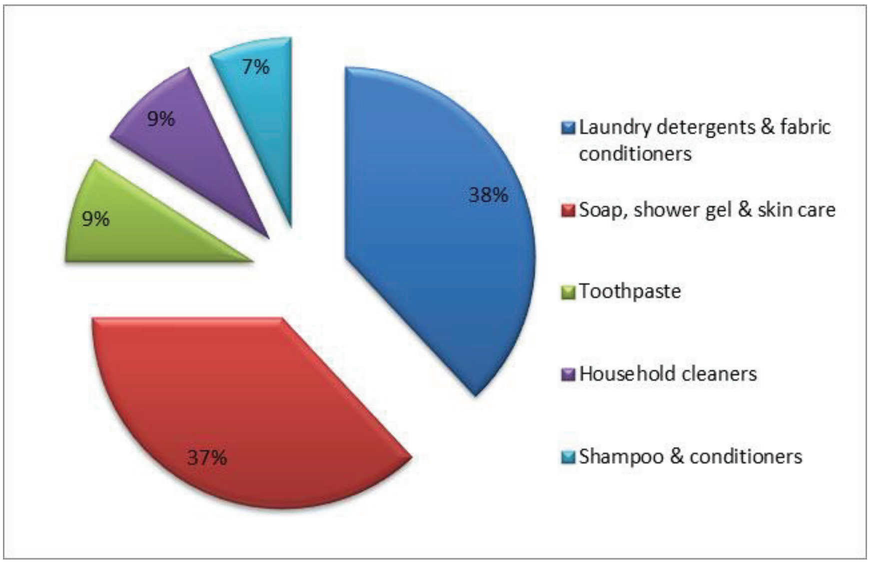


Figure 3.12 Distribution of water footprint by product type for Unilever cleansing and hygiene products (Unilever 2008)

3.2.5 Lafarge

Lafarge is a French industrial company which produces cement, construction materials and wallboard. In an effort to understand the water impacts of its operations and take steps to reduce impacts, Lafarge conducted a pilot study to understand the freshwater requirements of one of its plasterboard production facilities in the UK. It then set up additional water footprint studies focussed on cement production to develop a guide to manage and conserve water resources.

Limited information could be located on the results of the Lafarge water footprints. From what can be gathered, for the plasterboard facility the water footprint was found to be 6.6 litres of water per m^2 of plasterboard produced. The water footprint was primarily the result of direct water use and waste water produced during operations, as opposed to being driven by indirect use in the supply chain as is the case with food and beverage companies. Similarly, in its cement water footprint studies, the majority of the water footprint resulted from blue water use during operations, grey water from operations discharge, and some supply chain water use in the quarrying of raw materials.

Lafarge attempted to contextualise its water impacts in the local environment, and found that for its plasterboard facility there was not an immediate negative impact on the local water resources. Challenges were encountered when trying to understand the impact of a cement production facility on the local environment, and more work was required. Lafarge indicated it would use water footprint as an awareness tool, and to develop a water action plan.

The Lafarge case studies illustrate that general manufacturing companies will likely find that the majority of their water footprint results from direct water use and discharge during operations, making the water footprint's focus on supply chain a less valuable tool. Additionally, the Lafarge case studies highlighted the difficulties in calculating the grey water footprint due to difficulty in obtaining the needed data, and the need to more clearly define terms such as withdrawal or consumption.

3.2.6 Levi Strauss & Co.

Levi Strauss & Co. conducted a water-focussed life-cycle assessment where it determined the water required for the raw materials, production processes, use and disposal of a pair of Levi's jeans. While this analysis did not break down blue, green and grey water or identify the origin of the water used, it went beyond a typical life-cycle assessment by understanding all water inputs in the supply chain. It also provides an interesting example of an analysis in the textiles industry, and one in which the "use phase" of a product contributed significantly to water impacts.

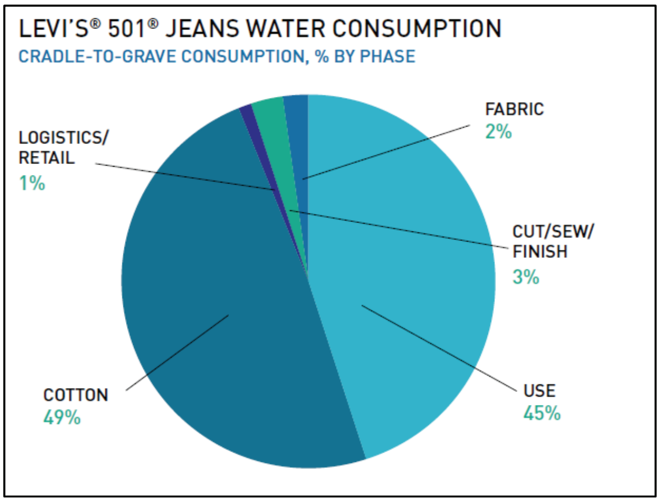


Figure 3.13 Water consumption in a life cycle assessment for Levi's jeans (Levi Strauss & Co 2010)

The Levi life cycle assessment showed that 49% of the freshwater required for a pair of Levi's jeans stemmed from the growing of cotton needed for its raw materials, and another 45% of the freshwater requirements in the life cycle of a pair of jeans was due to washing by the consumer. Thus, the upstream agricultural water use and the downstream consumer water use were the most significant contributors, whereas water use in operations was relatively much smaller. Once again, this highlights the importance of looking at the supply chain and taking steps to engage with suppliers and consumers.

3.2.7 CDP Water Disclosure

A final example of water footprint in the corporate space is through reporting and disclosure. While companies have to this point been able to use water footprint for internal benchmarking, a water footprint may also be useful as an external reporting and disclosure mechanism.

Similar to a carbon footprint, water footprint is viewed as being a useful accounting tool which addresses direct and supply chain water use. The Carbon Disclosure Project (CDP), which had originally focussed only on carbon disclosure, launched an analogous Water Disclosure project and released its first report in 2010. The CDP Water Disclosure project discusses the value of water footprints in terms of gaining a comprehensive understanding of supply chain water use. Although no formal reporting forum currently specifies water footprint as an accounting metric, water footprints may be useful for this purpose in the corporate space going forward.

3.2.8 Insights from product and company water footprints

Several important insights regarding the relevance of water footprint to companies can be gathered based on the case studies discussed.

A first insight is that certain industry sectors will likely find water footprints more relevant than other sectors. Most of the companies engaging with water footprints are those where water plays a significant role in the supply chain, which makes sense considering that the insight which water footprints enable is the ability to see virtual water as opposed to only direct water use. The most active companies with water footprints are those which rely on agricultural inputs, as is the case in the food and beverage sector or textiles. To a lesser extent but increasingly, companies with significant downstream water implications are also exploring the use of water footprints, such as in the beauty and cosmetics industry where products add pollutants to water during washing.

To date, water footprint has not gained significant traction in industries such as chemicals or mining. This is likely because direct water use and waste water from operations are the most significant water concerns, rather than water use elsewhere in the supply chain. Thus, it makes more sense to remain focussed on water use and treatment in operations rather than using a water footprint to determine water use through the supply chain. An exception to this is the production of chemical products for use by consumers such as soaps, in which case downstream grey water would be of concern, similar to the cosmetics industry.

A second message is that water footprint at present is better-suited to understanding blue and green water than it is to understanding grey water. Questions arise regarding the grey water methodology, and important distinctions that are missed when water quality impacts are represented as a water quantity. Thus, companies where grey water is the most significant factor suggest that critical questions must be further explored.

A third insight is regarding how water footprint can be most useful to companies. One of the most valuable contributions of a water footprint is in understanding blue and green water use in the supply chain, and the potential contribution to understanding water risk. Additionally, water footprint can be useful as a benchmarking tool to understand supply chain water use as a starting point, and to track improvements. Water footprint could assist with benchmarking products within a company, or between companies.

However, a fourth insight related to the point above is that companies have noted the importance of carefully communicating a water footprint as information can be misinterpreted if the context is not known. Thus, in addition to computing a water footprint, the local context of water use must also be understood and communicated along with the water footprint number itself. This need to understand the context, particularly the local context of water requirements for raw materials, leads a need to understand global commodity markets and alternatives. For example, is it better from a water-perspective to buy wheat produced in one area of the world as versus another? This question will be addressed in the next section. However, although water scarcity can be addressed to some extent, the political, social, economic and other environmental considerations cannot be easily integrated.

