Chapter 31

Water footprint: A sustainability tool for industries

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31.1 INTRODUCTION

The decreased availability of water resources, in quantity and quality, represents a great threat to humanity as a whole, as well as to the global economy (UN, 2015). Rapid growth of population coupled with the growth of the Global Gross Domestic Product (GDP) encourages more people than ever to aspire to a higher standard of living, producing rapid urbanization and industrialization (UN, 2017; IDB, 2018). Added to these increases are the effects of climate change, and the result is overwhelming pressure on global water resources.

Unsustainable water use and poor management of water resources, resulting in a lack of suitable quality water, also constitutes a significant constraint on industrial productivity. It is anticipated that in 2030 the planet will face a global water deficit of 40%, while the global demand of water for industrial production is projected to increase by 400% by 2050, more than in any other sector (UN, 2015). As a consequence, industrial water management is more important than ever, including water use, distribution, and the pollution generated by all facets of production.

There is an urgent need to reinforce the management of water basins to guarantee the regeneration of the resource and to avoid potential threats to development and economic growth. Companies must measure their impact on water to encourage conservation and to compensate cities for impacts. They need to improve water management by implementing water replacement projects in water basins, conservation of water recharge areas, etc.

This chapter compares two “water footprint” indicators used worldwide to assess and analyze industrial impact on water resources: (1) the Water Footprint Network water footprint tool; and (2) the International

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Standard (ISO) water footprint tool which includes the use of Life Cycle Analysis (LCA). Case studies of the application of each method are presented which revealed practical opportunities to reduce impact on the water environment. In addition, this chapter explores *alternative measurement frameworks* that allow industries to take a more participative role, from regulations to elaborating policies and strategies. In many cases the *municipal governments* take the lead in alliance with the private sector, which may participate through chambers of industry and commerce. A successful case study of collaborative participation among these key actors is also presented.

31.2 CONTEXT

Under the premises '*something that has not been measured, cannot be managed'* and '*something that has been measured, can be improved'*, methodologies have been develop to provide indicators of water use, consumption, and other effects. Among the most popular methodologies worldwide are:

- *Water Footprint Network's Water Footprint (WF-WFN)*: Based on the methodology of the Water Footprint Network, this tool allows industries to analyze their direct impact on water quantity and quality during the production stages in which they directly utilize water; and
- *International Organization for Standardization's Water Footprint (WF-ISO)*: Based on the International Organization for Standardization's ISO 14046, this tool enables companies to trace their use of water more broadly throughout the supply chain, and helps to identify key points where timely and convenient actions could mitigate their impact.

31.3 ORIGIN, METHODOLOGIES, AND CASE STUDIES

31.3.1 Water footprint network's water footprint

In 2002 Arjen Hoekstra and Chapagain (2006), a researcher at the UNESCO-IHE Institute for Water Education, developed a water footprint methodology while working to measure the total volume of water consumed and contaminated related to the production of specific goods and services (including 'non-obvious' water uses). (The usual measure used by industries to measure their impact did not consider other impacts such as water sources, the volume of water that is no longer available in the basins, or the impacts of pollution.) Hoekstra's method reflected the total amount of water used, lost, and contaminated per unit of product produced. Given the importance that the methodology was gaining, the Water Footprint Network was created in 2008.

This methodology came under more scrutiny when these water footprint numbers began to be commonly applied as a means to gauge the relative water impact of various agricultural products. Previously, the cost of water did not routinely factor into the evaluation of agricultural exports, and the need to replenish overdrafted supplies was not given particular importance, even in countries with a high water deficit. As an example, a WF study of Kenya's Naivasha basin (a major flower exporting region) showed that to improve water management the price for water had to increase to reflect its actual cost to the community. Only then could the region consider adopting water replenishment projects and various regulatory measures (Mekonnen & Hoekstra, 2012).

