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Short communication

Enforcing and improving water data reporting in the energy system is urgently needed

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ABSTRACT

As it is a commentary we do not have a usual abstract Today's energy systems are critically dependent on water for hydropower and thermoelectric power generation, which relies on a large amount of cooling water. However, even with increasing climatic pressures and growing concerns surrounding energy security, the availability of high-quality integrated water data sets remains poor (1, 2). This is surprising considering broad climate impacts on energy systems worldwide. Numerous regions experienced water-related power generation issues throughout the 2010 s, including coal generation during the 2015 Polish drought, repeated curtailment of French nuclear plants, and hydropower curtailment in the US, Romania, China, Ghana, and Brazil, among others (3). The 2022 heat waves saw broad water-energy issues across the EU, with France altering regulatory requirements to keep nuclear plants running (resulting in higher water temperatures) (4) and hydroelectric curtailment across several countries. There is clear evidence of impacts on energy security today (5) and how this issue is poised to become more acute into the 21st century (6, 7).

Today's energy systems are critically dependent on water for hydropower and thermoelectric power generation, which relies on a large amount of cooling water. However, even with increasing climatic pressures and growing concerns surrounding energy security, the availability of high-quality integrated water data sets remains poor [1,2]. This is surprising considering broad climate impacts on energy systems worldwide. Numerous regions experienced water-related power generation issues throughout the 2010s, including coal generation during the 2015 Polish drought, repeated curtailment of French nuclear plants, and hydropower curtailment in the US, Romania, China, Ghana, and Brazil, among others [3]. Repeated summer heat waves in recent years have seen broad water-energy issues across the EU, with France altering regulatory requirements to keep nuclear plants running (resulting in higher water temperatures) [4] and hydroelectric curtailment across several countries. There is clear evidence of impacts on energy security today [5] and how this issue is poised to become more acute into the 21st century [6,7].

Despite these impacts, limited data availability on water use in energy systems means that policymakers and scientists are often forced to use assumptions to extrapolate water consumption and withdrawal from other results. Assumptions are often made based on generator type (gas, coal, and others), cooling system (once-through, cooling tower, and others), or by using estimates from other countries that may not be directly transferable [2]. However, even when new information becomes available, such as updated capacity factors, the heat content of fuels, or ambient temperatures, critical data gaps in one or more other factors often remain, and plant-specific data are rarely available [2]. The picture is further complicated by the fact that thermoelectric power is the only sector where water withdrawals can be significantly different from consumption for some generation types. This can mean water use data is often misreported or misinterpreted.

The availability of both water quality- and water volume- data is a significant issue for researchers and policymakers (Fig. 1). Water used to cool power stations, particularly nuclear power plants, cannot exceed a certain temperature and is often returned to waterways at a significantly higher temperature, with significant potential impacts on aquatic

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biodiversity [8]. Crucially, there are limited time-series of power-plant water use or temperature throughout the year. Such information is essential given climatic impacts on seasonal water availability and water temperature impact.

The lack of systematic knowledge and data on the interlinkages between water use and energy systems has profound implications in both energy system modelling and investigations into climate resilience. For example, different pathways to net-zero emissions imply significant differences in water use. While wind and solar photovoltaic power have much lower water demands, there are many potential energy and carbon reduction technologies, such as bioenergy, hydropower, concentrated solar power, and carbon capture & sequestration (CCS), that require large volumes. For example, CCS retrofits to allow the continued operation of newer Chinese coal plants may significantly impact power availability both because coal power requires large volumes of water for cooling and so do many CCS technologies [9]. Targets for new nuclear power in China, France, and Poland will require large volumes of water and will impact water quality (via temperatures). Further, expanding the use of hydrogen may place significant requirements on freshwater [10]. Given the depth and pace of the energy transition, it is vital to estimate the water impacts of these different pathways. Yet, while energy systems models (ESMs) often address the implications of different pathways on land and, increasingly, material availability, they largely omit impacts on natural and managed water systems due to data availability.

Meanwhile, climate pressures across different regions are unfolding faster than previously thought with Working Group II of the Intergovernmental Panel on Climate Change plainly stating that the "Evidence of observed impacts [in Assessment Report (AR) 6], projected risks, levels and trends in vulnerability, and adaptation limits, demonstrate that climate resilient development action is more urgent than previously assessed in AR5″ [11]. Climatic impacts on hydropower are particularly concerning, as a generation source well-matched to balancing renewables. Realistic assessment of the hydroclimatic impacts on future energy systems requires both detailed climate-water projections and a detailed understanding of the water use in current and future energy systems.

While climate data are abundant, water use data are generally heavily modelled on aggregated scales rather than informed by specific locational data. Energy security across the EU and the world will depend on the relationship between the speed of climatic changes and the energy transition pathways chosen. To make policy-relevant assessments, researchers and planners must have access to the relevant data. An administratively simple solution is the requirement of power producers to report water source (river, lake, groundwater, or sea), volumes of abstractions and returns, along with plant-level temperature throughout the year to central authorities. However, given the cross-border nature of many water resources, this requires both regulation and enforcement across administrative levels.

Unfortunately, significant regulatory gaps exist, especially in the European Union, which positions itself as a leader. The EU ostensibly requires water abstraction records under the Water Framework Directive (2000/60/EC) and reporting of pollutant emissions to water under the European Pollution Release and Transfer Register (EPRTR) (EC/166/2006), but reporting is hugely uneven and under reinforced. Efforts by the European Environmental Bureau (EEB) revealed significant issues in obtaining water use data from EU members. The EEB made data access requests on water consumption to 22 Member States and found a "systemic failure in ensuring public access to key environmental information" where 16 countries failed to respond to data requests [12]. Even those that did, "authorities could not extract the relevant water data" in electronically readable formats. Of all countries approached, only France (providing temperature, release information and installation-scale abstraction volumes) and Czechia (with limited information accessible via a web portal) gave any accessible data. The centralised portal for data on industrial emissions also provides no data on water. There are clear, systemic and EU-wide failures in the implementation practice of water data collection, especially within energy systems.

