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ORIGINAL ARTICLE

Proposal of an index to evaluate the 'dewaterization' of the urban water cycle and a practical application

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Abstract
Analyses of the relationship between water and energy do not account for the fact that the energy used in the urban water cycle is a consumer of water. To ensure the efficient use of water resources, the operator must know the raw water use associated with the energy input of the urban water infrastructure. The main contribution of this research is the proposal of an index that measures how much raw water is consumed by the energy used to produce 1 cubic m of water. The resulting index is a decision-making tool that enables the sustainable use of water resources. This article first explains the index, which is called the Water Footprint of the Urban Water Cycle. It then provides examples of how to apply the proposed method; among other applications, it can be used to establish a classification of energy sources based on their relative consumption of raw water, according to the electricity generation mix in each service area. The proposed method is useful for operators, policymakers and other stakeholders, enabling them to make decisions that contribute to the 'dewaterization' of the urban water cycle.

Keywords Dewaterization · WFUWC · Water–energy nexus · Water footprint · Urban water cycle

Introduction

This article presents a novel method for quantifying the interdependence between water and energy in the urban water cycle (UWC). The proposed index, which is called the Water Footprint of the Urban Water Cycle (WFUWC), measures the volume of water used in the analysed facilities due to the electrical energy consumed. This connection is referred to as the water–energy-water nexus (see Fig. 1).

Previous studies have clearly demonstrated and explained in detail the relationship between water and energy (Hoekstra and Mekonnen 2012; Heshmati et al. 2015; He et al. 2019; Gerbens-Leenes et al. 2020). Nevertheless, the lack of simple tools to measure it means that it is not assessed. Such a tool is therefore needed for the management and planning of water resources (Javadinejad et al. 2019b), energy sources and related infrastructure.

The two basic elements of the method proposed here are the water used in electricity generation and the electricity consumed in the production of water. Energy use has a major environmental impact (Dincer 1999). Global energy consumption accounts for two-third of greenhouse gas emissions (European Environment Agency 2017) and is the primary cause of climate change (Heshmati et al. 2015; Javadinejad et al. 2019a). Over the years, various authors have identified and analysed other impacts linked to the use of energy (Dincer 1998; Dincer 1999; Bilgen 2014), including those specifically linked to the UWC (Venkatesh and Bratteboe 2011; Amores et al. 2013).

The UWC is energy-intensive and the main source of that energy is electricity (Kenway et al. 2008; Venkatesh and Bratteboe 2011; Lemos et al. 2013; Elias-Maxil et al. 2014; Loubet et al. 2014; Oppenheimer 2014; Wakeel and Chen 2016; Al-Omari et al. 2022; Huang et al. 2023). In the specific case of wastewater treatment plants (WWTPs), electricity has been identified as the main cause of their environmental impact (Gallego et al. 2008; Shao and Chen 2013; Zappone et al. 2014; Capodaglio and Olsson 2020), accounting for as much as 95.85% of the total impact (Pasqualino et al. 2009; Li et al. 2013; Morera et al. 2016).

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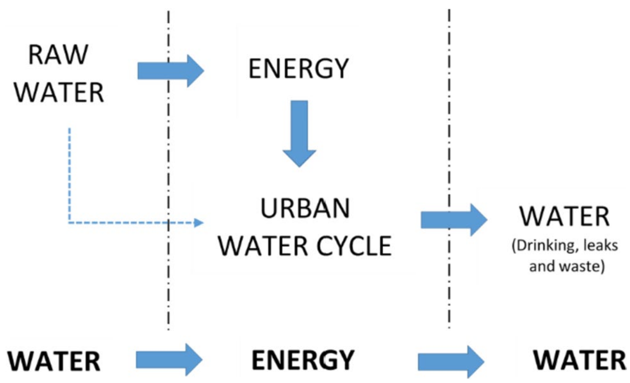

Fig.1 The relationship between water and energy in the urban water cycle

Recent studies have employed different methodologies and scopes of analysis to spotlight the relationship between water and energy (Hamiche et al. 2016; Dai et al. 2018; Fayiah 2020; Gerbens-Leenes et al. 2020; Helerea et al. 2023). However, unlike other studies that analyse the impact of the UWC in terms of the volume of water used for each unit of energy consumed, the novel method proposed here goes one step further in examining the water–energy nexus, by determining the Water Footprint (WF) for each unit volume of water involved in the functioning of the UWC.

