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Hydrology and Earth System Sciences Discussions

Interactive comment on "The water footprint of electricity from hydropower" *by* M. M. Mekonnen and A. Y. Hoekstra

Anonymous Referee #1

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The paper tries to address an interesting problem –estimation of the water footprint of electricity from hydropower, which has traditionally been viewed as a clean source of energy with regard to water consumption. It is very well presented in terms of discussing methods used as well as quantification limitations. I highly support the authors' recommendation about considering water footprint assessment as a component of hydropower systems' evaluation at the planning stage.

The following questions still need to be answered to clarify some ambiguities and determine the accuracy of the results.

1. Does the definition given for blue water footprint suffice for the purpose of measuring the actual water footprint of electricity generated from hydropower?

This paper suggests blue water footprint as the major component of hydropower water footprint. It defines the blue water footprint as the water evaporated from reservoirs to produce electric energy. According to the definition, the amount of evaporated water calculated from Penman-Monteith equation is the only value plugged in blue water footprint calculations. However, according to some studies on climate change effects of man-made structures [1, 2, 3], the evaporation from reservoirs results in local atmospheric instabilities. The instability of atmosphere together with the moisture content due to evaporation induces more precipitation in the area, returning a portion of the evaporated water to the reservoir. Although water is evaporated into the air and may be considered as consumed water at first glance, a portion of the evaporated water goes back to the reservoir. So, it is important to determine the period in which measurements are implemented [in a longer period, the consumed water is less than that in shorter period] and it is highly recommended to take into account the actual (net) consumed/evaporated water consisting of total evaporated water minus the volume of water returned to the reservoir due to precipitation. Considering this issue in calculations leads to less water footprint for hydropower energy, making it more competitive with regard to other sources of energy.

Overall, the reviewer believes that the water footprint of hydropower is overestimated in this study and could be improved by taking into account the real behavior of water cycle.

2. Can a small set of hydropower sites represent all hydropower plants reliably?

The paper studied 35 plants and found that hydropower has significant water consumption. Although this might be true for selected plants, I am afraid, it cannot be generalized to all hydropower plants in different areas with various situations. Given the spatial variability of climatic conditions, I am afraid the selected sample is not reliable. For example, in northern European countries that are not tropical, the evaporation rate is far less than that of tropical countries like Brazil.

3. Can one estimate the hydropower water footprint through studying multi-purpose reservoirs?

The selected reservoirs in this study are multi-purpose reservoirs. Therefore, undoubtedly the authors are overestimating the water footprint of hydropower. Since disaggregating of water uses (water footprint) for each purpose of a multi-purpose reservoir is very challenging, I suppose the only reliable systems for studying water footprint are the single-purpose reservoirs for hydropower production (e.g., the high-elevation systems in California) or run-of-the-river systems. Given that construction of more small hydropower systems is on many countries' agenda, a reliable estimation of water footprint of these systems is of particular importance. As log as reliable information is not at hand, impacting policy seems impossible. 4- What are the limitations of the Water Footprint concept? While I highly appreciate the water footprint concept that has made many of us rethink the planning process, this concept is associated with limitations. Discussion of such limitations will improve the quality of the paper.

Other comments:

- I find the current title misleading. Suggested title: "The Blue Footprint of Hydropower from Multi-Purpose Reservoirs"

- Claiming that hydropower is a significant water consumer cannot be based on a method which overestimates the water footprint significantly.

- I am not sure if dams always bring about significant social improvements. The materials on the first and second page of the paper regarding social aspects of the dams are contradicting.

- P 8357, L 14: Citation needed ("it has been debated").

- I am not really sure that data has been a real limitation in this study. Information about the dams in the developed world are not hard to access in most of the case. Of course, some effort is required.

- The authors have past publications on water footprint of other energy sources. At least a table to facilitate comparison of hydropower's water footprint with water footprint of other energy sources is necessary. Some discussion can be helpful.

- This analysis does not consider the water used in the dam and hydropower plant construction processes.

- P 8362, L 6-7: Why?

- I suggest producing figures which show the relation between water footprint and climate variables. Such tables can be helpful when presented together with Figure 1.

- I suggest categorizing the studied reservoirs into three categories with respect to their flooded area (Figure 1). Providing a rough estimate of the number of hydropowers in each category in this study and around the world will be really helpful.

- One conclusion from this study is that those large reservoir which have deep lakes and smaller flood area do not have a high water footprint. Is this a valid statement?

- Add the location (country) and longitude and latitude of the reservoirs to Table 1.

References

1. Eltahir, E. A. B. and Bras, R. L., "Precipitation recycling", Ralph M. Parsons laboratory, Department of Civil and Environmental Engineering, Massachusetts Institute of Technology, 1996. 2. Feddema, J. J. and Oleson, K. W. and Bonan, G. B. and Mearns, L. O. and Buja, L. E. and Meehl, G. A. and Washington, W. M., "The importance of land-cover change in simulating future climates", 2005, Science, 310, 1674-1678. 3. Hossain, F. and Jeyachandran, I. and Pielke, R., "Have Large Dams altered Extreme Precipitation Patterns?", EOS-AGU , vol. 90(48): 453-454.

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