Advances in Science, Technology & Innovation
IEREK Interdisciplinary Series for Sustainable Development

Vincenzo Naddeo · Kwang-Ho Choo ·
Mohamed Ksibi *Editors*

Water-Energy-Nexus in the Ecological Transition

Natural-Based Solutions, Advanced Technologies and Best Practices for Environmental Sustainability

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Preface

The Water-Energy Nexus is one of the most important and priority issues to be resolved for both current and next generations. Water and energy underpin economic and social development. Water is needed for each stage of energy production, and energy is crucial for the provision and treatment of water. In the energy community, much of the attention has centred on the impact of water availability on the different processes of the energy sector and the energy sector's impact on water quality and quantity. This interdependency has significant implications for both energy and water security. With both water and energy needs set to increase, it has become ever more important to understand the linkages between the two, to anticipate future stress points and to implement policies, technologies and practices that soundly address the associated risks.

The findings show that there are ways to mitigate risks. Policies and technologies are already studied and proposed by scholars and technicians for sustainable development. However, a clear vision of both state of the art and all possible solutions is needed for decision-makers to assess the possible trade-offs and different scenarios. A successful action will require a strong, coordinated focus across different branches and levels of government and collaboration between policy-makers, researchers, industry and consumers.

This volume will include papers that broadly address recent and novel developments in technology and in the solutions that could be proposed to help ease chokepoints and reduce demand in both sectors, meaning that water does not have to be a limiting factor for the energy sector and a rise in water demand does not have to be accompanied by an equal rise in energy demand. This volume will provide an opportunity for knowledge exchange to advance our understanding of the current state of Water-Energy systems and their nexuses that will lead to guiding and developing sustainable and resilient systems. The scope of the volume is extended to the relative environmental, management and economic aspects related to the Water-Energy systems.

In detail, this volume includes selected contributions presented during the III edition of the international conference on WaterEnergyNEXUS, which was held in December 2020. This edition of the conference was organized by the University of Sfax (Tunisia), in cooperation with the Sanitary Environmental Engineering Division (SEED) of the University of Salerno (Italy), the Advanced Institute of Water Industry at Kyungpook National University (Korea) and The Energy and Resources Institute, TERI (India)). The first edition of WaterEnergyNEXUS was organized in Korea in 2017 during the Asian International Water Week, one of the more pertinent and significant meetings in Asia for scientists and professionals working in the field of water use and sustainability. The second edition was organized in Salerno (Italy) in 2018. The third WaterEnergyNEXUS conference provided an international digital platform where key topics on water management were discussed by participants with the presentation of nature-based solutions, advanced technologies and best practices by a panel of experts invited as plenary and keynote speakers. Another objective of the third edition of the WaterEnergyNEXUS conference is to enhance cooperation, integration and sustainable development in the Euro-Mediterranean region on the critical links between Water and Energy.

The WaterEnergyNEXUS series of conferences are supported by the UNESCO World Water Association Programme (WWAP) and the International Water Association (IWA). It also enjoys the patronage of several international scientific societies, associations and organizations and has established a publishing partnership with Springer Nature.

This volume gives an overview of current research focusing on emerging Water-Energy Nexus issues and challenges and their potential applications to a variety of environmental problems that are impacting the Euro-Mediterranean zone and surrounding regions. A selection of novel and alternative solutions applied worldwide will also be presented. The volume contains carefully refereed contributions selected from the conference. Topics covered include (1) Nexus framework and governance, (2) environmental solutions for the sustainable development of the water sector, (3) future clean energy technologies and systems underwater constraints, (4) environmental engineering and management and (5) implementation and best practices.

Intended for researchers in environmental engineering, environmental science, chemistry and civil engineering, this volume is also an invaluable guide for industry professionals working in both the water and energy sectors.

Fisciano, Italy — Vincenzo Naddeo
Daegu, Korea (Republic of) — Kwang-Ho Choo
Sfax, Tunisia — Mohamed Ksibi

Contents

About the Editors

Prof. Vincenzo Naddeo is Full Professor at Department of Civil Engineering of the University of Salerno (Italy) and Director of the Sanitary Environmental Engineering Division (SEED), where he drives research and academic activities in the Environmental Engineering fields. He serves as Affiliate Professor at both the Department of Civil and Environmental Engineering of the University of Washington (Seattle, WA, USA) and at the Department of Water Resources and Environmental Engineering of the Tamkang University (New Taipei City, Taiwan).