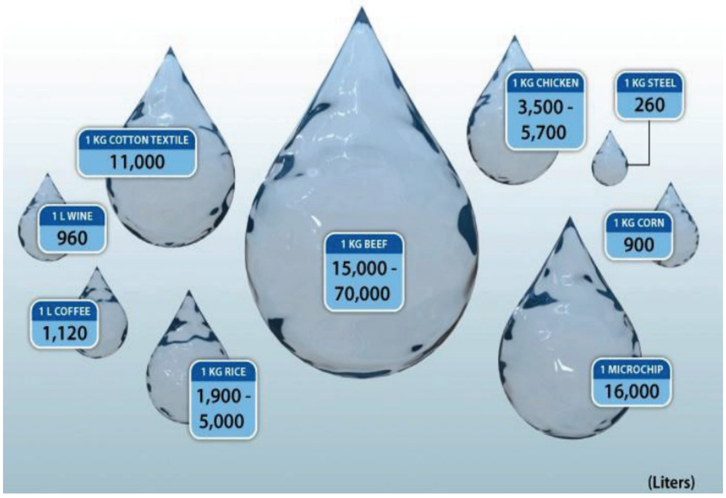
Finally, the complexity and information-intensive nature of a water footprint must be acknowledged. For a company to conduct a comprehensive water footprint across all of its products, with tens or hundreds of ingredients from various places around the world, will be extremely difficult. This leaves a question regarding whether the main benefits of a water footprint can be realised using a more simplified approach, or whether a water footprint is simply not applicable to an entire company or a very complex product.

Key Points for WF of Products and Companies

- Water footprint is most relevant to companies and products where significant water impacts occur during the supply chain, such as the food and beverage industry. Water footprint is less relevant where direct water use is of the most concern, such as in the chemicals or mining sector.
- Water footprint can be useful as a benchmarking tool, and to understand blue and green water supply chain risks.
- Significant questions exist regarding the methodology and relevance of a grey water footprint.
- The local context of supply chain water use, including social, economic and environmental considerations, is necessary to give meaning to a footprint.
- Completing a WF assessment for a complex product, or for a company with a large number of products, is a time and data-intensive exercise and may not be practical in all circumstances.

3.3 Commodities and Markets

Water footprints for commodities and markets emerged next. This follows a natural logic, as footprints for commodities and markets can link a country-level footprint to a company. A commodity water footprint can help companies understand the water dimensions of the supply market based on location.



3.3.1 Wheat at a Global Level

As one of the most widely cultivate cereals on a global level, an academic study of the water footprint of wheat was conducted by M. Mekonnen and A. Hoekstra (2010). The aim of the study was to estimate the blue, green and grey water footprint of wheat from a production and consumption perspective, and at a fairly granular level. The study divided up the globe into grid of approximately 10 by 10 kilometre squares if measured around the equator, and then took into account local climate and soil, and nitrogen fertiliser application rates in order to calculate crop requirements.

The global average water footprint of wheat was calculated to be 1622 m^3/ton. The Unites States, China and Russia had the largest absolute wheat water footprints. Significant variation was observed regarding water footprint per ton of wheat produced. For example, Morocco and Iran had water footprints of more than 3600 m^3/ton of wheat, whereas France and the UK had water footprints of less than 600m^3/ton of wheat. Differences are largely driven by climatic conditions and agricultural efficiency. Figure 3.14 shows the green, blue, grey and total water footprint of wheat per ton of wheat produced.

The study also depicts virtual water imports and exports from the trade of wheat products, as shown in Figure 3.15. The study found that global trade enabled significant 'water savings' through trade, and that the water footprint of wheat would be 6% higher if no trade occurred. The United States, Canada and Australia were the largest virtual water exporters through the trade of wheat products, responsible for 55% of the virtual water exports. As blue water often has higher opportunity costs than green water, it is also helpful to understand virtual water flows by footprint component. The United States and India were the largest exporters of blue water.

This detailed understanding of the water footprint of wheat can be used to understand global trade patterns, and can be used to understand the water footprint of particularly production at a fairly local level. The ability to use this information was not discussed in the study, but may have value from both a policy and corporate perspective if it can be used together with environmental, social and economic indicators.

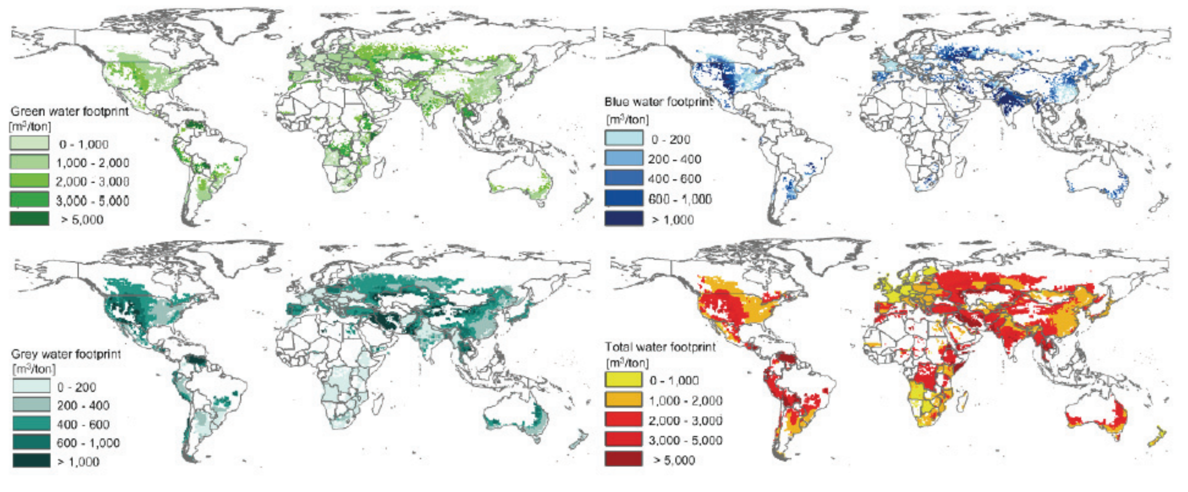


Fig. 1. The green, blue, grey and total water footprint of wheat production per ton of wheat. Period: 1996–2005.

Figure 3.14 Green, blue, grey and total water footprint of wheat production per ton of wheat (Mekonnen and Hoekstra 2010)

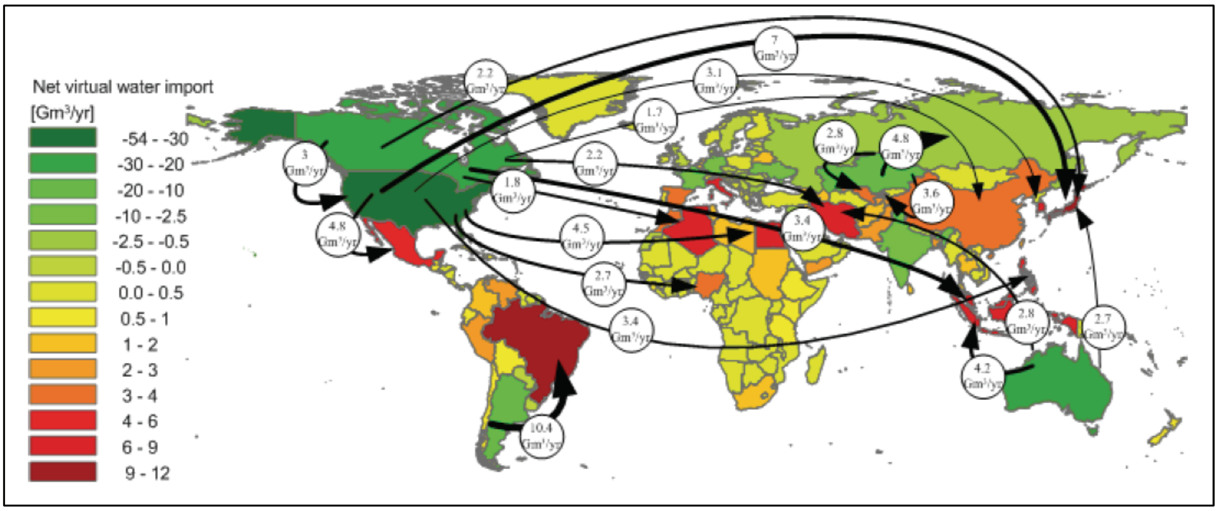


Figure 3.15 Net virtual water flows from the trade of wheat products (Mekonnen and Hoekstra 2010)

3.3.2 Cotton

Chapagain et al. (2005) conducted a water footprint study of worldwide cotton consumption, including identification of the location of production sources. One of the motivations for this type of study is to provide transparency of product information to consumers in order to enable consumers to become aware and responsible for the impacts of consumption. The authors state that this is particularly important considering the absence of proper water pricing mechanisms and the absence of access to product information given that impacts typically occur across boundaries.

