Novelty and transferability

Overall, the model's methodology is based upon previous work, e.g., Wada et al., 2011; The model's novelty is associated with representing country-scale industrial water use as the aggregated water use of ten sub-sectors, and the explicit representation of infrastructure through the inclusion of connectivity to the water supply network and non-renewable water (e.g., supply system losses).

Furthermore, the authors suggest that novelty is associated with the very high resolution of 3 arcseconds and indicate that unlike other regional models – the structure of this model 'can be extended to other regions, given appropriate socioeconomic inputs and harmonized statistical data.' (P. 1, lines 28 -29).

I find some gaps in the presentation of the novelty associated with the two latter points.

a) First, while achieving a very-high resolution of 3 arcseconds is possible due to the resolution of the population grids and the use of point-data for industries – the reason for why such high resolution is needed remains unclear. The authors shall discuss the advantages and practical uses of such detailed dataset against the introduced uncertainties associated with downscaling.
   For LHMs, current state-of-the-art is at approximately 1 km resolution, and is already challenging computationally (Hoch et al., 2023) – yet the propose ~90 meters resolution is 10 times higher, and probably provides little, if any, benefits for water resources modeling. Further, choosing the high-resolution gridded population dataset should acknowledge the uncertainty in gridded population products (e.g., see Kuffer et al., 2022; Láng-Ritter et al., 2025)
   For utilities management and detailed planning – this data may be too uncertain, as all its structural components (households' size, NRW, GDP per capita) are based upon data at coarser resolution. This discrepancy may hide important spatial distinctions associated with very local urban elements affecting land value, development, and thus lifestyle and water use.
b) Second, the authors do not provide sufficient detail of how to transfer the model to other locations. Gaps are mentioned below:
   a. The authors suggest that the model structure could be replicated and transferred – but do not define the scope of such structure. For example, sub-sector selection seems biased towards a representation of the oil-economy – which is a cornerstone of the case-study; though, would it fit other areas where some of the aggregate other manufacturing category is dominant, e.g., Bangladesh (Ahaduzzaman et al., 2017), or data-center clusters?
   b. Sector selection (including sub-set of mining activities) is based only on water quantity – ignoring completely the impact of some sectors (e.g., textile industry, mining industry, etc.) on water quality. This is a

shortcoming and shall be mentioned in the context of usability and transferability.

c. The paper lacks sufficient description of the data processing (e.g., input harmonization) and sources to support reproduction (see Reproducibility section below).
d. While for some industries exact location is available globally (e.g., oil extraction, electricity generation), for most sectors data source used in this study, and required data for transferability remain unclear (e.g., paper, food processing, refining, chemicals, cement, metals, etc.).

The authors discuss the different stages (as shown in the conceptual figure 1, including scoping and data preparation), including the logic or reasoning behind different choices (e.g., in the discussion section, maybe proposing a blueprint for transferability). The authors shall provide more information regarding the decisions made during data harmonization – as other researchers shall go through the same challenges compiling data from different sources. Specifically, they shall disclose the methods used for interpolation of missing data (i.e., over time or across countries), as currently there are some pieces of information that do not form a clear understanding for the reader. Finally, they should indicate how to handle missing data – e.g., how to downscale industrial water use if high resolution industry's location is missing for some sectors.

<u>Validation and modeling improvement</u>

The authors validate their country's scale and regional scale results in the GCC region as well as in European countries. The techno-economic factor (TEF) is validated by comparing the normalized observed and predicted water use intensity. Regional water use intensity is also compared for different regions.

These sections require some additional input and clarifications.

1. Observed data is shown as a median value +/- 1 s.d.; The source of the data and its treatment is unclear- why is observed data an array and not a single annual point? What is its source? This should be clarified by the relevant figures (3, 8, and 9).
2. Additional discussion shall be dedicated to clear cuts in observed data – why do they occur? What do the mean for validation – e.g., Saudi Arabia and Bahrain.
3. The authors indicate that some countries WWI (industrial) have considerable inconsistencies (P. 22, lines 17-18). They don't mention Kuwait and Bahrain, which seems to have similar inconsistencies with most other countries.
4. The authors suggest that these inconsistencies occur in countries with 'limited, aggregated, or inconsistent data' (P. 22, line 15 -17) – yet the figure or the text do not provide sufficient proof for this claim – instead it shows that the model fails

to replicate historical dynamics for most countries' industrial water use intensity (4-6 out of 7). Figure S3 presents a better result, yet some countries are not performing so well. The authors shall improve their arguments regarding model performance and capacity to capture long-term dynamics, as it currently seems they are missing some structural element.