Efforts to improve the efficiency of water resource management in the UWC have traditionally focused on reducing network losses and encouraging consumers to use water more efficiently. A novel aspect of the proposed index is that it measures the volume of water that is used (consumed or polluted) by the UWC itself, highlighting the role played by the operation of the UWC in saving water.

The calculation of the proposed index starts with the WF (Hoekstra and Hung 2002; Hoekstra 2003; Hoekstra and Chapagain 2007; Aldaya et al. 2011; Hoekstra and Mekonnen 2012), which is the volume of freshwater appropriated to produce a product. In this case, the product is the electrical energy used in the UWC. The electricity generation mix determines the impact of the energy used (Amores et al. 2013) and therefore the WF. In a joint analysis, the aim of reducing the WF may come into conflict with the goal of cutting carbon emissions (Mekonnen et al. 2016; Bello et al. 2018; Muhammetoglu et al. 2023). In this respect, the proposed index is a decision-making tool that can be used to help reconcile the two objectives. The second step of the calculation requires data on the electricity consumption per unit volume of water treated in the facilities.

Another novel contribution of this article is the concept of "dewaterization", which can be understood as the process of reducing the use of water in an economic activity. Achieving dewaterization is essential to help balance the uses of water resources.

For illustrative purposes, we demonstrate how the method can be applied to two types of UWC facilities: WWTPs and a reverse osmosis (RO) plant. The examples show the effect of the different electricity mixes on the calculation of the proposed index and its evolution over a 10 year period.

Methodological proposal

Below we present the proposed method for estimating the impact of the UWC on water resources, based on the WF of the electricity generation mix and the energy consumption per unit volume of water treated in the UWC or part of its facilities. The end result is an index called the WFUWC.

The starting point of the proposed method is the annual electricity generation mix in the country or region where the UWC facilities are located. Based on this information and applying the method developed by Mekonnen et al. (2015), we calculate the WF of the different energy sources that make up the electricity generation mix. From that point on, the rest of our method is entirely novel. As such, it represents the main contribution made by this research to the current body of knowledge.

The second step is to collect data on the flows of water involved in the processes of abstraction, water treatment, transport, distribution, use, sewage collection and wastewater treatment. Exactly what data are collected will depend on whether the aim is a partial or full evaluation of the UWC.

The last data requirement is the electricity consumption of the analysed facilities. To evaluate a future scenario in which the facilities are not yet in operation, the consumption will have to be estimated.

WF of electricity generation

Each source of electricity has a different WF, which we calculate using the method proposed by Mekonnen et al. (2015). The estimation of the total WF in m^3/year, corresponding to the fuel supply and construction stages—together regarded as the supply chain—plus the operational stage, is formulated by Mekonnen et al. (2015) as follows (Eq.1):

$$WF = WF_{\text{supply chain}} + WF_{\text{operation}} \tag{1}$$

Where: WF is the water footprint of electricity and heat production (WF in m^3 per year), WFsupplychain is the water footprint of the supply chain and $WF_{\text{operation}}$ is the operational water footprint.

The WF corresponding to the electricity generated from fossil fuels, nuclear energy and biomass is calculated by Mekonnen et al. (2015) as follows (Eq.2):

$$WF_{\text{e,total}}[f] = WF_{h,f}[f] + FEE[f] + (WF_{e,c}[f] + WF_{e,o}[f]) \times E[f] \tag{2}$$

Where: WFh,f [f] is the water footprint per thermal unit of energy (m^3TJh^{-1}), FEE [f] is the annual consumption of fuel "f" needed to produce electricity (TJh per year), WFe,c[f] is the water footprint linked to the construction of the power plant per unit of electricity produced over the useful life of the plant (m^3TJh^{-1}), WFe;o[f] is the water footprint corresponding to the operation of the plant per unit of electricity produced by fuel "f" (m^3TJh^{-1}), and E[f] is the annual production of electricity from fuel "f" (TJh per year).

