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Water accounting for (agro)industrial operations and its application to energy pathways

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ABSTRACT

Discussions about the water needed for the provision of goods and services have been hampered by a lack of a generic water-accounting methodology from the industrial operations perspective. We propose a methodology based on the concept of “economic water stress” that enables the assessment of water-related risks at the level of an industrial site and the level of an industrial supply chain or pathway. We then rigorously apply it to quantify the freshwater withdrawal and consumption needed for fuel and electricity supply chains. Those data make it possible to present, in comparable source-to-service terms, estimates of the freshwater intensities of mobility. Most of the estimated supply-chain and pathway freshwater intensities range over orders of magnitude on account of the variety of technologies and geographic locations. On average, fuels from unconventional fossil resources and biofuels derived from irrigated crops have higher freshwater withdrawal and consumption than conventional fossil fuels. Cooling in thermal power generation can also make severe demands on freshwater withdrawal and consumption, but technological options are available for most levels of freshwater scarcity. The mobility results reveal that vehicles with internal-combustion engines and electric motors have biofuel and power-generation technology options that lie roughly within the same freshwater-intensity ranges as that of conventional transport based on refined oil. In any case, the local context is critical: industrial sites with high freshwater withdrawal and consumption may be sustainable if there is ample water supply. Conversely, low freshwater withdrawal and consumption may be unsustainable in water-stressed regions.

1. Introduction

Freshwater – or, to be more precise, liquid economically accessible freshwater – is already a scarce resource. A growing world population, rising per capita GDP and the changing global climate will only increase its scarcity under business-as-usual scenarios (Addams et al., 2009). Although the scarcity of freshwater is a global issue, its resourcing is always local. The consequences of its unavailability therefore tend to be most immediately felt by the users – both commercial and residential – of particular water basins.

Businesses throughout the world must therefore increasingly confront the localised risks of water stress. Physical disruptions of supply, changes to the regulatory regime and prohibitively high costs of supply are some of these risks (Environmental Resources Management Ltd., 2010). So too is the reputational damage from the perceived misuse of this precious resource. But such risks also have their business-opportunity upsides. By managing water-related risks and opportunities well, companies can build a competitive advantage and ensure that they have society’s “licence” to operate.

A company should therefore be able to assess the cost and benefits of water-related options. But a generally accepted methodology for accounting operational water use does not exist (Morrison et al., 2010). Existing water-accounting methodologies, such as the Water Footprint and Life Cycle Assessments, approach the problem from a non-industrial[1] operations perspective. This is surprising in view of the fact that industries throughout the world extract more groundwater by mass than oil, gravel or other mineral and metal resources (Barth et al., 2010).

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[1] For the purposes of this paper, we regard any civil or commercial technology-based activity as an industry. Hence, both agriculture and the provision of water utilities are industries.

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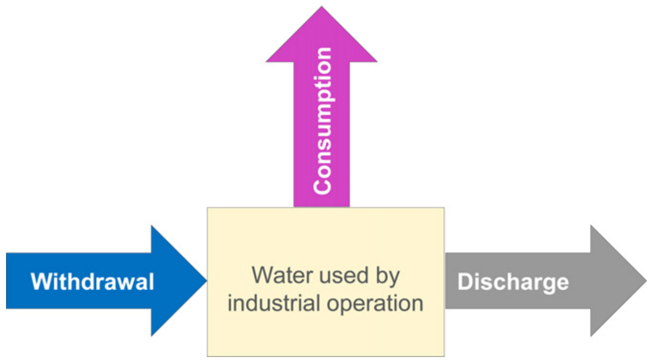

Fig. 1. Off-stream water use defined in terms of on-site water flows.

In this paper we propose a generic water-accounting methodology based on a set of requirements for industrial operations. Our methodology enables companies to assess managerial or technical options to deal with water stress not only for a given operational site but also for an entire industrial supply chain or energy pathway. The term "supply chain" is well-known: it includes all industrial operations from the development of raw-material sources to the delivery of a derived product, such as from crude oil to gasoline. An energy pathway is an extension of the supply chain, but rather than linking raw-material sources to an end product it links them to an end service, such as from crude oil to mobility. Industrial pathways thus encompass supply chains, but the reverse is not true.

We show how three existing water-accounting methodologies do not meet the industrial requirements, because they were developed for other purposes. We then apply our methodology to compile and – when necessary – calculate a comprehensive set of freshwater-intensity values for the supply chains for fuels and electricity. To the best of our knowledge, this paper is the first to derive these estimates in a transparent fashion from the operational perspective. These values of freshwater consumption and withdrawal per unit of energy ultimately make it possible for us to frame a source-to-service pathway comparison of mobility.