5. Specifically – TEF misses the human behavior aspects associated with national policies aimed for controlling water use – e.g., campaigns, water pricing, etc. This should be discussed.
6. Domestic water performance is better – yet similar problem is evident in Bahrain and Jordan (Figure 9).
7. To demonstrate improvement – the authors may consider running their models with a restricted version (e.g., lumped industrial sector) and compare with the current version and the observed data.

Reproducibility

1. Geolocation data of industries is not stated for all the sectors and is not clearly shown. To enhance reproducibility – the authors shall add a column with the references to table 3 or a relevant row to table 2.
2. Some references associated with data associated to industrial water use/production are broken – specifically those directing to KAPSARC website. For example, the link to the metal production data (P.44, line 3) indicates a page stating, no results found', yet using the search box of the KAPSARC data yields 82 datasets. Other links lead to an error 404.
3. Data used to distinguish urban from rural cells is not explicitly mentioned.
4. The authors should clearly indicate how their model accounts for cooling water, as it is separated from WWI in table 3. Further, the authors shall not assume that all cooling water (e.g., in other areas) is seawater or other saline water.

Specific comments:

P. 9, line 4

Florke et al (2013) uses economic metric manufacturing gross value added (GVA) and not GDP per capita as stated.

P. 9, line 8-9

I believe that the relationship between water use intensity and energy intensity was assumed by Shen et al., 2008, not by Hanaski et al., 2013 as mentioned).

P.13, lines 20-25

The electricity generation water requirements can include additional dynamic parameters – e.g., water temperature – as shown by Jones et al (2025) – should be mentioned in limitations.

P.13, lines 31

'…to-heavy crude oils have …' instead of had

P.13, lines 34 – P.14 lines 1

Figures seem to be associated with light-to-medium and not medium-to-heavy.

P. 15, line 31

The use of 42% to indicate consumption-to-withdrawal is not completely justified. Some evidence may be found in material flow analysis of water footprint accounting papers. For example, Henningsson et al. 2001 – suggest that 70% of the water use in the F&B sector end up as wastewater. Authors shall also check other cases where an average approach was applied.

P.16, section 2.1.8

Additional explanation of the model used for oil extraction could be useful – as it is very specific application (in a broader paper) and it includes a lot of technical language. E.g., what does surface oil and produced water production rates – some clarification regarding production process would be good.

P.17, lines 14-29

Sensitivity analysis of selected parameters B_0, B_w, and WOR shall be advanced to shed light on the uncertainty associated with researcher choice of representative value.

P. 20, lines 12

Which countries did not have DWW? Further (line 13) – the choice of 50 l/cap/day is either prescriptive or assuming some initial development status. This assumption would is not suitable in other regions, e.g., SSA. The details are important for transferability.

There are areas in the world (e.g., in SSA) where water withdrawal is far below 50 l/cap/day – the choice of this minimum value is normative, whereas a descriptive approach is probably better for this model.

Furter – is the 500 l/cap/day justified – why is it restricted to the local

P. 21, line 20

The authors used a fixed water consumption fraction (CF) to represent urban and rural areas (0.1 and 0.5, respectively). In a previous work Wada et al (2010) argued that these fractions (termed recycling ratios -> 1 – CF), are expected to change with country development. Yet, this information is lacking in this paper, and readers may think that the indicated fractions are globally applicable.

P. 26, line 17

You have probable meant figure 6

P. 26-28

Currently Figure 6 is not referenced in the text – following my last comment – make sure all figures (6 & 7) are referred to from the text.

P.30, lines 3-10

The distinction of what drives national water withdrawal and consumption is presented as a result – but the observation that national fluctuation in withdrawal closely follow economic growth and changes in household size, and that consumption is related to network efficiency and urbanization – is rooted in the modeling framework – this is not a result, rather an outcome of the model design.

P.33, line 14

The use of monetary water intensities instead of physical units in the F&B sector is presented as a limitation. Yet it is also an opportunity to be used with widely/globally available input-output tables (IOT) and to be linked to IAMs to inform projected water withdrawal at a sectoral level. These should be acknowledged.

References:

Ahaduzzaman, .-., Sarkar, P., Anjum, A., & Khan, E. A. (2017). Overview of Major Industries in Bangladesh. Journal of Chemical Engineering, 30(1), 51-58. https://doi.org/10.3329/jce.v30i1.34798

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