Since all the other renewable energies apart from biomass are not fuel-based sources, the WF is calculated using the following expression (Eq.3) given by Mekonnen et al. (2015):

$$\mathrm{WF}_{e,\mathrm{total}}[r] = (\mathrm{WF}_c[r] + \mathrm{WF}_o[r]) \times \mathrm{E}[r] \tag{3}$$

Mekonnen et al. (2015) use these operations to obtain the WF data for each source of energy, as shown in Table 1:

In our case, we calculate the WF of the electricity generation mix using Eq. 4, below, which takes the WF data from Table 1 for each of the energy sources, their production and the annual amount of electrical energy generated:

$$WF_t\left(m^3/TWh\right) = \frac{\sum_{F=1,e=1}^{n}\left[E_F(TWh)\cdot WF_e\left(m^3/TWh\right)\right]}{E_a(TWh)} \tag{4}$$

Where: WFt is the total water footprint of the electricity mix of the analysed country or region; E_F is the energy generated from each of the sources in the mix; WF_e is the water footprint of each of the energy sources (Mekonnen et al. 2015) and E_a is the total energy produced annually in the analysed country or region.

Table 1 The global consumptive WF per unit of electricity output for different energy sources, with reference to the regional specifications established by Mekonnen et al. (2015)

Fuel	$Wf_{e(m^3\ TJe^{-1})}$=Fuel supply+ Construction+ Operation
Coal	79–2100
Lignite	93–1580
Conventional oil	214–1190
Unconventional oil (oil sand)	419–1340
Unconventional oil (oil shale)	316–1830
Natural gas	76–1240
Shale gas	81–1270
Nuclear	18–1450
Firewood	48000–500000
Hydropower	300–850000
Concentrated solar power	118–2180
Photovoltaic	6.4–303
Wind	0.2–12
Geothermal	7.3–759

Electricity consumption ratio in the UWC

We use the water flow data from the UWC facilities and the electricity consumption data to calculate a ratio indicating the amount of electrical energy used per unit volume of water involved (extracted, pumped, purified, supplied, collected, etc.) in the process under analysis.

The source of the data may vary depending on the objective and scope of the calculation of the WFUWC index: primary data, such as direct measures of energy consumption; secondary data, based on the installed capacity of a facility; or a tertiary source of data, such as the consumption ratios of similar facilities (Mizuta and Shimada 2010; Guo et al. 2014; Trapote et al. 2014; Gu et al. 2017).

WFUWC index

Using the data on the WF of the electricity generation mix of the country or region under study, together with the data on energy consumption per unit volume of water treated in the whole UWC or part thereof, we calculate the WFUWC index using Eq. 5:

$$WFUWC_i\left(m^3/m^3\right) = WF_t\left(m^3/TWh\right)\cdot\sum_{i=1}^{n} C_i\left(TWh/m^3\right) \tag{5}$$

Where: $WFUWC_i$ indicates the WF of each cubic metre of water processed in facility i (facility or the entire UWC); WF_t represents the total water footprint of the electricity mix of the analysed country or region; and C_i is the electricity consumption per cubic metre of the analysed facilities.

To help interpret the result of Eq. 5, we provide a classification of the WFUWC index values (Table 2).

Example of an application of the proposed method

To illustrate how the WFUWC index (Eq. 5) works and how it might be useful, we apply it to two types of UWC facilities. We thus calculate the WFUWC index for six WWTPs and for an RO plant. Given that both types of facilities are

Table 2 Range of values for the WFUWC index

Classification	l/m^3
Excellent	<10
Very good	10–25
Good	25–50
Fair	50–100
Poor	100–250
Very bad	>250

aimed at improving the quality of treated water, the index captures the depletion of water resources due to a treatment used to improve water quality.