31.3.1.1 WF-WFN methodology

The WF-WFN calculates water impact as the sum of (1) losses through evaporation or incorporation, (2) the direct or indirect contamination of the water, and (3) agricultural water remaining in the soil or incorporated into crop material. The information visualized through the WF-WFN allows the user to analyze the

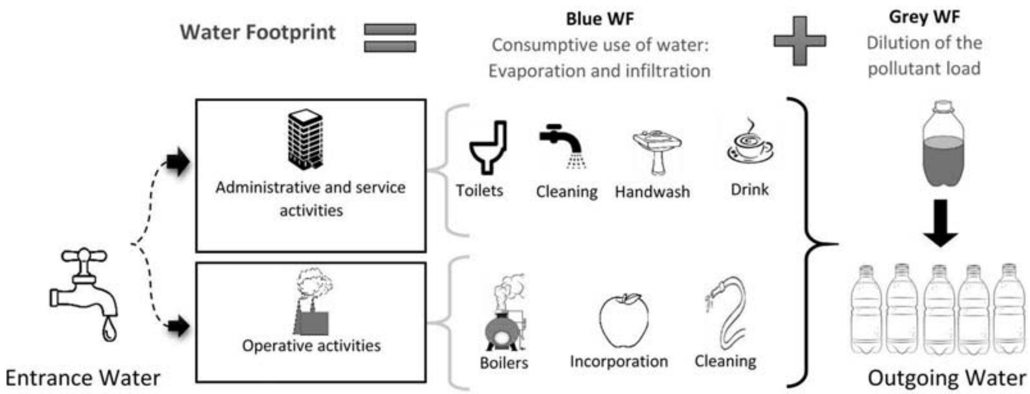

Figure 31.1 The Water Footprint Network's Water Footprint Analysis. (*SASA, 2019*)

environmental, social, and economic implications of the use of water in different geographical areas by calculating the total water footprint as the sum of these three types of water impacts, labeled Blue, Gray, and Green, and defined further as follows:

Blue Water Footprint is an indicator of *consumptive use* of freshwater (surface or underground), including water that evaporates, that is incorporated into a product, that does not return to the same flow zone, which is returned to another catchment area or to the sea, or that does not return in the same period. (An example of the last is water removed during a dry period and returned during a rainy season.)

Gray Water Footprint is an indicator of *pollution* expressed as the volume of water needed to dilute an activity's pollutant load to the point where the quality of the water remains above local regulations and the ecological requirement of the basin. (The lower the regulatory limit, the more water is required to dilute the pollutant loading). By expressing the impact of water pollution on local supplies in this way, the WF-WFN methodology can convey the total water impact of an activity or enterprise as a number – the 'water footprint'.

Green Water Footprint is an indicator of the volume of water that remains in the soil, on the surface, or is incorporated into the vegetation. This footprint measure is only calculated for agricultural crops, defined as any vegetation produced through anthropogenic activities. (Natural vegetation is not considered to exert a 'green' water footprint.)

Figure 31.1 shows the calculation and the analysis that is carried out in an industrial process for the analysis of the water footprint, from the point that the water enters the facility, throughout its use, and the generation of residual effluents.

31.3.1.2 Case study: WF-WFN management in a production facility of beverages

Objective: By determining how production of beverages directly impacts water, recommend steps to reduce those impacts and demonstrate to clients the company's commitment to sustainability (The name of the company has been withheld for reasons of confidentiality; the study was prepared by Servicios Ambientales SA.)

Scope: Measure the WF-WFN that results as a direct consequence of the beverage production based on a one-year study of the production of isotonic drinks, soft drinks, energizers, and water in the company's main facility.

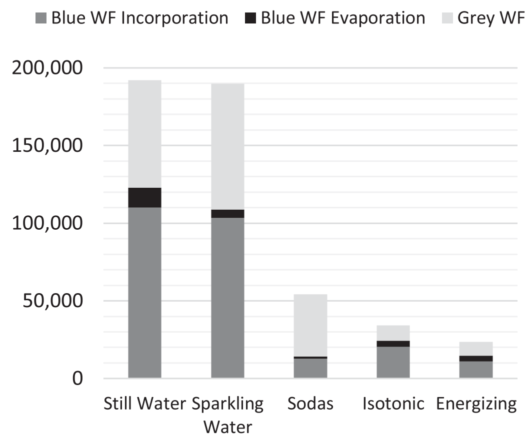

Figure 31.2 Total WF-WFN of evaluated products (m^3). (SASA, 2019).