Figure 3.16 illustrates the potential water impacts of cotton production at the crop production and processing stages. The impacts include blue and green water use during crop production, as well as grey water impact due to fertiliser use. During the processing stage, most water impact is due to grey water from polluted return flows.

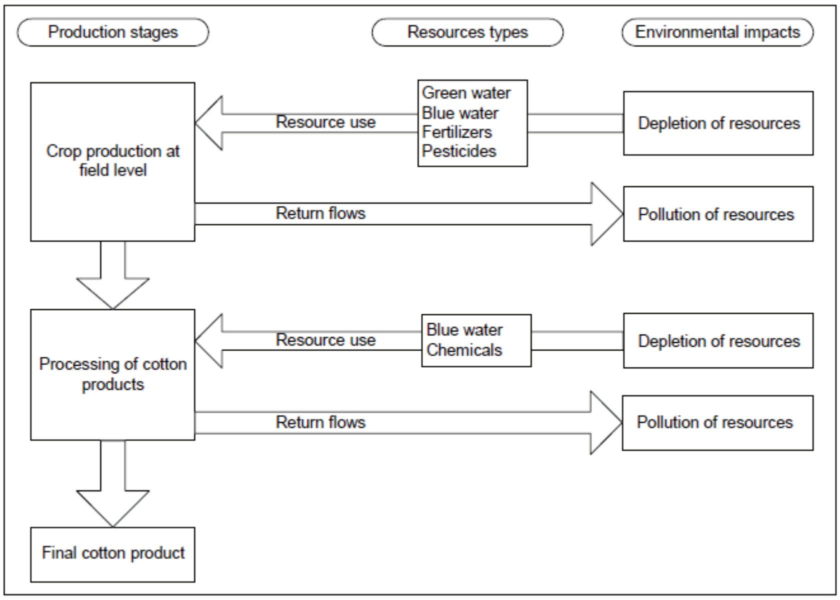


Figure 3.16 Water impact of cotton production (Chapagain et al. 2005).

The blue, green, grey and total virtual water flows due cotton consumption in various geographical areas was determined. Figure 3.17 represents the virtual water flows from cotton consumption in the European Union. This illustration of water impacts can help consumers link their consumption patterns to the water required for production stages, creating transparency and creating an opportunity for accountability. For example, cotton consumption in the European Union can be linked to significant blue water consumption and a large grey water footprint in Uzbekistan, contributing to the desiccation of the Aral Sea.

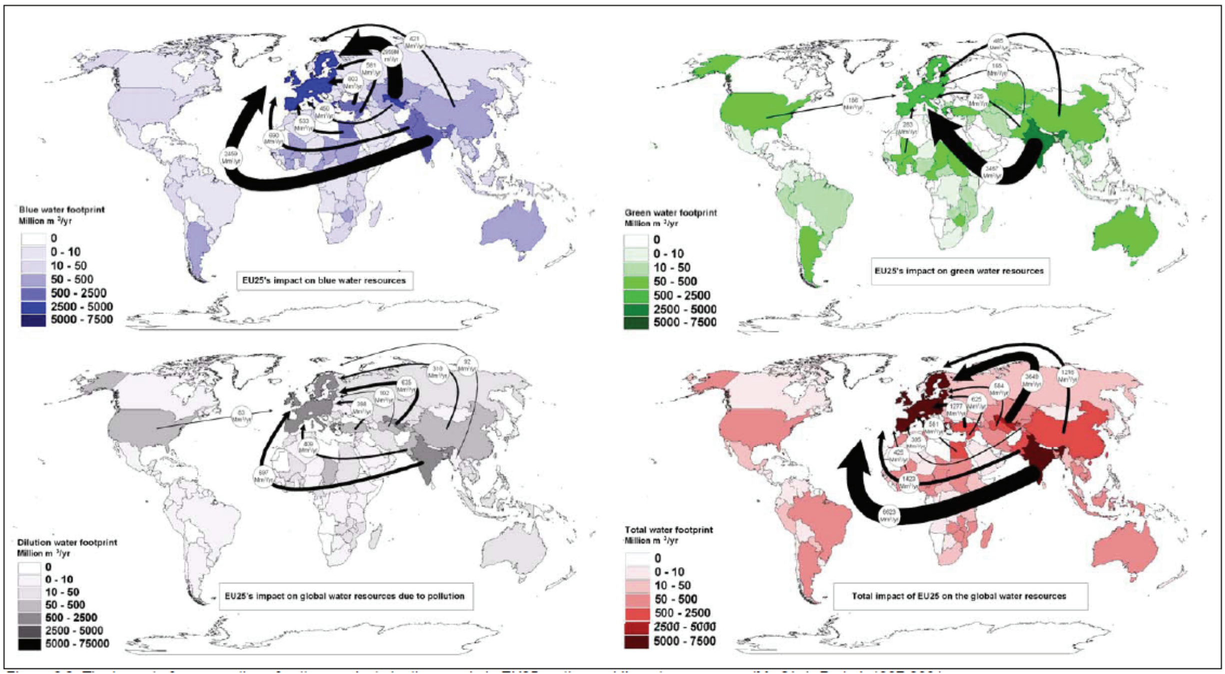


Figure 3.17 Virtual water flows from cotton consumption in the European Union (Chapagain et al. 2005)

3.3.3 Biofuels

As efforts turn toward developing renewable energy sources, biofuels present one option. However, production of biomass to produce heat, electricity or biofuels carries significant water implications, as well as food implications. Water footprint is beginning to be used as a tool to compare the water impacts between different types of biofuels, and to compare the water implications of different types of energy sources such as biofuels, hydropower and fossil fuels.

An academic study was conducted by W. Gerbens-Leenes et al. (2009) to compare different sources of biofuel, and to indicate the water footprint per unit of bioenergy produced from different crops used to generate bioelectricity, bioethanol and biodiesel. The water footprint of bioenergy is large compared to other sources of energy due to the water requirements during agricultural production. The water footprint of bioelectricity per unit of energy was smaller than the water footprint of biofuels because the entire crop can be used in the generation of heat or electricity, whereas only certain parts of the crop can be used in fuel production. Additionally, the study showed that the water footprint varied greatly with the type of crop. This type of study can have policy and research implications, as the water required for bioenergy production will be one of the factors considered in developing energy sources.

Biofuel-based transport was also studied by asking how the water footprint of European countries would change if they replaced 10 percent of transport fuels with biofuels by 2020 (Gerbens-Leenes and Hoekstra 2011). The study found that the transport-related water footprint would grow to 60 Gm^3 per year if the most water-efficient crops for making biofuels are used. This is a significant requirement, and would likely have impacts on food prices, land use and water depletion. As a point of reference, the total food and cotton water footprint for European countries is approximately 600Gm^3 per year. However, it is important that 95% of this water would likely be green water, which generally has a lower opportunity cost than blue water.

Proponents of biofuels may push back on the footprint methodology, stating that net green water consumption is a better indicator than gross (total) green water consumption. This is because natural or reference vegetation, which would be present if the biofuel crops were not grown, would also utilise green water. Thus, the impact is better represented by the difference from a natural vegetation reference point. This is particularly important with biofuels, as much of the water footprint would likely come from green water.