WF for the electricity mix in Spain

To calculate the WF of the electricity generation mix in Spain, we use Eq. 4, which consists of two main parameters: the electricity generation data (European Commission, Directorate-General for Energy 2020); and the WF presented in Table 1 for each of the energy sources (Mekonnen et al. 2015).

For this case, only the electricity generated in Spain is included in the analysis, as the average share of imports in the analysed period is minimal (5.24%). In addition, imports are offset by electricity exports during this period. If this were not the case, the WF of electricity imports could be calculated and weighted according to their percentage share in the mix.

In Spain in 2019, coal, lignite, oil, natural gas, nuclear, hydropower, solar thermal, solar photovoltaic and wind accounted for 97.59% of all energy sources. Some energy sources are omitted from the calculation (European Commission, Directorate-General for Energy 2020)—namely, solid biofuels and renewable wastes, biogases, liquid biofuels, tide, wave and ocean and non-RES waste—as they are not directly addressed in the paper by Mekonnen et al. (2016). We also omit shale gas, firewood and geothermal as they are not used for electricity generation in Spain, according to published data (European Commission, Directorate-General for Energy 2020).

To ensure a sufficiently representative figure for the WF of the electricity mix, we use electricity data from the last 10 years (2010–2019). This addresses the potential issue of specific annual variations caused by factors such as economic conditions, fuel prices, weather conditions, international conflicts or the level of energy dependence, which may significantly influence the result.

Table 3 shows the WF of each of the energy sources used in the electricity mix in Spain, the total electricity generated annually, and in the last row, the WF per unit of electricity generated (Eq. 4). The WF data are in l/kWh to provide a figure that is suitable for the scale of this analysis.

Figure 2 presents the data from Table 3, distinguishing between the renewable energy sources (firewood, hydropower, concentrated solar power, wind, and geothermal) and the non-renewable energy sources (coal, lignite, conventional oil, unconventional oil, natural gas, shale gas, nuclear). In addition, the annual WF data for electricity generation are represented in bars along with the corresponding trend line.

Electricity consumption ratio figures

Annual operational data have been collected on both electricity consumption and the flow of treated water for six WWTPs (Table 4) and an RO plant.

In the case of the WWTPs, the values lie within the range of energy intensity reported in other articles that analyse the use of energy by this type of facility in Spain (Trapote et al. 2014) and in various other countries (Panepinto et al. 2016; Wakeel et al. 2016).

As for the RO plant, the data are from a small standard plant which has two osmotizers with a production flow of 8 m^3/h. Under current operating conditions, consumption is 2.05 kWh/m^3, which lies within the standard consumption range for these facilities (Al-Karaghouli and Kazmerski 2012; Dashtpour and Al-Zubaidy 2012).

Calculation of the WFUWC index

Using the data on the WF per kWh of the electricity generation mix in Spain (Table 3) in l/kWh and electricity consumption ratios of the WWTPs (Table 4), we apply Eq. 5 to calculate the WFUCW index. The results are shown in Table 5.

Figure 3 depicts the WFUWC index of each of the WWTPs (Table 5).

The results of the WFUWC index calculated for the RO plant are shown in Table 6. In this case, the WFUWC index refers only to the impact on water resources of the gate-to-gate electricity consumption by the osmosis plant; it does not account for the reject water generated by the process nor the energy used to pump it.

Figure 4 depicts the WFUWC index calculated for the RO plant (Table 6) together with its trend line.

Calculation of the WFUWC index with the electricity generation mix in other countries

A facility or process can also be evaluated by applying different electricity generation mixes in the calculation of the WFUWC index.

By way of example, we take the electricity generation mix in Austria, Denmark and the European Union average (EU27) (European Commission, Directorate-General for Energy 2020). First, we calculate the WF for each one (Eq. 4). Table 7 shows the WF of the electricity generation mix in each country and the EU27.