Results: The Company's beverage production was found to represent 7% of the total water footprint of industry in the city where the plant is located. Due to the larger volumes produced (see Figure 31.2), production of bottled water represents 77% of the total WF-WFN. On the other hand, as shown in Figure 31.3, the Gray Water Footprint of soft drinks is three times greater than the other produced drinks since these beverages generate most of the contamination. Isotonic drinks and energizers account for most of water losses due to evaporation, more than double the other products.

Conclusion and Recommendations: Based on this water footprint analysis, reduction proposals focused on the production of sparkling and still bottled water, since together they account for 80% of the whole annual production and represent the dominant share of the total water footprint. Both water types are sold in reusable glass bottles, so the gray water footprint could be reduced by improving efficiency in the bottle washing process and by using biodegradable detergents, which are easier to dilute. In addition, the evaporation losses that occur during the purification of the drinking water could be reduced through the

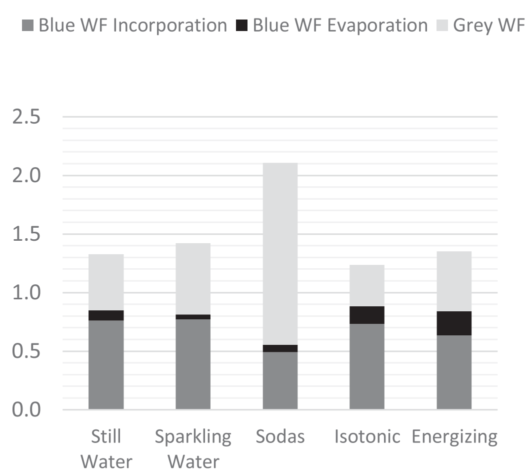

Figure 31.3 Liter WF-WFN per liter of product ($l/l_{produced}$). (SASA, 2019)

implementation of a vapor recovery system. The production process of isotonic drinks and energizers could also be improved by adding a vapor recovery system that would recycle water from the continuous filtration process as washing water. An alternate approach to reducing the Gray Water Footprint from production of soft drinks would be to construct a residual effluent treatment plant that would improve the load of organic materials that are generated and emitted.

31.3.1.3 Footprint of cities

The WF-WFN methodology was applied to water use in 14 cities in Latin America in the Footprint of Cities Project, and the impact of different sectors was determined (CAF, 2012–2018). Results are shown in Figures 31.4 and 31.5. Based on the WF-WFN analysis, on average the industrial sector contributes 6% to the total water footprint of the evaluated cities, mostly due to the impact of the water pollution it generates (To calculate Gray Water Footprint, BOD5 and COD were selected as the best indicators of the quality of urban effluent). Although the industrial sector contributes significantly less to the total water footprint than the residential sector, a greater percentage of its contribution is due to 'gray water' (as shown in Figure 31.5) compared with residential use, so reducing industrial pollution may lower water pollution overall.

31.3.2 International organization for standardization's water footprint

The Water Footprint-ISO (ISO 14044) is part of the ISO's environmental management suite of standard methods. It preserves the concept of the WF-WFN methodology, but extends the scope of the measurement of water impacts throughout the supply chain in greater detail. The LCA is '*the collection and evaluation of inputs, outputs and potential environmental impacts of a product system through its life cycle*' (ISO 14040). This analysis considers all the stages of the productive process of a product from obtaining the raw material, transport, its transformation, distribution and generation of waste, taking into account the consumption of resources and generation of impacts, at each of these stages. This methodology is aligned to the measurement of impacts on climate change with the accounting of greenhouse gases (ISO 14067) and the impact on water in terms of quantity and quality (ISO 14046). Use of the LCA became widespread during the 1970s when, in response to the rise in world oil prices, conservation advocates looked for ways to measure the potential to save energy for a given product (Raúl, 2008).