3.3.4 HYDROPOWER

Water footprint has been used in an effort to understand the water impacts of hydropower, with Hoekstra and Mekonnen (2011) suggesting that a water footprint assessment be added as an evaluation component of hydroelectric dams. Significant divergence exists, however, around the most appropriate water footprint accounting method to use to when calculating the impacts of hydropower. The applicability of water footprint to hydropower is a case where the core methodology of a water footprint has been challenged, and where the results of a footprint can be misleading. Two key questions arise:

- **Gross versus net evaporation from the dam** – A water footprint traditionally gives the total, or gross, evaporation. An alternative would be the net evaporation, which would consider the evaporation as it differs from a natural reference condition. In other words, what the evaporation would have been if the dam had not been constructed. With net evaporation, the capturing of rainfall which would not otherwise have been captured is also taken into account.
- **Attribution of evaporative losses** – A dam has multiple users, so it is not clear that all evaporative losses from the dam should be attributable to hydroelectricity generation. For example, a dam ensures water availability to downstream users during low flow periods.

4 stages of water use during the production cycle are most relevant when thinking hydropower, and are useful to compare different sources of energy. These are: (1) Water use in fuel supply, including extraction of raw materials, (2) Water use which occurs as a result of water storage required for generation, (3) Water use in generation, and (4) Downstream water quality.

Different from most of the product or commodity footprints thus far, the most significant water footprint impact of hydropower is during the storage phase due to evaporation. With most products and commodities, water use during the storage phase is negligible compared to upstream, direct or downstream water use. Thus, calculating the water footprint of hydropower has a fundamentally different point of water use as its primary consideration.

Hoekstra and Mekonnen's study (2011), released by the Water Footprint Network, calculates the blue water footprint of hydroelectricity through a study of 35 dams. The method used by Hoekstra and Mekonnen calculated gross evaporation as opposed to net evaporation, and attributed all evaporative losses to hydropower generation. The main findings include:

- The size of the water footprint in terms of m^3 of water per unit of hydroelectricity varies significantly between dams, as illustrated in Table 3.2. The size of the reservoir surface area in relation to the installed capacity is the largest determining factor of the size of the water footprint.
- The size of the reservoir has a larger impact on evaporation than climate.

Table 3.2 Range of water footprint results for hydropower generation (Mekonnen and Hoekstra 2011).

Minimum	Average	Maximum
0.08 m^3/MWh	18.8 m^3/MWh	235 m^3/MWh

Subsequent literature has challenged the approach of using gross evaporation, and attributing all evaporation to hydroelectricity generation. In 2011, Manitoba Hydro in Canada completed a water footprint which uses a net as versus a gross evaporation calculation (Adams 2011). In this study, due to the cold climate and high rainfall, the dam actually resulted in a net water gain because it captured more rainfall than was evaporated from the dam. A case study in New Zealand also took a net instead of a gross approach, and showed that comparing evaporation to the evapotranspiration that would have occurred if the dam had not been built has profound consequences on the size of the water footprint (Herath et al. 2011).

Pegram et al. (2011) assert that in order to reflect the impact of water use on local water resources, net evaporative loss is the appropriate measure. Comparing evaporation with evapotranspiration from pre-impoundment vegetation has a profound impact on the calculated water footprint. Additionally, capturing of precipitation must be considered. This is because the reservoir serves as part of the river system, and therefore the loss and gain of water from the reservoir surface has a direct impact on the water resource and must be understood. Pegram et al. also contend that evaporation from a reservoir should be attributed to all users, and that downstream opportunity costs should be considered.

The result of a water footprint assessment for hydropower depends profoundly based on the methodology used. This is potentially dangerous and misleading, particularly with the increasing global attention being paid to the relationship between water and energy.

3.3.5 Insights from Commodity and Market Footprints

Water footprints focussed on commodities and markets can help companies understand supply chain risks and alternatives by providing a global perspective, and provide information which allows them to make more informed decisions. Additionally, this understanding of supply chain can create transparency and provide information which allows the public to hold companies accountable for supply chain decisions. As with all water footprints, though, understanding the local context, including economic and social factors, is critical in order to understand impacts. Commodity water footprints can also help to understand global trade patterns, and thus potentially inform trade policy or strategy.

Further, water footprints for commodities are beginning to be utilised to compare supply alternatives, for example in comparing different types of biofuels or different types of energy sources. This type of comparison could be useful from a policy perspective as well as a corporate perspective. Need for caution arises, however, when applying the water footprint concept in different settings. Hydropower water footprint is an example where applying the same methodology that is used for agricultural products creates a misleading metric.

3.4 Basin-level water footprints

A final area where water footprints are being explored is at the basin-level. The intended audience of a basin-level footprint is often the public sector, including national, provincial or local government. Among the ways in which a water footprint could assist the public sectors are in awareness creation, fostering of strategic dialogue, and informing sector policy or development planning.

Exploring the applicability of water footprints at the basin level is in the early stages of development, with the Nile Basin, the Spanish river basins, and the Breede-Overberg basin in the Western Cape below illustrating some of the lessons learned thus far. Much uncertainty exists regarding how a water footprint may be useful at the basin-level.

3.4.1 Nile Basin

Virtual water flows for selected crops and livestock products through Nile Basin countries were studied in an effort to inform a discussion on national water security (Zeitoun et al. 2009). This represents a basin-level study which crosses state boundaries, as opposed to other basin-level studies which take place entirely within one state. Observations and opportunities around trade and water security between Nile Basin countries was the focus, with the intent that understanding virtual water flows can help devise policy.

Several insights regarding trade in the region were gained from studying virtual water flows. First, virtual water trade between Nile Basin Countries was much smaller than virtual water trade between Nile Basin countries and countries elsewhere in the world. Only 900 million m^3/year of virtual water trade through crops occurred between Nile Basin countries, whereas 39,000 million m^3/year of virtual water was imported from elsewhere and 11,000 39,000 million m^3/year of virtual water through crops was exported. Thus, trade within the basin does not contribute significantly to water and food security. Second, overall the basin is dependent on importing significant amounts of virtual water in the form of crops from outside of the basin, and the level of trade varies significantly by region. The Southern Nile states produce and export more virtual water through crops compared to the Eastern Nile states which import significantly more.

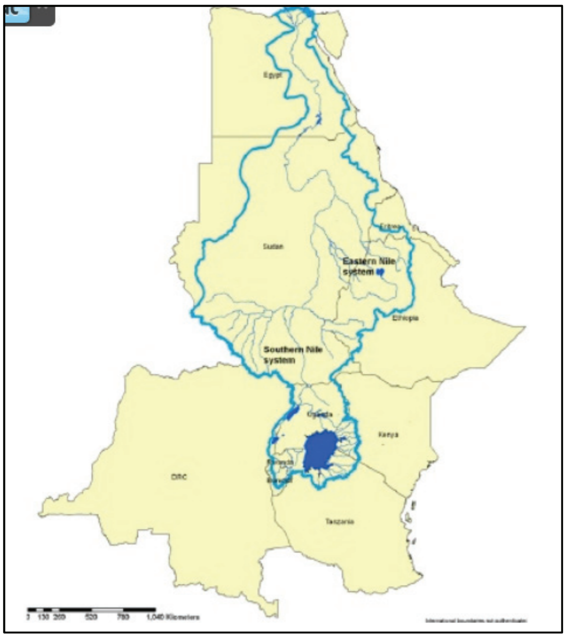


Figure 3.18 Hydrological border of the Nile Basin in relation to its riparian states (Zeitoun et al. 2009)

In addition to the virtual water flows study, an initiative is in progress under the Nile Equatorial Lakes Subsidiary Action Program (NELSAP) to use water footprint to inform trade policy and strategy to improve the efficiency of water use for production. This initiative builds on the idea that opportunities exist to improve food and water security through trade within the Nile Basin, and seeks to begin discussions around trade, agricultural policy and water use efficiency. The initiative is currently in a stage of capacity building and awareness creation with representatives from Nile Basin countries.