The United States leads the EU by some distance, offering water

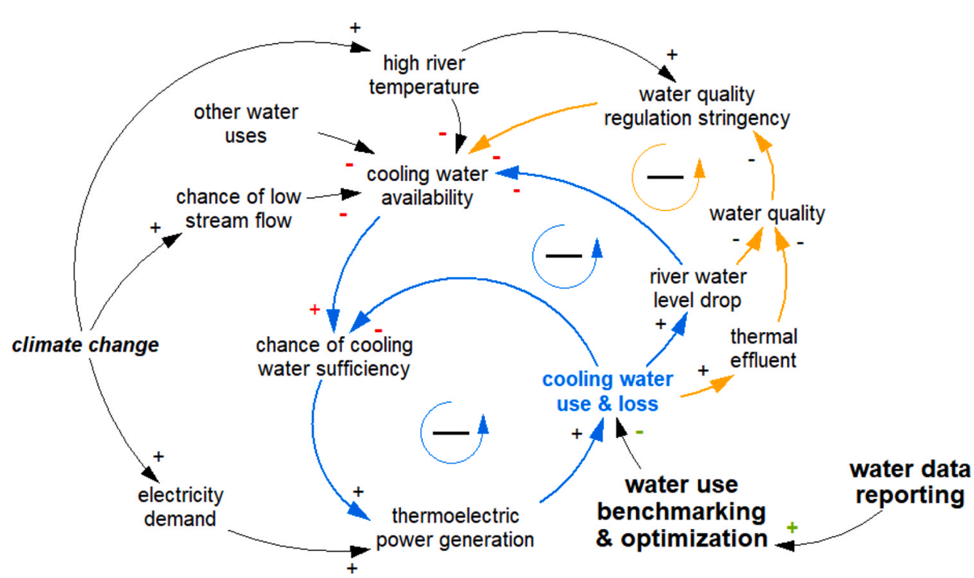

Fig. 1. A system diagram of the water use in electricity production. A positive (negative) link polarity suggests an increase in X would result in Y being higher (lower) than it would have been. The link polarities (+/-) do not describe what actually happens in Y. To discern actual outcomes, one must consider changes in Y's inputs and be mindful of nuances when Y is a stock variable. The two negative feedback loops shown in blue and gold colours constrain power generation driven by increasing demand (blue indicates a balancing loop due to quantity, and gold is a balancing loop due to quality, driven by temperature). The negative feedback loops share two elements: while 'cooling water availability' faces growing pressures from multiple sources (climate, regulations, and development), scientists and policymakers could facilitate future policy interventions to reduce 'cooling water use & loss' (in blue) by improving cooling water reporting & management (in bold), hence mitigating the loops' negating effects in the face of increasing energy demand. Red negative signs indicate the constraints on cooling water availability. Note that arrows show general trends but that climate change is not homogenous. While the frequency of lower stream flow and high temperatures are projected to increase in many regions, a smaller number of other regions may see a different systems loop.

withdrawal, consumption, and temperature per thermoelectric plant at a monthly resolution [13] and a general abundance of data at plant levels [14]. However, a higher temporal resolution and more regular updates would still be desirable. China now requires quarterly or annual reporting of thermal power plant water withdrawals, but regulations are still being rolled out, and there is no requirement for the reporting of water returns, water temperature, or type and heat content of the fuels [15,16].

The European Commission aims to address some of the shortcomings in data availability. Proposals within the Industrial Emissions Directive (2010/75/EU), or IED, focus on mandates for water use reporting and the setting of quantitative limits, specifically on resource efficiency and reuse as part of the environmental management system (which will also ensure open access). They also include a change to the Industrial Emissions Portal, or IEP, to ensure that the reporting of water use of large-scale industrial activities are included.

Recent changes in the IED revision process in 2023 has introduced exemptions to permit conditions on water consumption and an up to 14 year delay in compliance with water consumption limits for existing installations [17]. Even with this delay in compliance, its not mandatory for the forum deciding emission standards to prescribe water consumption limits. In any case, in July 2023 the European Parliament voted against mandatory limits on water consumption, watering down the wording to 'indicative' (that is, non-binding). In the IEP, while the European Council has supported a mandatory reporting of water consumption at a facility level, this would only be phased in by 2028. Requirements to report on facility operating hours which are useful for deriving comparisons of water use among facilities has been removed by the Council. It is crucial that these recent changes do not prevent access to timely and reliable water use data in the energy system.

However, even if the negotiation efforts are successful, there is still no clarity on the water consumption limits for large consumers, and European operators may still resist sharing water consumption data as they often consider such data confidential business information. It may be beyond 2030 when maximum consumption levels are fully regulated and data are available for energy system researchers and policymakers. In comparison, water efficiency standards for power plants have been published in China (2011) and India (2018) and are in force now [18, 19].

In 2016, the World Energy Council stated, "we will start to see the effects of water scarcity on energy supplies in the very near future". As of early 2024, while many countries are experiencing increasing energy security issues due to water availability issues, there has been very little progress in collecting the data necessary to mitigate and adapt to a changing climate. Stricter data-reporting requirements across the world are necessary, especially in the EU. A lack of water volume and quality information (including temperature and chemistry) makes it much harder to make robust, scientifically-based environmental assessments. Given the rapidly changing climatic conditions that are altering precipitation patterns and water availability, along with concerns over the impact of thermal pollution on biodiversity loss, the availability of water data is critical to the international community to inform policy in a green and climate-resilient transition.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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