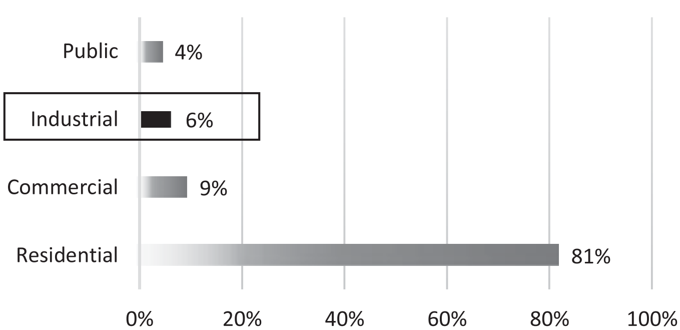

Figure 31.4 Industrial sector contribution to the Water Footprint of the Cities.

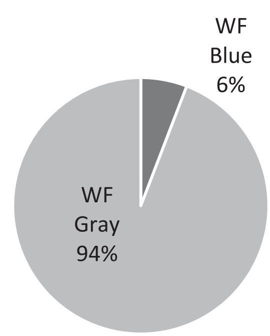

Figure 31.5 Industrial sector footprint types. (*Source: Footprint of Cities Project*)

31.3.2.1 Water footprint-ISO methodology

By carefully accounting for the impact of water use in all steps of the supply chain, the WF-ISO methodology allows the user to compare the water footprint of the same product produced by different methods or with raw materials from different supplies, as well as between similar products manufactured of different materials. As a result, this information can be used in the design and development of products, continuous improvement of processes, strategic planning, green marketing, as well as in the development of policies. The LCA accounts for the potential environmental impacts throughout the life cycle of a product from the acquisition of the raw material, passing through the production, utilization, final treatment, recycling, until its final disposition (that is, from the cradle to the grave) including the use of resources and the environmental consequences of emissions and discharges. As shown in Figure 31.6 below, The ACV ('*A*nálisis del *C*iclo de *V*ida completa, or life cycle analysis) is composed of a number of phases: (1) definition of objectives and scope; (2) inventory analysis; and (3) impact evaluation.

The flow lines in the Figure 31.6 go both ways, forward and backward, because the LCA is an iterative process: that is, as information is acquired about the system studied, the goals and scopes can be modified, adding or suppressing environmental impacts. This means that an LCA can be adapted to the availability of information for its implementation.

The life cycle approach and the methodologies described in the ISO 14040 and 14044 standards can interact with other environmental management tools, such as environmental impact studies and/or environmental audits, and also support other standards such as ISO 14046 (water footprint). This is illustrated in Figure 31.7, where the calculation for each type of impact indicator quantifies the type of substances that specifically cause this impact. Phosphorus, for example, causes eutrophication of freshwater while NOx, NH_3, SO_2, and hydrogen ions result in terrestrial acidification. These tools rely on extensive databases based on field studies that measure the impact on the production of different types of materials. Among the most well-known software systems are SIMAPRO and ECOINVENT.

31.3.2.2 Case study: Analysis of WF-ISO at a soft drink bottling facility

Objective: Evaluate the WF-ISO in the production chain of returnable (RB) and non-returnable bottles (NRB) and promote the consumption of the more footprint-friendly product through massive publicity/advertising campaigns. (This study was prepared by Servicios Ambientales SA for the unnamed company under terms of confidentiality.)