Table 3 WF (m^3) for the electricity mix in Spain

Fuel	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Coal	7.16E+07	1.19E+08	1.55E+08	1.12E+08	1.22E+08	1.43E+08	1.03E+08	1.27E+08	1.06E+08	3.55E+07
Lignite (brown coal)	2.64E+06	8.22E+06	6.21E+06	4.61E+06	6.03E+06	6.66E+06	3.79E+06	5.27E+06	3.57E+06	1.91E+06
Conventional oil	4.59E+07	4.07E+07	4.24E+07	3.81E+07	3.91E+07	4.77E+07	4.68E+07	4.36E+07	4.01E+07	3.57E+07
Unconventional oil (oil sand)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Unconventional oil (oil shale)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Natural gas	9.87E+07	8.93E+07	7.64E+07	6.07E+07	5.02E+07	5.54E+07	5.55E+07	6.72E+07	6.12E+07	8.74E+07
Shale gas	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Nuclear	1.95E+08	1.82E+08	1.93E+08	1.78E+08	1.80E+08	1.80E+08	1.84E+08	1.83E+08	1.75E+08	1.84E+08
Firewood	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Hydropower	1.14E+10	8.23E+09	6.04E+09	1.03E+10	1.07E+10	7.85E+09	9.97E+09	5.27E+09	9.20E+09	6.72E+09
Concentrated solar power	3.56E+06	6.61E+06	1.37E+07	1.69E+07	1.76E+07	1.78E+07	1.75E+07	1.84E+07	1.62E+07	1.02E+07
Photovoltaics	2.20E+06	2.60E+06	2.54E+06	2.52E+06	2.63E+06	2.67E+06	2.64E+06	2.79E+06	2.49E+06	4.24E+06
Wind	1.91E+05	1.85E+05	2.14E+05	2.40E+05	2.25E+05	2.13E+05	2.11E+05	2.12E+05	2.20E+05	2.40E+05
Geothermal	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total WF (m^3)	1.18E+10	8.68E+09	6.53E+09	1.07E+10	1.12E+10	8.30E+09	1.04E+10	5.72E+09	9.61E+09	7.08E+09
Total electricity generation (TWh)	296.69	288.27	291.69	279.15	272.65	274.16	268.24	268.79	267.43	266.54
Electricity generation WF (l/kWh)	39.78	30.11	22.40	38.26	40.95	30.27	38.71	21.27	35.93	26.56

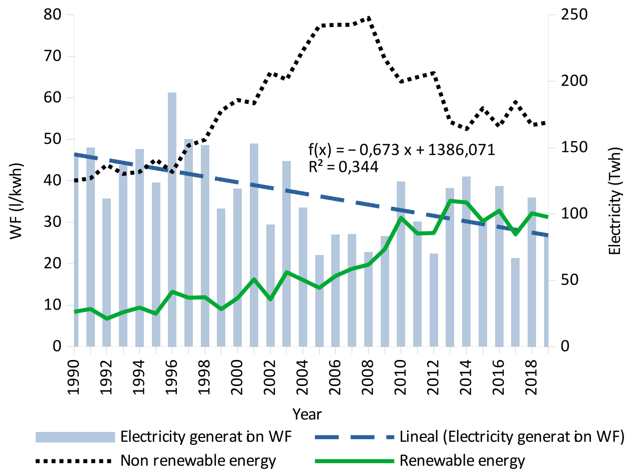

Fig.2 Electricity generation mix in Spain and the evolution of its WF

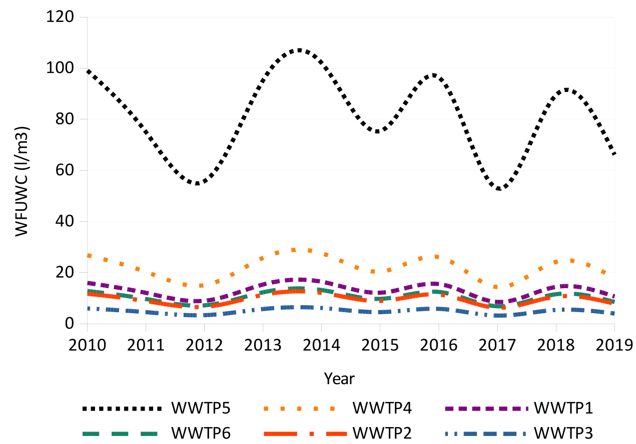

Fig. 3 WFUWC values for the WWTPs used as an example, calculated with the electricity generation mix in Spain

We then apply these results (Table 7) to the facilities analysed earlier. Figure 5 shows the results of the WFUWC index. This calculation does not account for countries' electricity imports and exports.