3.4.2 River basins in Spain

As the most arid country in the European Union, water resources management in Spain is an important and controversial issue. To help improve inform and optimise water policy decisions and to contribute to the implementation of the EU Water Framework Directive, government policy as of 2008 required a water footprint of different socio-economic sectors to be used in the development of River Basin Management Plans (Official State Gazette, 2008). Water footprint is seen as tool which can be linked with hydrological, socio-economic and environmental indicators to support decision making in water management planning, to inform water accounting, and to improve allocation.

Since this requirement was introduced, initial water footprint studies have been completed which have largely focussed on agricultural production within each basin. Many practical challenges have been encountered in performing these studies which leave them still in the early stages of understanding the footprint and how it may inform policy:

- ***Integration with other indicators*** – Water footprint is not yet sufficiently integrated with socio-economic, hydrological or environmental status indicators to allow the footprint to inform planning decisions.
- ***Data availability*** – Data is often available at a national or provincial level, which must then be adapted and simplified to a basin boundary, introducing uncertainty and errors.
- ***Inconsistency in terminology*** – It was found that water footprint terminology sometimes varied in literature, and therefore it was difficult to ensure that each group utilised a consistent approach.

In summary, while water footprint at the basin level continues to be investigated as a tool to inform water management planning and allocation, key challenges must be overcome to allow its use in decision-making processes.

3.4.3 Breede-Overberg River Basin

As part of the development of a catchment management strategy by the Breede-Overberg Catchment Management Agency (BOCMA) in the Western Cape, South Africa, a WF of the catchment and sub-catchment areas was completed (BOCMA, 2011).

The intent of the WF was to provide insights which could inform strategy and planning in the water sector, for example with allocation, by connecting economic indicators with productive water-use metrics. The WF considered economic sectors and specific crops within the agricultural sector, sub-catchment areas, blue versus green water use, and the link between water use and economic contributions from income and employment. Example results of the footprint in terms of economic productivity and jobs for blue water use are shown in Figure 3.19.

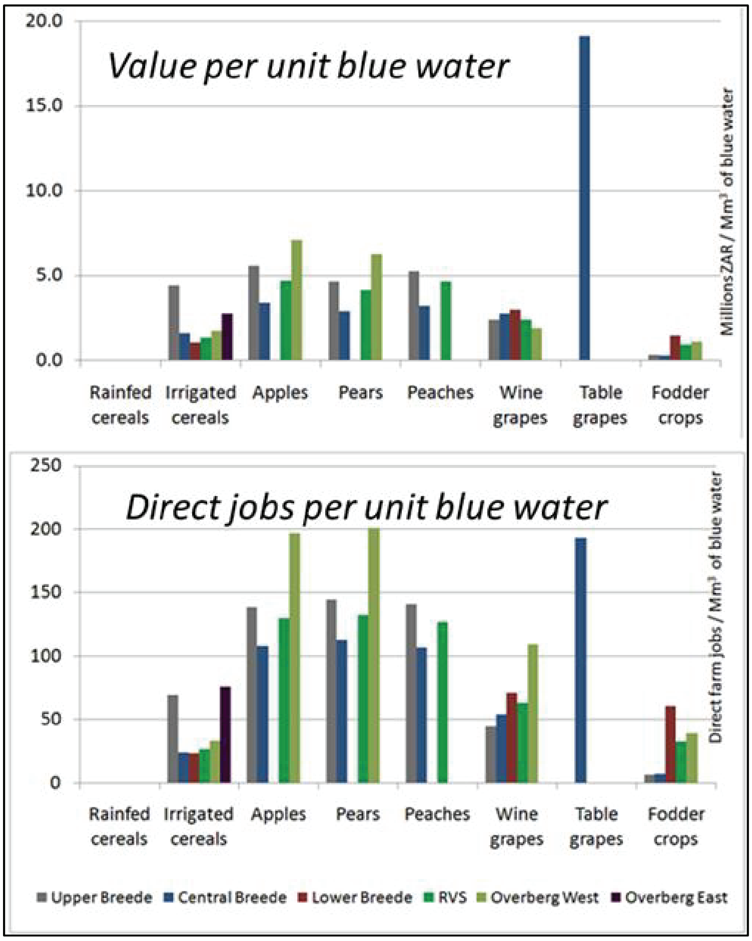


Figure 3.19 Economic productivity and jobs in relation to the blue water footprint of agricultural products in the Breede-Overberg catchment (BOCMA 2011)

Among the insights provided by the footprint:

- Agriculture, particularly irrigated, dominated water consumption. Areas with higher blue water consumption were also more economically active.
- Clear differences existed in the value and employment created between different types of crops. Crops grown in certain locations generate higher economic returns per unit of water used than if grown in other locations, leaving space for dialogue around how to use water in an economically efficient way.

The results of the WF were presented to both the catchment management agency to inform strategy, and to water users. Although interesting to the catchment management agency, the footprint was not sufficiently connected to other environmental, social and economic indicators to play a significant role in strategic planning or allocation. However, water users particularly in the agriculture sector found it a useful point of departure for discussion and for understanding the roles of other sectors. The main benefit of the WF was thus as a communication and discussion tool rather than as a tool to directly inform strategy, planning and allocation decisions.

3.4.4 Insights from basin-level water footprints

Basin-level footprints as relevant to the public sector have been completed, but significant question still remains around how to use the water footprint of a basin in the public sphere. In short, if one has a water footprint, 'so what'?

Intents to use a basin-level water footprint to inform policy or allocation have noted that the complexities of public interests and political decision-making processes make it difficult for a water footprint to directly inform policy. Before the public sector can effectively use a water footprint, the water footprint must fully contextualise the information and present it alongside environmental, social and economic considerations. A water footprint in itself may be interesting, but it presents too narrow of a story to be of use to the public sector for informing decisions.

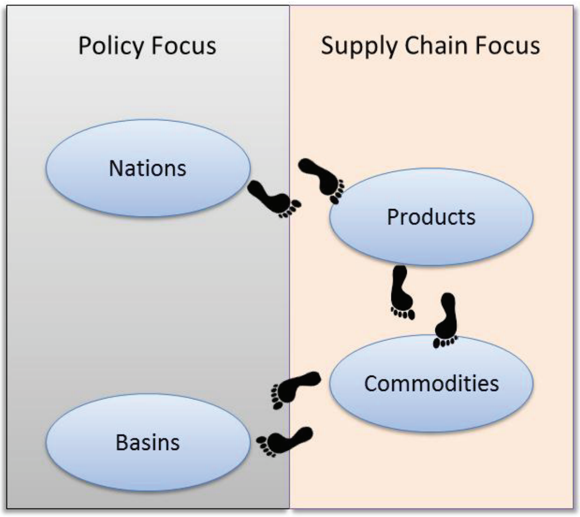
What water footprint has been more helpful for in the public sector is a communication tool, and one which can spark dialogue between sectors such as agriculture and trade. Studies currently underway will continue exploring the value of water footprint to the public sector.

A final, more technical point is that water footprints for a river basin could be very challenging in terms of data collection. This is because the political boundaries of countries or provinces are the boundaries by which data is available, and natural boundaries such as river basins do not follow these same lines. Thus, significant effort must be put into collecting the right data.

3.5 Review of water footprint contribution and challenges

Water footprints have been completed for nations, products and companies, commodities and markets, and river basins. Through these different applications, the methodology and the purpose of the footprint have evolved as well. While the first footprints focussed on consumption by country, many footprints now have much more of a production focus and are targeted at specific products.

Two fundamentally different streams of water footprints exist. One stream has a policy focus, and includes nation and basin footprints which are intended to help understand trade, agricultural or other policy issues. The second stream has a supply chain focus, and includes product and commodity water footprints which are intended to help understand risks and dependencies. The water footprint studies conducted in each of these streams have very different purposes, and the approach and methodology should be informed by the intent.



The reviewed case studies for the **policy-focussed water footprints** highlight the following points:

- ***Contribution of water footprint:*** A water footprint has potential to inform sector policy and planning, and also to raise awareness, facilitate communication and understanding between diverse sectors, and foster strategic dialogue around issues such as agriculture, trade or economic development.
- ***Challenges with water footprint:*** Despite its potential, it is unclear how a water footprint for a nation or a basin can be used to inform policy or response as efforts thus far have not been able to create a clear link between WF and policy.
    - In order to be meaningful, a water footprint must be rooted in a local context which considers the environmental, social and economic implications of water use.
    - In order to be understood and used by decision-makers, a water footprint must be presented as one of many considerations, for example by connecting the water footprint to economic, social and environmental indicators.