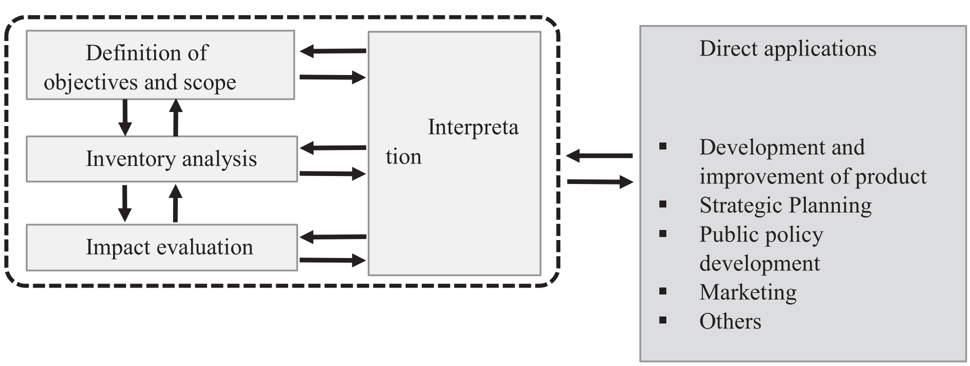

Figure 31.6 LCA phases. (*Source: IBNORCA, 2007*)

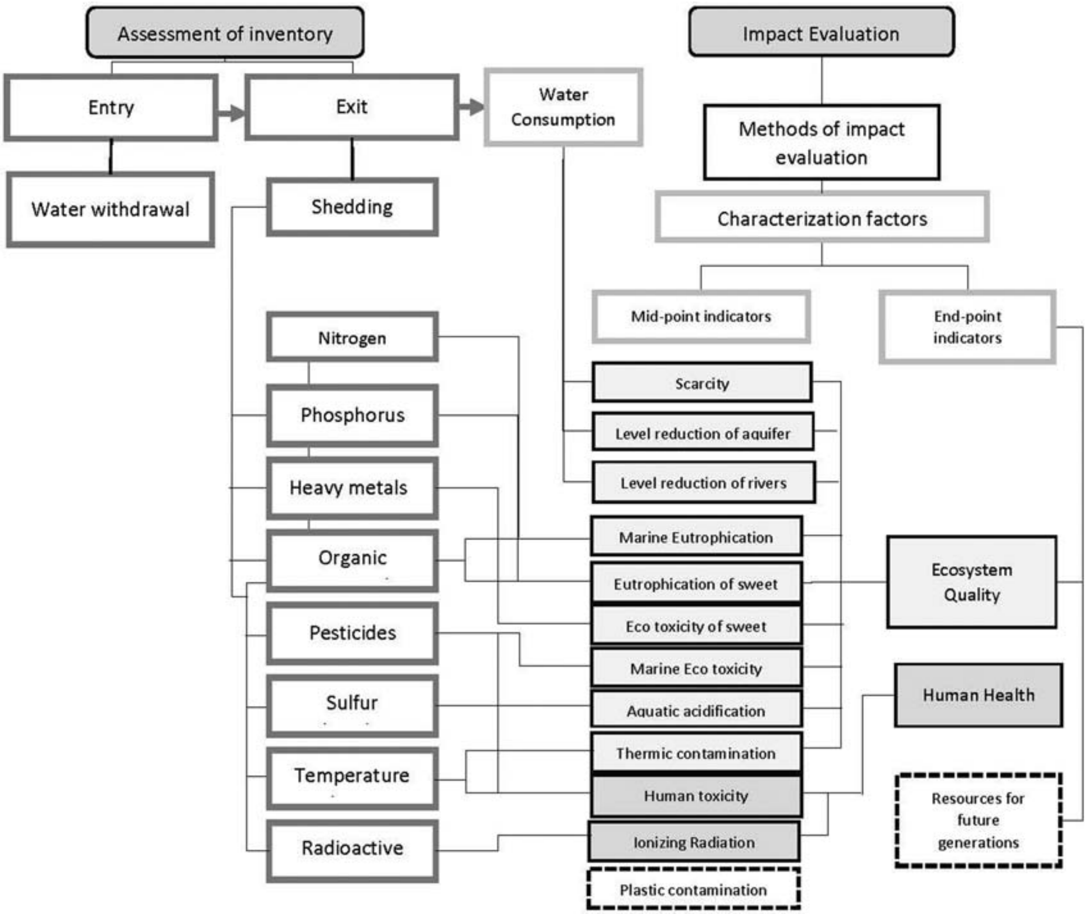

Figure 31.7 Water Footprint-ISO analysis. (*Based on CADIS, 2017*)

Scope: Perform an LCA of the two different bottle types from the procurement of raw materials to the final packaging ('cradle to door') for a timespan of one year.

