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Virtual water embodied in international energy trade of china

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Abstract

There exists a large amount of water consumption embodied in the global energy trade. Global energy trades among countries may have influences on global water environment. China plays an indispensable role on global energy trade, which thereby has a huge influence on global water scarcity. In this paper, we studied the virtual water flows embodied in the international energy trade in China, and investigated the scarcity-weighted virtual water flows, region-based scarcity-weighted virtual water flows based on China's water scarcity. In the past 14 years (2001-2014), China's net virtual water import hidden in energy trade has increased from 221.1 million m^3 in 2001 to 1709.0 million m^3 in 2014, implying China is a virtual water importer. China's net scarcity-weighted virtual water import is also increasing. The import of scarcity-weighted virtual water embodied in crude oil from the Middle East has the most profound effect on global water scarcity because the Middle East is in severe water stress. Through regional-based scarcity-weighted virtual water flow in energy trade, we can figure out that importing virtual water from Mexico and Russia through crude oil, the impact on global water scarcity will be mitigated. All the results show that importing virtual water embodied in crude oil trade play the most crucial role in the whole energy-water nexus.

Keywords: energy-water nexus, virtual water, water scarcity, energy trade

1. Introduction

The global oil trade in 2014 grew by 490,000 barrels per day, which implies that many countries have increased dependency on international trade for domestic energy consumption. Particularly, China has contributed the most to the world's largest increment in primary energy consumption since 2001, a large part of which relied on the international energy import. In fact, global energy import growth was driven by China and other emerging economies, (e.g. China replaced the US as the world's largest net oil importer in 2013 [1].)

A great deal of water is required to produce energy, and it is predicted that in 2030 global water consumption for energy sector will increase by 85% more than in 2012 [2]. In China, energy production is responsible for 61.4 billion m^3 water withdrawals, 10.8 billion m^3 water consumption, and 5.0 billion m^3 wastewater discharges, which are equivalent to 12.3%, 4.1% and 8.3% of the national totals, respectively [3]. The notion of virtual water flows has been introduced to provide a useful indicator to investigate the water embodied in the energy products. Virtual Water refers to the amount of water embodied in the

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production of natural and manufactured goods [4]. At first, virtual water was utilized to evaluate the impacts on water resources from trading agricultural products [4-9]. Then, it was applied to other trading products.

Beneath the international energy trade of China, the virtual water embodied in energy production flows with the energy trade. Such large scale of virtual water flow could have a benefit to global water distribution (with the energy trade, the virtual water exported from water-abundant region to arid region), or a severe problem (virtual water is exported from arid region to a water-abundant region) [6]. Thus, the impacts of the virtual water circulation hidden in the energy trade on the global water resource condition deserve more attention. There has been an growing number of studies aimed to systematically quantifying the water circulation embodied in the energy trade, especially in water scarce nations and regions, such as the Middle East and North Africa [9]; Mexico [10]; Spain [11]; and the United States [12-15]. However, very few comprehensive studies have been conducted for China's virtual water flow embodied in energy trade. In this paper, we aim to calculate the water flows embodied in the China's energy trade and identify the unreasonable water circulation through the trade. To avoid unreasonable water circulation that can exacerbate water shortages, the policy relevance of mitigating water scarcity is discussed.

2. Methodology

2.1. Virtual water flow

The virtual water calculation methods are basically divided into two classes: bottom-up and top-down ones. The top-down one is difficult to study the virtual water flow in China's energy trade due to limited water-use data for sectors. Here we choose the bottom-up method, although it requires some major assumptions (e.g., assuming the same kind of production in different countries has the same virtual water content [16, 17]).

The virtual water embodied in energy trade is calculated as follows.

$$\mathrm{VWI}(n,i)=\mathrm{vwc}*\mathrm{im}(n,i) \tag{1}$$

$$\mathrm{VWE}(n,i)=\mathrm{vwc}*\mathrm{ex}(n,i) \tag{2}$$

where vwc is the production i's virtual water content; $\mathrm{VWI}(n,i)$ is the import virtual water through importing production i from nation n; $\mathrm{im}(n,i)$ is the amount of production i imported by nation n; $\mathrm{VWE}(n,i)$ is the export virtual water through exporting the production i to nation n; $\mathrm{ex}(n,i)$ is the amount of production i exported by nation n.

2.2. Virtual water scarcity

The scarcity-weighted virtual water flows (SVWI) can be calculated by multiplying the water stress index (WSI) with imported/exported virtual water flows related to the energy production trade [16]:

$$\mathrm{SVWI}(n,i)=\mathrm{WSI}(n)*\mathrm{VWI}(n,i) \tag{3}$$

$$\mathrm{SVWE}(n,i)=\mathrm{WSI}(f)*\mathrm{VWE}(n,i) \tag{4}$$

$\mathrm{SVWI}(n,i)$ means scarcity-weighted virtual water import, which is embodied in importing production i from nation n; SVWE is scarcity-weighted virtual water export, exporting of energy commodity i to nation n; $\mathrm{WSI}(n)$ and $\mathrm{WSI}(f)$ are water scarcity indices of nation n and the concerned region, respectively. Eqs.(3-4) can provide consistent results for both arid and humid regions, but the use of another