Similarly, with **supply-chain focussed water footprints**:

- ***Contribution of water footprint:*** Particularly where water impacts in the supply chain are large, such as in the food and beverage industry, water footprint can be helpful as a benchmarking tool and to understand supply chain risks of a product or business. It is also useful as a communication and knowledge-sharing tool for high-level managers. Understanding the water footprint of a commodity at a more global level can help a company understand these risks and supply alternatives. Companies with downstream consumer water use impacts, such cosmetics or hygiene, are also investigating the applicability of the footprint concept.
- ***Challenges with water footprint:***
    - The water footprint must still be understood in a local context, and must address social, economic and environmental considerations in order to be meaningful. It is not yet understood how to best provide this local context.
    - Certain parts of the water footprint methodology need to be further explored, or may not be appropriate for all applications of water footprint. For example,

representing water quality impacts as a quantity of water with the grey water footprint may not be appropriate or helpful, and there is question around whether evaporation should be calculated using a gross or net approach.

- Communication of a water footprint requires caution and contextualisation. The water footprint concept provides a nice illustration, and the basic concept is easy to grasp. This is good for awareness purposes, but potentially dangerous if the message is overly simplistic.

4 CARBON, WATER AND OFFSETTING

This chapter will explain the concept of offsetting, and discuss its potential applicability to water and water footprints. Additionally, it will explore the linkage between carbon and water through energy, and the often necessary trade-offs between carbon emissions and water use which result.

4.1 Offsetting

4.1.1 Introduction to Offsetting

Offsetting is the process of counteracting or compensating for the harmful effects of human production and/ or consumption on the environment. Any one production process impacts the environment in multiple ways – freshwater use and carbon emissions are two examples – which put a strain on otherwise renewable resources. Offsetting has become an important element of environmental science because these renewable resources are being consumed at a rate faster than they are able to regenerate naturally. Despite the promise that the concept of offsetting offers, uncertainty exists around its effectiveness.

Offsetting, along with the market structure within which it is facilitated, was originally designed for carbon emissions. It is therefore important to first understand the underlying assumptions that make carbon offsetting possible if it is to be applied within a different context – water. Once these underpinning assumptions are understood, some comparison to the key characteristics of water will be made in order to arrive at a conclusion about some efforts to offset water use.

4.1.2 Assumptions of carbon emissions

A ton of CO_2 is emitted when you:

- Travel 2 000 miles in an airplane.
- Drive 1 350 miles in a large sport utility vehicle.
- Drive 1 900 miles in a mid-sized car.
- Drive 6 000 miles in a hybrid gasoline-electric car.
- Have your computer on for 10 600 hours.
- Graze one Ugandan dairy cow for 8 months.

Figure 4.1 Examples of carbon-emitting activities (Clean Air-Cool Planet 2006)

Certain assumptions regarding carbon create the foundation on which the practice of carbon offsetting is built.

Carbon is emitted into the atmosphere during the production of goods and services. Emitting too much carbon into the atmosphere can have a harmful impact on the environment. However, these emissions can theoretically be absorbed from the atmosphere in order to return the balance of gasses in the atmosphere to their original composition.

One key assumption regarding carbon emissions is that they go into a global pool and the consequences of its assumed negative impact on the atmosphere will be experienced by everybody around the world with varying degrees of intensity. Efforts to offset carbon emissions are also equally useful regardless of where in the world they are executed. Carbon emissions are a global problem that can be solved on a global scale. The amount of carbon emitted by a process, production or consumption pattern can be estimated using a carbon footprint, as described in Chapter 1 of this document.

A second key assumption regarding carbon is that carbon emissions always have a negative impact, and therefore it is always better to reduce emissions. The harmful impact that carbon emissions have on the atmosphere has led to the development of possible methods for compensating for the emission of CO_2. The most publicised of these methods is carbon offsetting which individuals and corporations use so as to become carbon neutral, or to minimise emissions.

4.1.3 Carbon Efficiency and Offsetting

To offset 1 000 tons of CO_2 you could:

- Move 145 drivers from large SUVs to hybrids a year.
- Run 600kW wind turbine for an average year.
- Replace 500 100-watt light bulbs with 18-watt compact Fluorescent lights (10 year life).
- Install 125 home solar panels in India (20 year life).

Figure 4.2 Examples of carbon offsetting activities (Clean Air-Cool Planet 2006)

The first step in minimising a carbon footprint is to reduce internal carbon emissions as much as possible. Following efficiency, the next step towards minimising a carbon footprint is to offset residual emissions by financing a number of different carbon offsetting projects. Among other possibilities, this can include reducing deforestation and forest degradation, planting trees, or executing energy efficiency projects and developing renewable energy sources. These efforts can occur either from an individual or private initiative, such as a single person planting trees or a company investing in energy efficiency. However, formal mechanisms to facilitate carbon offsetting also exist. For example, the Clean Development Mechanism is a formal program which allows industrialised countries to meet some of their emissions targets by purchasing credits which support carbon-reduction projects in developing countries. This mechanism of cross-border offsetting illustrates the global nature of carbon offsetting.

While carbon offsetting is a promising concept, some uncertainty exists with carbon offsetting practices. For example, there is uncertainty surrounding the complicated exchanges of the active part of the carbon cycle. This uncertainty creates an information gap which makes it impossible to tell with any degree of accuracy how many trees need to be planted in order to precisely 'neutralise' emissions (Smith, 2007).

In addition, there exists a problem with the time delay between emission and offsetting. It is unclear when a tree planted today begins to offset the emissions of today's consumption and what the implications for the atmosphere's ability to regenerate itself are. However, companies and individuals continue to pursue carbon neutrality through offsetting markets because it is the best currently available mechanism for reducing carbon footprints.

While the need is to reduce emissions directly through changes in behaviour or technological improvements, some emissions, at least in the short to medium term, are unavoidable, thereby necessitating offsetting. Voluntary carbon offset markets allow companies, public bodies and individuals to purchase credits (UK House of Commons, 2007).

4.2 From carbon to water: Does the offsetting leap make sense?

4.2.1 COMPARING WATER AND CARBON

Unchecked freshwater use can cause harm to the ecosystems that rely on water for their survival. In an attempt to counter the negative impact of water use on the environment an attempt has been made to use water offsetting, an adaptation of carbon offsetting, to neutralise the water footprint.

Certain similarities exist between water and carbon which make the application of the concept to water use interesting. Like carbon, water impacts result from human activities and these impacts can be at least approximately measured and linked to specific water users. Additionally, minimising water use typically begins with reducing internal water consumption as much as reasonably possible, and is then followed by efforts to offset the negative externalities of the remaining water footprint.

However, fundamental differences exist between carbon and water in an offsetting context which raise questions regarding how applicable offsetting may be, and how well offsetting might work with water.

The most important of these differences is the fact that carbon emissions have global implications while water use mainly has local implications. Thus, a critical consideration with water offsetting is the geographic location of offsetting initiatives. Unlike carbon, the impacts of water overuse affect the environment and communities around the water source, therefore the offsetting must take place in the same place. The water footprint tracks the geographic location of water sources for the freshwater used in production processes, which helps to provide the information required to know where offsetting must occur. Still, the challenge of how to offset in a particular catchment to offset water use is significant as it requires detailed information and mechanisms to facilitate offsetting in very specific locations.

A second difference is that not all water use is harmful, and some water use is beneficial and necessary. For example, water use by industry which still allows for the fulfilment of social and environmental quantity and quality standards is often beneficial to a community in terms of the economic benefit it creates, rather than harmful. The use of water is required to grow crops for food, and further development of water resources may be desirable in areas where sufficient resources are available and provide opportunities for economic growth. This is in contrast to carbon where carbon emissions are always considered harmful.

A third difference is that some water consumption is irreversible and/or "unsubstitutable". A water footprint can never be zero. Water consumption activities that exemplify irreversible consumption include the following: a person drinks water and it cannot be returned into the water cycle, the same applies with crops and livestock feeding. A carbon footprint, however, can theoretically be reduced to zero.