Results: The production steps and activities were analyzed and are presented in Figure 31.8: Considering the water consumption in all production stages, NRBs have an impact 17% greater than the RBs, mostly due to the use of virgin resin which accounts for 57% of the water footprint. This is followed by the production of the preform which accounts for 21% of the water footprint.

The impact of raw material procurement for the RBs is reduced considerably due to the fact that the bottles are used at least 15 times in the span of 10 years, meaning that fewer new bottles have to be produced. The largest water impact of the RBs can be found at the washing stage. Here, for every liter of bottled soft drink, the washing process requires 0.6 liters of cleaning water. This stage represents 61% of the water footprint, but has to be carried out to ensure the safety of the product. Detailed information about the impacts of the two bottle types can be found in Figure 31.9.

Conclusions and Recommendations: Based on the data, the consumption of RBs should be promoted due to their lower WF-ISO impact. However, it is also recommended that cleaning efficiency should be

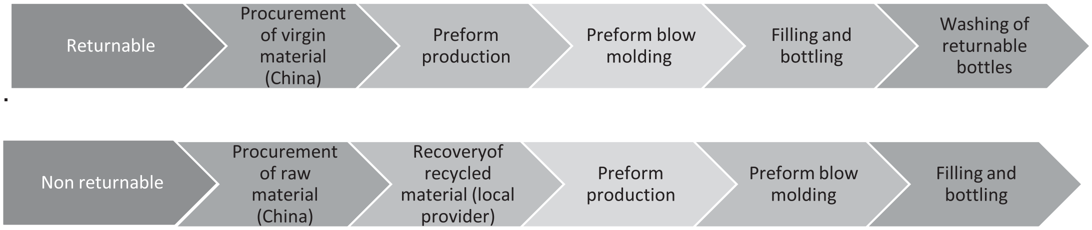

Figure 31.8 Production steps of non-reusable and reusable bottles. (*Source: SASA, 2017*)

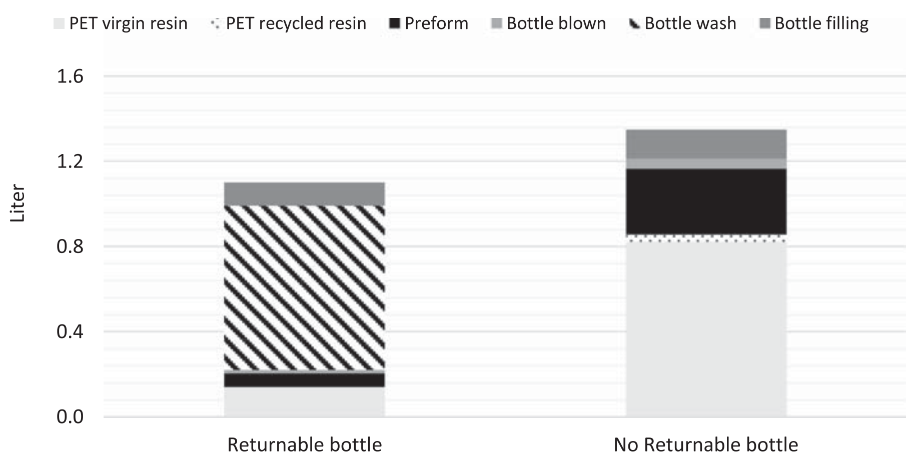

Figure 31.9 WF-ISO of the two bottles per consumption. (*Source: SASA, 2107*)

improved by using biodegradable detergents and reusing the cleaning water for other sanitation purposes. Also, it should be noted that since the LCA was only conducted from 'cradle to door' (not 'cradle to grave') there may be other impacts from product use not accounted for here. One example would be the waste generated by consumers after drinking the water contained in NRBs.