He is Editor of the Water Environmental Research (Wiley) and Associate Editor of Case Studies in Chemical and Environmental Engineering (Elsevier), *Euro-Mediterranean Journal for Environmental Integration* (Springer), Scientific Report (Nature Portfolio) and of the Earth, Frontiers for Young Minds (Frontiers). He is Special Issues Editor and Social Media Editor for *Journal of Hazardous Materials* (Elsevier), *Journal of Hazardous Materials Letters* (Elsevier) and *Journal of Hazardous Materials Advances* (Elsevier). He presently serves on the editorial board of several ISI journals including Science of Total Environment (Elsevier), Desalination (Elsevier), PeerJ (Life, Bio, Environment and Health Sciences), Frontiers in Bioengineering and Biotechnology, Water (MDPI) and Bioengineered (Taylor & Francis). Dr. Naddeo is also actively involved in a variety of scientific organizations, funding agencies, and European networks. He holds seven patents, four on innovative technologies for the advanced treatment of water or wastewater, two on the next generation of electronic nose (e.Nose) and one patent on an innovative photo-bioreactor for the sequestration of CO_2. Prof. Naddeo serves the editorial board of several ISI journals, and he is (co-) Author of over 200 refereed publications in ISI journals, congress proceedings and book volumes.

Prof. Kwang-Ho Choo received his Ph.D. degree from Seoul National University, Korea, in 1996 and since then has been working on membrane science and technology for water and wastewater, pursuing innovative solutions for sustainable water production and reuse. His recent research interests include membrane electro-oxidizers and quorum quenching membrane bioreactors. He is currently keen to find synergistic options for Water-Energy Nexus issues, using membranes in conjunction with physicochemical/biological strategies, such as iron oxide adsorption, photocatalysis, electrocatalysis and microbial quorum quenching. He has been actively involved in academic societies, such as International Water Association, Korean Society of Environmental Engineers, Membrane Society of Korea and Korean Institute of Chemical Engineers, as Active Board/Editorial Member.

Prof. Mohamed Ksibi completed his Ph.D. in 1993 in Applied Chemistry at the University of Poitiers, France. He also gained the Habilitation (HDR) in Chemistry from the University of Sfax, Tunisia, in 2003. He was appointed as Full Professor of Chemistry in 2009 at the Higher Institute of Biotechnology of Sfax (ISBS). His areas of research interest include removal and toxicology assessment of persistent organic pollutants in the environment (water and sediment/soil). He has supervised ten theses to completion and examined a further five Ph.D.s. He has also supervised 15 M.Sc. theses. He has co-published about 55 papers, 8 chapters and co-edited a book (2 volumes): Recent Advances in Environmental Science from the Euro-Mediterranean and Surrounding Regions. He is Co-editor-in-Chief of the *Euro-Mediterranean Journal of Environmental Integration* (h-index 24). He had been Institute's Deputy Director of the ISBS from August 2011 until December 2017, and he served as Director of the Department of Biotechnology and Health at ISBS from May 2008 until May 2011. He has also been Chairman for the 1st in 2017 and the 2nd in 2019 of the Euro-Mediterranean Conference for Environmental Integration (https://www.emcei.net).

Nexus Framework and Governance: Economic Evaluations for Investment Projects in the Water and Energy Sectors

Water Conservation Indexing: The HVAC of Suranaree University of Technology Hospital Main Building Case

Andreas Prasetyadi and Atit Koonsrisuk

Abstract

A water conservation indexing using availability and accessibility was proposed in order to have an index that is reliable, consistent, free of site character, and easy to interpret. A year simulation of the heating ventilating and air conditioning (HVAC) system of Suranaree University of Technology Hospital (SUTH) main building was conducted for the case using TRNSYS. Water availability was applied to show the total amount actually or potentially being harnessed during the process. Accessibility indicates the fitness of the available water. The results show that indexes of the water conservation of the system in 22, 24, and 26 °C temperatures setting are around 50%. It implies that there are amount of unused water. The higher the temperature setting is the less conserving the system becomes.

Keywords

Index of water conservation • Energy water nexus • HVAC

1 Introduction

Water conservation is a main issue and needs a metric to be measured (Proença and Ghisi 2010). Water conservation metrics tend to be biased of location due to uneven water distribution. It implies a difficulty in comparing the approaches in different locations.

Indexing water conservation as a mix of quantity and quality of the water at use was proposed as a metric. The index shows the system performance level in conserving water during its use process. The metric ability to be free of location bias with different water potential conditions is expected.

2 Methods

The water conservation index has two main important features. They are water availability showing all the water amounts that people can obtain from the process and water accessibility. The concepts are derived from the work of Georgescu-Roegen (1975) about thermoeconomics. Generally, both metrics show the ratio of the actual condition over the ideal one.

2.1 Water Availability, Capped Water Availability, and Water Accessibility

Water availability (W_{av}) is determined to show ratio of available water over utilized water at the point of use through Eq. (1). W_a and W_r are the available water and the water required for the process, respectively.

$$W_{av} = W_a/W_r \tag{1}$$

The capped water availability ($\hat{W}_{av}$) shows ratio of water usage over available water at the point of use with maximum condition of 1 and is defined in Eq. (2).

$$\hat{W}_{av} = \begin{cases} 1, & 1 < (W_a/W_r) \\ W_a/W_r, & 1 > (W_a/W_r) \end{cases} \tag{2}$$

Water accessibility (W_{ac}) shows the water provision fitness to the water requirement. It is determined by Eq. (3) with C_i is the water energy coefficient.