2. Industrial water use

Virtually every industry uses water. In some cases, such as with hydropower or maritime shipping, it is used in-stream. In other cases, such as in manufacturing, water is used off-stream: it is removed from a natural body of water. An industrial operation that uses water off-stream *withdraws* water from the local water system, *consumes* part of this and *discharges* the rest after use (see Fig. 1 and Table 1).

Table 1
Definitions of water flows crossing the boundaries of industrial sites.

Terms	Definition
Withdrawal	Inflow of water from surface water, groundwater, collected rainwater, the municipal water supply or the sea for any use (based on Global Reporting Initiative (2010)).
Consumption	Outflow of water by evaporation, transpiration, product embedment and chemical conversion as well as through discharge into non-adjacent water basins (based on Bayart et al. (2010)).
Discharge	The sum of water effluents from an industrial operation that flow into the original or an adjacent water basin. The effluents can include water that is a by-product of the operation itself, say, from a chemical reaction or the processing of succulent biomass. Receiving bodies include surface and subsurface waters and sewers that eventually lead to rivers, lakes, wetlands and oceans.

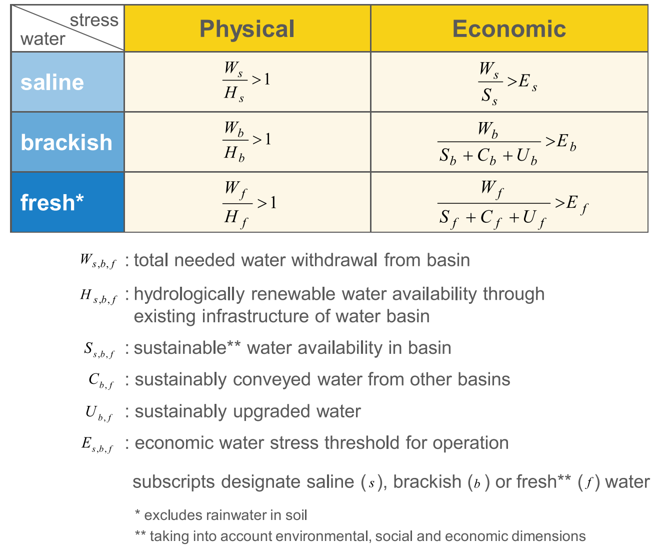

Fig. 2. Physical and economic water stress defined for a given water basin.

2.1. Water stress

Various metrics of water stress have been defined (Fingerman et al., 2011; Berger and Finkbeiner, 2010). But economic water stress, as we define it in Fig. 2, is what affects industrial operations.

As depicted in Fig. 3, industrial water can be secured directly from the local basin, by importing it from another basin or by upgrading it through treatment. Economic water stress occurs when an industrial operation is effectively curtailed by the cost of securing water that meets the operation's specifications within the environmental, social and economic restrictions of regulations. This differs from physical water stress, which arises when sufficient water of a given quality cannot be delivered through existing infrastructure. Within a given region, both physical and economic water stress can be induced, because water consumption and discharge of one industrial site reduces the water availability for other withdrawal sites in the same water basin.

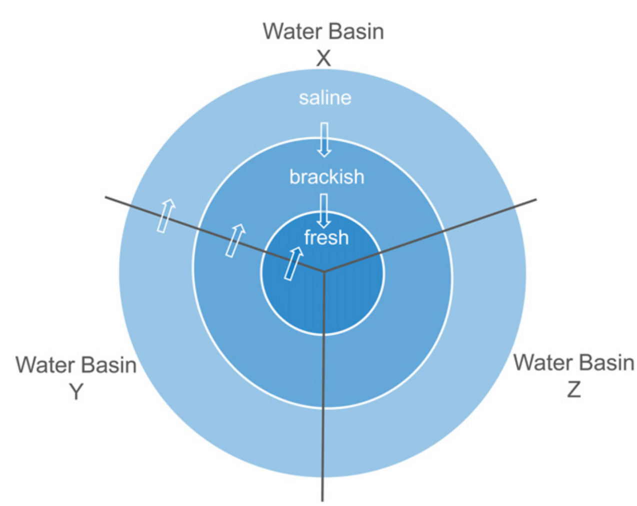

Fig. 3. Upgrading and inter-basin conveyance of water. Water is conveyed into Water Basin X, and it is also upgraded within the basin. Physical water stress can always be counteracted with technological and/or infrastructural measures as shown in water basin X; the question is whether these measures are economically and environmentally sustainable.