Without water no energy, significant trade-offs between carbon and water footprints important for global energy and water policy

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Abstract

Without water no energy, significant trade-offs between carbon and water footprints important for global energy and water policy Winnie Gerbens-Leenes1*, Junguo Liu2 1 Integrated Research on Energy, Environment and Society (IREES), University of Groningen, Nijenborg 6, 9747 AG, Groningen, The Netherlands; p.w.leenes@rug.nl 2. Southern University of Science and Technology (SUSTech), Shenzhen, China; liujg@sustech.edu.cn Water and energy are strongly related. Water supply needs energy and energy supply needs water. The focus of the pre-2009 water for energy studies was mainly on the quantification of cooling water use in thermoelectric generation and on water use for transport fuel production. Most of the studies were based on grey literature using data from industry, often from the USA. Water footprint (WF) studies have made it possible to quantify water for bioenergy and hydropower, because the assessments were made based on publically available data, e.g. weather data. WF studies provided new information on the amount of water needed for specific renewable energy types. Energy that originates from photosynthesis (e.g. crops, trees or algae) has relatively large water footprints compared to fossil energy sources. Energy that originates from hydropower also has large average WFs, but variation is large. This paper gives an overview of the contribution of water footprint studies on water for energy relationships. It first explains why water is needed for energy, gives an overview of important water-energy studies until 2009, shows the contribution of WF studies, and indicates how this contribution has supported new research. Finally, it provides knowledge gaps that are relevant for future studies. Energy source categories are: 1. biofuels from sugar, starch and oil crops (food crops); 2. cellulosic feedstocks (residues and energy crops); 3. biofuels from algae; 4. firewood; 5. hydropower and 6. various sources of energy including electricity, heat and transport fuels. Especially category 1, 3, 4, 5 and to a lesser extent 2 have relatively large WFs. This is because the energy source derives from agriculture or forestry, which has a large water use (1,2,4), or has large water use due to evaporation from open water surfaces (3,5). WFs for these categories can be calculated using the WF tool. Category 6 includes fossil fuels and renewables, such as photovoltaics and wind energy and has relatively small WFs. However, information needs to be derived from industry. The policy to decrease carbondioxide emissions has consequences for water. Energy policies need to account for significant trade-offs between carbon, land and water footprints.

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Introduction

- Water and energy are strongly related. Emphasis on decreasing carbon footprints (CFs) might increase water footprints (WFs).
- Pre-2009 water for energy studies focussed on cooling water for thermoelectric generation and water for transport fuel production.
- Most pre-2009 studies used grey literature data from US industry, often copying data from one source to the other.
- WF studies could quantify water for bioenergy and hydropower, because assessments used publically available data, e.g. weather and crop production data.
- This poster shows the contribution of WF studies to water for energy relationships. It explains why water is needed for energy, indicates most cited water-energy studies until 2009 and important WF studies.

Water for energy:

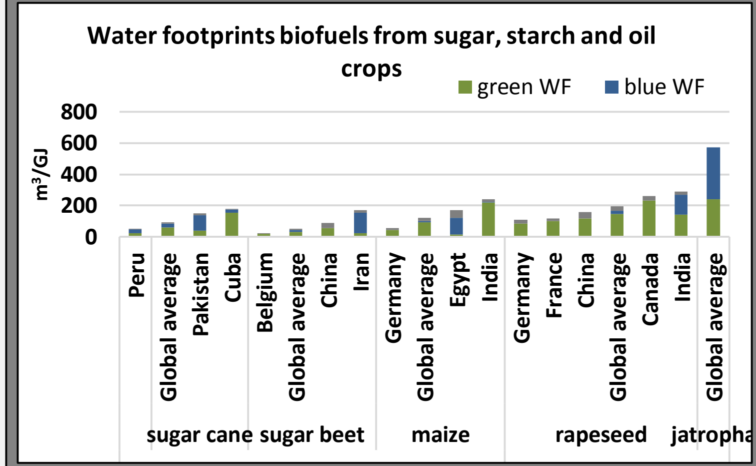
- Water for mining fuels, e.g. coal, natural gas or oil.
- Water for operations, e.g. to cool power plants.
- Water to grow crops, green, blue and grey WFs.
- Water lost due to evaporation from hydropower reservoirs.

Most cited water – energy studies before 2009:

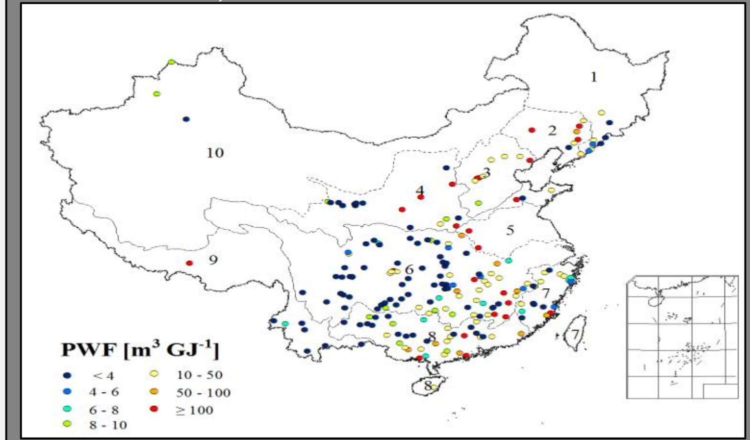
- Gleick, 1994. *Water and Energy*. Annu. Rev. Energy Environ. 19, 267–99.
- Macknick et al., 2012. *Operational water consumption and withdrawal factors for electricity generating technologies: A review of existing literature*. Environ. Res. Lett. 7.
- Meldrum et al., 2013. *Life cycle water use for electricity generation: a review and harmonization of literature estimates.* Environ. Res. Lett. 8, 015031.