The implications of these differences are that water offsetting is about investing in projects that promote the sustainable and equitable use of water within the environment and community that is affected, rather than reducing water use at a global level. As a result, water offsetting has to do with the reduction of negative economic, social and environmental externalities, and ensuring that that the remaining impacts are fully compensated (Hoekstra, 2008) at the local level where the water consumption took place.

Water footprints can play an important role in water offsetting practices, as offsetting required understanding the geographic origin of water use. The water footprint illustrates the origin of water use for the production of a good by including water use throughout the supply chain. If understood at a sufficiently detailed level, then, water footprints can provide the information needed to identify where offsetting must take place.

4.2.2 KEY QUESTIONS WITH WATER OFFSETTING

Keeping in mind the above distinctions between carbon and water, and their implications for offsetting, certain companies have attempted water offsetting projects. While these projects are in largely exploratory stages, certain questions have arisen which frame the challenges and potential of applying offsetting to water use particularly for the industrial sector:

- ***What water use is being offset?*** As shown by the water footprint case studies, it is important to consider both water use in internal operations and water use in the supply chain. Water footprints often show that water use in the supply chain is greater than internal use. When discussing water offsetting, it is necessary to specify whether one is offsetting just internal water use, or water use throughout the supply chain.

- ***What is necessary for an effective water offsetting measure?*** The methods of water offsetting will be different than those for carbon offsetting, and have different challenges. The first challenge is that offsetting methods must allow for catchment-specific initiatives because water is a local resource. A mechanism to facilitate and track local offsetting is a difficult task. A second challenge is regarding the nature of the offsetting measure.

> ***Coca-Cola*** pledged to become water neutral by both becoming more efficient, and by compensating for water us by investing in conservation programmes in water-stressed areas or helping to preserve major rivers. The term "water neutral" was not specified, but must have referred to only its operational water use, as offsetting water use required in the supply chain would be an enormous effort. Additionally, water offsetting efforts were not necessarily connected to the locations of Coca-Cola's water impacts, losing the required location-specificity for water offsetting.

> ***SABMiller*** undertook measures to offset operational water use by clearing of invasive alien plants along with WWF. These efforts were undertaken in a different catchment than where the company's operations occur, breaking the geographical connection between offsetting and impact. Additionally, the sustainability of this method is uncertain as clearing requires significant effort and must be done for several years in a row in order to clear the plants, making it more than a one-time effort.

Some offsetting measures, such as investing in water efficient technologies, may be more permanent and predictable. Others, such as clearing of alien invasive species, are more difficult to measure in terms of results and must occur year after year, as opposed to being a once-off effort.

- ***What will be the benefit to the corporation (or other entity) of offsetting?*** In addition to good corporate stewardship, other motivations for water offsetting exist. Consistent and reliable water use is often required by companies for operations, but water availability often varies within a year and between years. This variability creates uncertainty regarding availability. Thus, one of the potential benefits being explored with water offsetting is around increasing predictability through regulatory recognition of offsetting efforts. Regulatory benefits could include giving the companies that practice offsetting priority to water in times of drought or limited availability. This potential benefit and others must be explored in the water offsetting context.

In summary, water offsetting has potential, but will look different than carbon offsetting in practice and many difficult questions regarding water offsetting remain unanswered.

4.3 Water and energy

A second critical topic around water and carbon footprints is the linkages between them through energy, and the often-present need to consider trade-offs between carbon and water.

4.3.1 Water-Energy Relationship

Water and energy are intimately linked. Substantial energy is required to move water over long distances for social and economic purposes. In turn large amounts of water are necessary to produce all forms of energy for social and economic use (Gleick 1994). Figure 4.3 demonstrates the interlinking nature of water and energy.

For example, water is required for cooling, extraction and refining, as well as for fuel production. Energy is required for water treatment and distribution. Where energy used, carbon emissions will result from that energy use either directly or indirectly, with the amount of carbon being dependent on the energy source. Thus, the link between water and energy is also representative of a link between water and carbon.

For many generation technologies, water requirements are in every part of the generation cycle. For thermal power plants, water is required in the fuel extraction, transportation to the facility, generation and cooling of steam, as well as general maintenance. Nuclear, geothermal, and solar thermal facilities have similar requirements. Hydropower most obviously needs a consistent water supply. For some renewable technologies such as wind and photo-voltaic (PV) solar, there are lower direct water requirements but there may be water use implications associated with the land necessary for generation and construction materials.

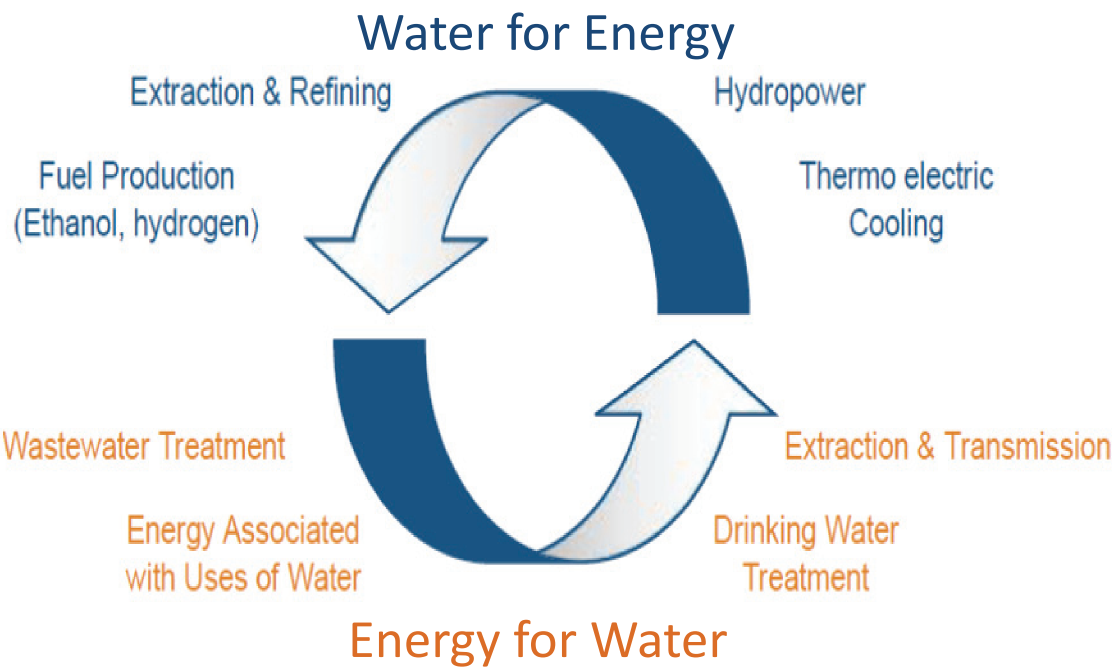


Figure 4.3 The interlinking nature of water and energy (World Energy Council 2010)

4.3.2 Water-Energy Trade-Off

Importantly for many technologies, there is a trade-off between water efficiency and carbon efficiency, and thus a trade-off between carbon and water footprints. This can happen both in energy-generation processes, water supply processes, and regular industrial processes.

Pegram et al. (2011) demonstrate the different scales of water use in different types of energy generation.

Table 4.1 shows the levels of water use in different energy production processes and the impact that these different energy production methods have on the quality of water. The table shows the amount of water used in fuel supply, storage, in energy generation and the impact the energy generation has on the quality of water downstream for seven different energy generation processes. Importantly, some of the energy sources which have lower carbon emissions, such as hydropower or biofuels, have significantly higher water requirements.