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$$W_{ac} = \sum_{i=1}^{n} C_i \hat{W}_{av,i} / \sum_{i=1}^{n} C_i \quad (3)$$

2.2 Water Conservation Level

The conservation level of water is defined as a score leveling system in conserving water amount and quality during the usage. It is calculated using Eq. (4), with W_{av}^* is determined by Eq. (5). WC is the water conservation level, and W_{av}^* is the availability factor.

$$\mathrm{WC} = W_{ac} * W_{av}^* \quad (4)$$

$$W_{av}^* = \begin{cases} W_{av}, 1 \le W_{av} \\ W_{av}^{-1}, 1 > W_{av} \end{cases} \quad (5)$$

2.3 SUTH Main Building HVAC Water

A year TRNYS simulation of the HVAC hospital system was conducted to find the HVAC water data as shown in author's former work (Prasetyadi and Koonsrisuk 2019). The procedure is shown in Fig. 1.

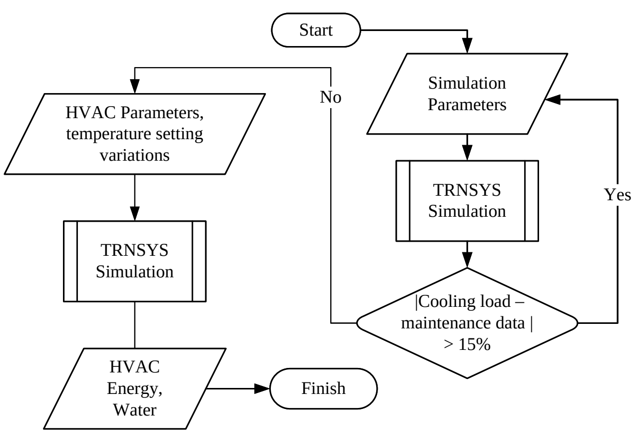

Fig. 1 Procedure of simulating the HVAC system of SUTH main building

3 Results and Discussion

The application of the coefficients to the water mentioned in Table 1 can provide the water availability, water accessibility, and water conservation level as shown in Table 2. The table shows that water accessibility of the system is 1 in various temperature settings. The table also reveals that the water need can be fulfilled in those temperature settings. The water conservation level is different for the temperature settings. The higher the temperature setting is the lower the water conservation level becomes.

Table 2 indicates that the system does not utilize water effectively. This is shown by the water availability score, being greater than 1 and was confirmed by the water accessibility score (1). If the water accessibility score is less than 1, but its availability score exceeds 1, the water conservation level is less than 1. The condition indicates that there is a water supply quality problem. In terms of amount, there is enough water, but it does not meet the requirement. If water availability and accessibility are less than 1, it shows that the system suffers from a shortage in the water supply.

The pattern relation of water availability and conservation level is shown in Fig. 2. When the water accessibility is less than 1, or the water quality does not match the requirement, water conservation becomes less than 1.

The water treatment and processing coefficients do not affect the index scale. Water accessibility is calculated using the energy for the water treatment and processing. The coefficient actually varies and depends on the site. However, Eq. (3) set shows that the maximum of accessibility becomes 1. This implies that the water conservation should not sacrifice the designed system capacity operation. Accordingly, the number is also free of the site character. Therefore, the water index conservation does not depend on the site.

4 Conclusion

A water conservation index using availability and accessibility was developed and applied to HVAC system of SUTH main building with score of 0.50. The index is free of the site treatment and processing coefficients. It has range of 0–1

Table 1 Type of water, daily water amount, and its coefficient

Water type	Amount of water in m^3 at temperature setting			Coefficient (Wakeel et al. 2016) (kWh/m^3)	Note
	22 °C	24 °C	26 °C		
Tap water	38.54	27.96	20.89	0.22	Main resource
Soften water	38.54	27.96	20.89	0.36	Water requirement
Brine	6.42	4.66	3.48	0.22	Alternative resource
Condensate	29.10	21.30	17.40	0.36	Alternative resource

Table 2 Water availability, accessibility, and conservation levels at various temperature settings

Temperature setting (°C)	Water availability	Water accessibility	Water conservation level
22	1.92	1	0.52
24	1.93	1	0.52
26	2.00	1	0.50

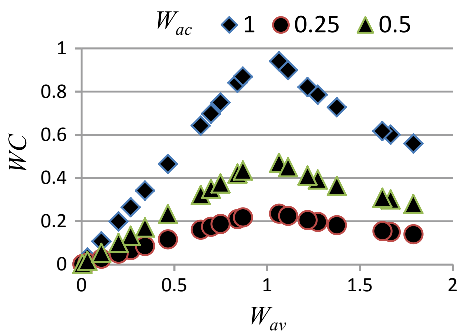

Fig. 2 Relation of water availability (W_{av}) and water conservation (WC). Water accessibility becomes the coefficient determining the maximum of water conservation, as well

with the higher score indicating a better condition of water usage. It shows the effect of temperature setting on the water conservation level. The higher the temperature setting is the lower the conservation level will be. The level of water conservation indicates the level of available water utilized by the system. The temperatures setting data show that alternative water resources are potentially harnessed to meet the energy need.

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