Results

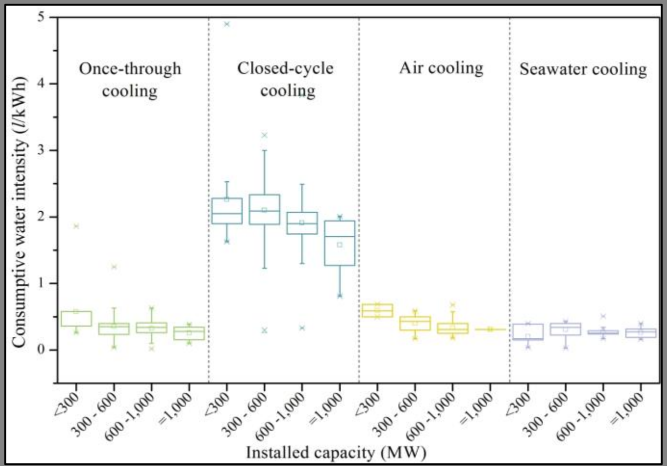
- WF studies indicating water consumption for specific renewable energy types, e.g. bioenergy and hydropower.
- Energy from photosynthesis (crops, trees or algae) has large WFs compared to fossil energy, wind and PV.



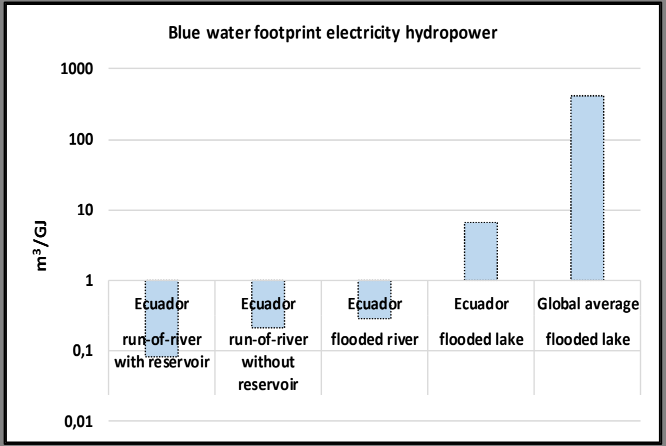
WFs of biofuels from sugar, starch and oil crops (sugar cane and beet, maize, rapeseed) for some countries with large WF differences and the global average WFs. *(Gerbens-Leenes et al., 2009. PNAS, 106: 10219–10223 ; Mekonnen and Hoekstra, 2011. Hess 15: 1577–1600).*



Blue WF of hydropower in China. China's hydroelectric WF totaled 6.6 Gm^3 yr^{-1} in 2010. This was about 24% of the reservoir WF. *(Liu et al., 2015. Scientific Reports 5: 11446)*



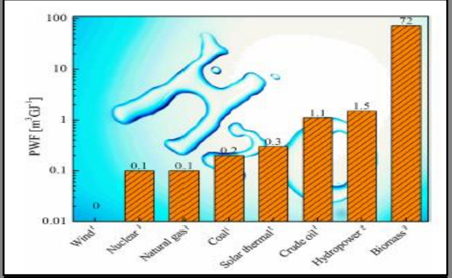
Blue WFs of China's coal fired power plants. The CCP WF is 1.15 l/kWh; WF for closed-cycle cooling is 3-10 times higher than WFs of other technologies. (*Zhang, Liu et al., 2017. Journal of Cleaner Production 161: 1171-1179*).



Blue hydropower WFs for Ecuador and the global average. (*Mekonnen and Hoekstra, 2012. HESS, 16, 179–187; Vaca-Jimenez et al. 2019. Water Resour. Ind. 22: 100112)*

Discussion and Conclusions

- WF studies gave new information on water consumption for specific renewable energy types.
- Bioenergy has large WFs and is less suitable to replace fossil energy than other renewables.
- Hydropower also has large WFs, but variation is large. Hydro with small WFs might contribute to decrease carbon footprints (CFs).
- Energy scenarios decreasing CFs should take large WFs of some renewables into account.



The way forward

- Energy policy needs reliable water data, and more case studies on energy WFs.
- Climate change affects crop growth and water needs, e.g. of energy crops, hydropower and thermal power plants. This requires more research.
- Policy should realise that the need to decrease CFs can only be realised when also water constraints are taken into account.