Discussion

The results show the WFUWC index expressed in l/m^3 for the six WWTPs and the RO plant for the period

Table 4 WWTP features

WWTP	WWTP1	WWTP2	WWTP3	WWTP4	WWTP5	WWTP6
Type	Trickling filter	Trickling filter	Sequencing batch reactor (SBR)	Stahlermatic batch reactor	Extended aeration	Biodisc
Observations	–	–	–	–	–	Influent pump station
Population equivalent (design)	1092	5460	249	1130	526	2146
Population equivalent (current)	741	5444	193	860	196	1872
Electricity consumption ratio (kWh/m^3)	0.4016	0.2956	0.15097	0.6743	2.491	0.322

Table 5 WFUWC for the WWTPs

WWTP	WFWUC (l/m^3)									
	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
WWTP1	15.98	12.09	9.00	15.37	16.45	12.16	15.55	8.54	14.43	10.67
WWTP2	11.76	8.90	6.62	11.31	12.11	8.95	11.45	6.29	10.62	7.85
WWTP3	6.10	4.62	3.43	5.87	6.28	4.64	5.93	3.26	5.51	4.07
WWTP4	26.82	20.30	15.10	25.80	27.61	20.41	26.11	14.34	24.23	17.91
WWTP5	99.09	75.00	55.79	95.32	102.01	75.41	96.44	52.98	89.51	66.17
WWTP6	12.82	9.70	7.22	12.33	13.20	9.76	12.48	6.85	11.58	8.56

Table 6 WFUWC for the RO plant

WFWUC (l/m^3)									
2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
81.55	61.72	45.91	78.44	83.95	62.06	79.36	43.60	73.67	54.45

2010-2019, applying the electricity generation mix in Spain (Tables 5 and 6). Figures 3 and 4 graphically depict the values of the WFUWC index for each of the analysed plants.

WWTP 5 shows a much higher impact than the rest. Its WFUWC index is 102.01 l/m^3 (Table 5), which indicates that 102.01 l of water are needed solely for the electrical energy consumed in the treatment of 1000 l of water. That is, the index does not take into account the WF caused by the effluent. WWTP 5 is classified as poor on the scale proposed in Table 2.

The RO plant also registers notably high WFUWC index values. In 2014, the maximum index value is 83.95 l/m^3 (Table 6). Based on its WFUWC, it is classified as fair (Table 2).

Among other reasons, the differences in the WFUWC index can be explained by the fact that electricity consumption may vary depending on the location of the facilities—due to differences in altitude and in the local climate—and also depending on operational efficiency and the size, state and age of the facilities (Morera et al. 2016).

The application of different electricity generation mixes (Table 7) in the facilities points to several practical uses of the WFUWC index. For example, it enables an evaluation of the use of water over a period of time and in different locations (see Fig. 5).

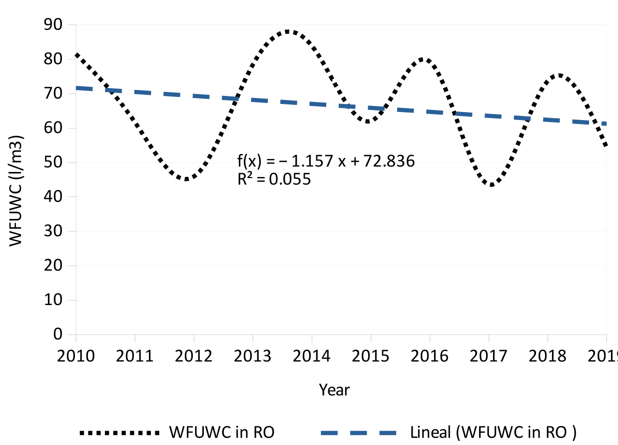

Fig. 4 WFUWC values for the RO plant example calculated with the electricity generation mix in Spain

The data in Fig. 5 reach maximum values in 2014 for Austria and the EU27, with values of 463.87 l/m^3 and 89.18 l/m^3, respectively, and in 2010 for Denmark, with 1.97 l/m^3. In the case of the RO plant, Austria registers a value of 381.75 l/m^3 in 2014.