31.4 WATER MANAGEMENT BASED ON THE MEASUREMENT OF THE FOOTPRINT

After measuring the water footprint and implementing actions to reduce it, there may still be a gap between a product's overall water impact and true sustainability (i.e., a neutral water impact). To account for this gap, other tools have been created that suggest additional measures to attain true water sustainability. The following is a case study of the implementation of a successful municipal project involving an alliance between the industrial sector and local government.

31.4.1 Case study: mechanism for footprint management of the city of Cuenca, Ecuador

The municipal government of Cuenca allied with the Chamber of Commerce to implement a pilot project designed to comply with the goals of both the Carbon Footprint and WF-WFN (This study was prepared by Servicios Ambientales S.A. company). Called a 'mechanism of footprint management in alliance with the private sector', it incorporates measurement, reduction, and compensation strategies into industry management policies and businesses models so that they contribute to the fulfillment of footprint reduction goals established by the municipal government. The mechanism aims to make incremental improvements in business operations, promoting voluntary interaction between public and private sector participants within an overall framework of commitment to the goal of footprint reduction and water conservation.

As part of the project an online tool was developed that allows businesses to measure their footprint and to identify possible reduction activities. These activities will help businesses not only to reduce their use of resources, but it can also reduce costs, improve their production processes, and present them with possible technological improvements. Thanks to the progress that participating industries can achieve, they become eligible for international certifications that allow them to be more competitive in foreign and local markets. Furthermore, they identify compensation projects that will secure the conservation of water sources and the sustainability of their business.

31.5 BOUNDARIES, CHALLENGES AND LESSONS LEARNED

It is clear that there is an urgent need to manage water resources sustainably, and to promote these actions at all levels including communities and academic and non-profit institutions as well as private companies, industries, and municipal and regional governments. The WFN and ISO water footprint analysis tools allow industries to measure their impact on water at various stages of the production, so they can take timely action to create greater efficiency, reduce cost, and the lower their impact on all resources, promoting a 'circular economy'. However, widespread use of these tools will not automatically result in the sustainable use of water by industry. While some companies fail to manage their water impact due to a lack of knowledge of the water footprint methodologies, others may simply be waiting for regulations or other government mechanisms to require them to do so.

If a company decides to conduct a water footprint analysis, it is crucial for the management staff of the company to demonstrate their commitment not only to collect valid data, but also to follow-up on the findings gained from the evaluation process. The footprint evaluation is usually done in cooperation with industry technicians, but involvement by decision-makers is key: the greater their participation, the higher the possibilities that the findings from the water footprint analysis will result in measurable improvements. Only at these higher levels will an equilibrium be found between industrial production, which is intended to produce goods and services desired by consumers, and the problem of water sustainability due to productive activities.

To reach a balance, governments must incorporate holistic and sustainable water management strategies and policies. It will be necessary to consider all stages of the water life cycle, from the catchment sources, to the water distribution, the demand of different sectors and the general contamination. Only through a holistic approach will it be possible to guarantee the renewal of water resources. Where water costs are far below the true value of the water consumed, and the cost of water replenishment and wastewater decontamination are not considered, it will be difficult for municipal governments to obtain the funding required to implement best practice projects or better infrastructure works.

Since the benefits of replenishment actions may take decades to become fully visible, it is important to institute sustainability actions in the short-term to ensure the provision of water for following generations, including availability of water to support industry.

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The 14 cities in the project include: Paz, Santa Cruz, Cochabamba, Tarija and El Alto (Bolivia); Quito, Loja, Santa Cruz de Galápagos, Guayaquil and Cuenca (Ecuador); Recife and Fortaleza (Brazil); Cali (Colombia); and Lima (Peru).

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