Table 4.1 Water use in different energy generation techniques (Pegram et al. 2011)

	Fuel supply	Water storage	Water use in generation	Downstream water quality
Coal	No water required for fuel supply	Medium levels of water storage required for assurance of supply	Medium levels of water used in power generation	High impact on downstream water quality
Unconventional Oil & Gas	Medium levels of water required for fuel supply	Medium volumes of water storage required for assurance of supply	Low levels of water used for power generation	High impact on downstream water quality
Gas & Oil	Low levels of water required for fuel supply	Medium levels of water storage required for assurance of supply	Low levels of water used for power generation	Low level impact on downstream water quality
Nuclear	Medium levels of water required for fuel supply	Medium levels of water storage required for assurance of supply	Medium levels of water used in power generation	Low impact downstream water quality
Biofuels	High water use through crop evapo-transpiration	Small volumes of water storage necessary for crop irrigation	Small volumes of water use in power generation	Low impact on downstream water quality
Hydropower	No water required for fuel supply	Large volumes of water needed for storage for assurance of supply	No water use in generation	Low impact on downstream water quality
Solar & Wind	No water required for fuel supply	No water storage required	Small to medium volumes of water use in generation	No impact on downstream water quality

Similarly to energy generation, water use is dependent on energy. Water planners are aware of this, and account for the costs of energy when considering alternatives. Figure 4.4 Supply augmentation options for the Vaal River system with unit energy requirements. Figure 4.4 illustrates the marginal cost of various water supply augmentation options for the Vaal River system. The horizontal lines indicate the marginal costs of different options, while the red numbers indicate a unit energy requirement per volume of water supplied. For example, water transfers or desalination schemes have very high energy requirements due to the pumping required. This analysis is done from a cost perspective rather than a carbon emissions perspective, but demonstrates the trade-off between water and energy, and thus water and carbon.

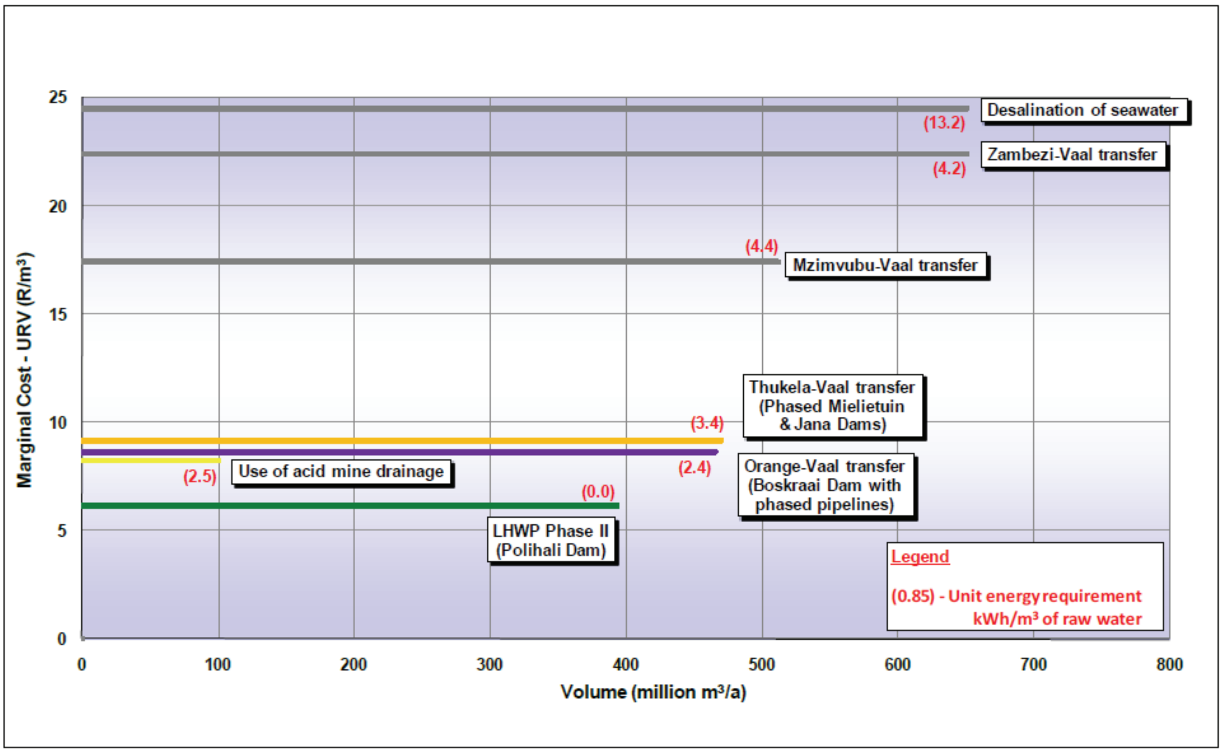


Figure 4.4 Supply augmentation options for the Vaal River system with unit energy requirements (DWA 2010)

In addition to the energy generation and water supply sectors, this trade-off between water and energy, and thus water use and carbon emissions, exists in other industrial processes. For example, a cooling tower which uses water cooling may be more efficient from an energy perspective but less so from a water perspective than a cooling system that uses dry cooling.

Water and carbon footprints can help a company to clarify this connection between water and carbon, and thus can help companies to see how each will be affected by decisions involving a trade-off between water and energy. Using footprints to help guide decisions is a more complicated task, given the need to understand the local context of water footprints, the need to connect water and carbon footprints, and the need to consider many other factors important to the business such as cost and strategic growth. Thus, footprints are at this point a way to visualise and more readily communicate the trade-off.

5 IMPLICATIONS FOR WATER FOOTPRINTS IN SOUTH AFRICA

Water footprints have gained significant traction in the private and public spheres across a variety of sectors. This is partly because a water footprint is an intuitive concept which enables it to be used as a communication tool with people outside of the water resources management sector. As a result, decision-makers such as CEOs and government ministers are paying attention to water footprints, and are exploring how water footprints may inform business or policy decisions.

The case studies have shown that in the private sector, the applicability of water footprint has been explored for three broad purposes:

- ***Disclosure and Reporting*** – This is the simplest use of a water footprint because the volume of water use is sufficient in itself, without having to understand the impact of that water use. Reporting can also be used in a benchmarking sense to measure progress in addressing a water footprint. Water footprint as a disclosure and reporting mechanism is valuable because it presents a more complete picture by considering water use in the supply chain in addition to just in-house use of water.
- ***Risk Filter*** – Water footprints may be used as a risk filter by understanding supply chain dependencies, and the origin of water used in the supply chain. Using a water footprint as a risk filter is more complex because the impact of water use and the local context of water use must be better understood.
- ***Planning and Decision-Making*** – Water footprints may be able to inform planning, for example regarding where to source supplies or where to build a new manufacturing facility. This is the most complex way to use water footprint as it requires a full understanding of the environmental, economic and social impacts of a water footprint, and an understanding of opportunity costs and trade-offs.

While water footprint has significant potential to contribute to corporate water management and to integrate water into decision-making in the ways outlined above, significant questions must still be addressed in order for water footprint to be a reliable and meaningful indicator. These include:

- ***Understanding Impact*** – A water footprint must be rooted in a local context and its local impact understood in order for the water footprint to inform decisions. A meaningful approach to understand impact has not yet been developed, and is a key challenge for the applicability of water footprint.
- ***Water Quality*** – Significant question exists regarding whether representing water quality as a volume of water is meaningful or appropriate. The nature of the water quality impact is lost, as is information which could inform potential responses. Based on the experiences of companies which have explored the use of the grey water component of the footprint, it must be further developed or reconsidered to be useful.
- ***Integrating Complexity and Nuance*** – A water footprint is a number which represents a single consideration. However, the decisions a water footprint is meant to inform are extremely complex and must considering a range of economic, social and environmental considerations. In order for a water footprint to play a role in complex decisions, it must be integrated with the broader context and linked with other considerations.

Using water footprints alongside carbon footprints to understand trade-offs, or applying the offsetting concept to water have potential. However, significant challenges remain, such as how to link water use and offsetting to a particular location.

In South Africa and other water-scarce countries, tools which can inform efficiency and raise awareness and create dialogue with people not previously involved in water debates are potentially very useful. Water footprints have the potential to contribute in this way, bringing new and important decision-makers into the water debate in a way that is intuitive and cuts across sectors. Additionally, water footprints create an opportunity for companies to join a global process of disclosure, understand risk and integrate an understanding of water into planning decisions.

However, the key questions outlined above have very important implications for the applicability of water footprint in South Africa and must be addressed. For example, while water footprint is currently very useful in the food and beverage industry to understand supply chain water use, a better way to represent water quality must be developed to make water footprints useful to the mining sector. The next steps of this project, including the development of a framework and case studies, will seek to address these gaps.

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