The large difference between countries is explained by the relevance of the electricity generation mix in the WFUWC index. As can be seen, Austria registers very high values in 2014, with a WFUWC index of 463.87 l/m^3 for WWTP5 and of 381.75 l/m^3 for the RO plant; these values are classified as very bad according to the proposed categories in Table 2. These results are close to the threshold at which the process of treating water generates the same impact as the treated water (WFUWC = 1 m^3/m^3). Austria registers such high values because its electricity generation is mainly hydroelectric, which has a large WF. Conversely, in Denmark—with maximum WFUWC index values of 4.91 l/m^3 for WWTP5 and 1.64 l/m^3 for the RO plant—wind energy predominates, which has a very small WF.

Over the analysed period, we observe positive progress in the dewaterization of the electricity generation mix (see Figs. 2,4 and 5), due to the increased production of renewable energy. However, biomass and hydroelectricity, which are considered renewable, significantly increase the WFUWC, as can be seen in Fig. 2 in the years 1996 and 2014. This fact is evidence of the divergence between dewaterization and decarbonization (Mekonnen et al. 2016; Vanham et al. 2019) in certain electricity generation scenarios (Gagnon and Vate 1997; Räsänen et al. 2018).

Finally, the examples we present here highlight the critical role of the electricity generation mix in the resulting WFUWC index; hence the importance of jointly planning water and energy policies (Gleik 1994; Lee et al. 2017). Given the growing global demand for electricity (IRENA 2019; IEA 2021), the application of the index in the analysis of other regions can help ensure progress in the dewaterization of the UWC, while its use in other fields can give rise to new lines of research.

Table 7 WF of the electricity generation mixes in Austria, Denmark and the EU27

Country	WF (l/kWh)									
	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Austria	157.92	156.29	178.03	182.04	186.22	169.71	171.63	160.91	164.09	159.93
Denmark	1.97	1.77	1.62	1.72	1.5	1.22	1.42	1.12	1.16	0.79
EU27	33.6	29.03	31.34	34.57	35.8	32.52	33	28.64	32.67	31.03

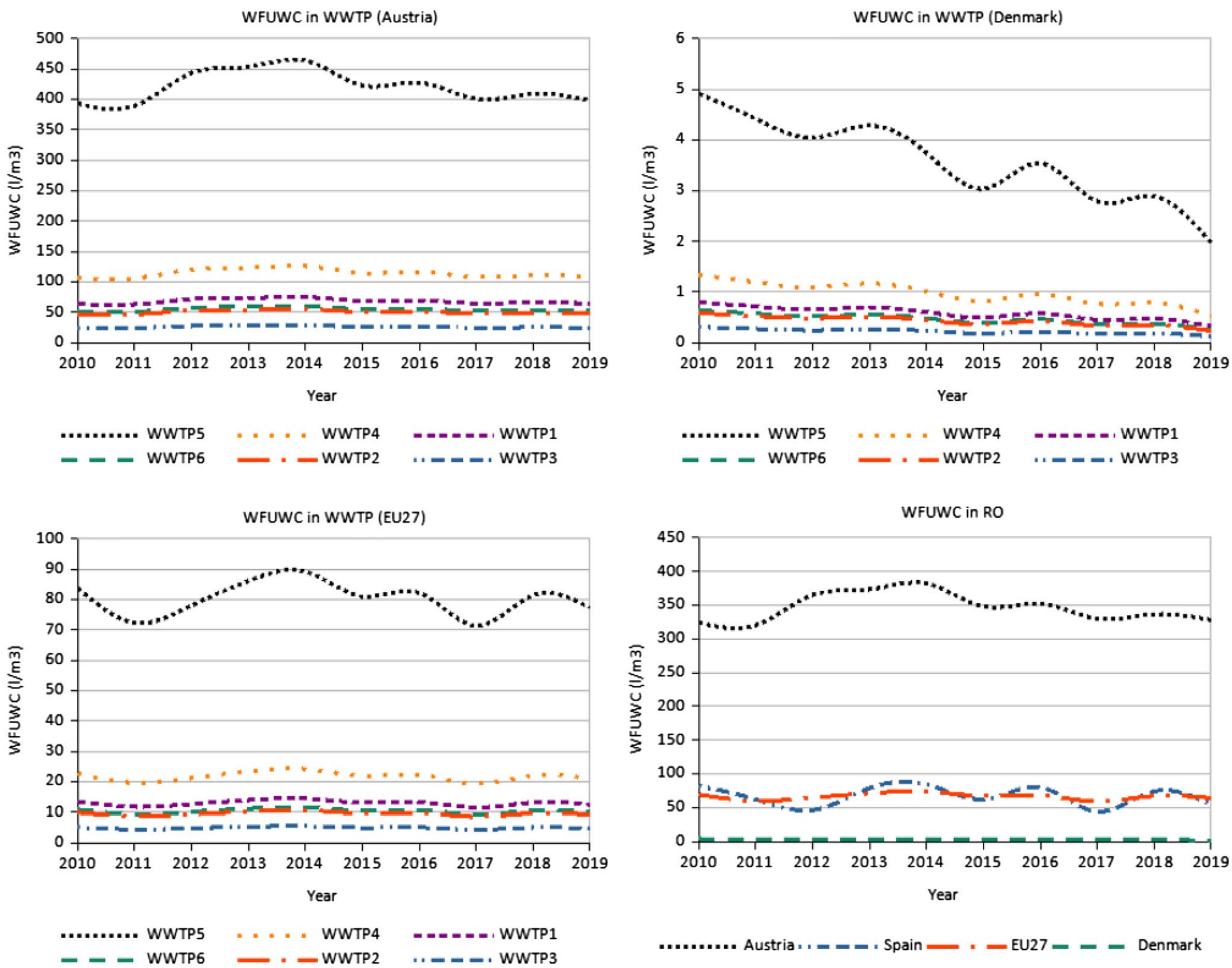

Fig. 5 WFUWC values for the WWTPs and the RO plant calculated using the electricity generation mix in different countries and the EU27

Conclusion

This research sheds light on the conflict between the goals of dewaterization and decarbonisation. Although water is the main raw material of the UWC, relatively little academic attention has been paid to the use of water in the operation of the UWC, referred to as the water–energy-water nexus. The main contribution of this research is the proposed WFUWC index for measuring the volume of water used by the energy consumed to produce one cubic m of water.

The proposed index underscores the idea that it is not only consumers who can make an effort to save water; the operation of the UWC itself plays a fundamental role in the availability of drinking water. Accordingly, the operators of the UWC must also pay attention to the water used via the energy used.

The main conclusions of this research are as follows:

- The WFUWC is an effective tool for assessing the impact of UWC infrastructure on water resources. It is simple to calculate and easily interpretable for analysis and decision-making, which makes it suitable for the purposes of communication and awareness-raising, and helpful for operators, policymakers and other stakeholders.
- It is applicable to varying types of infrastructure and different energy mixes, which makes it useful for the evaluation and planning of future UWC infrastructure. This is particularly important in areas facing water scarcity, a problem expected to become more common around the world as a result of climate change.

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Data availability The energy statistical datasets for EU countries analysed in this study are available in the EU energy statistical pocketbook and country datasheets repository, [https://energy.ec.europa.eu/document/download/be739faa-6f52-468a-b5c5-e5747f7086b7_en?filename=Energy%20statistical%20country%20datasheets%202023-04.xlsx]. The other data generated or analysed in this study are included in the published article.

Declarations

Conflict of interest On behalf of all authors, the corresponding author states that there is no conflict of interest.

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