Smart energy demand for the sustainable development of energy, water and environment systems

Gjorgievski, Vladimir Z.; Markovska, Natasa; Mathiesen, Brian Vad; Duić, Neven

Published in:
Smart Energy

DOI (link to publication from Publisher):
10.1016/j.segy.2022.100091

Publication date:
2022

Document Version
Publisher's PDF, also known as Version of record

Citation for published version (APA):
Gjorgievski, V. Z., Markovska, N., Mathiesen, B. V., & Duić, N. (2022). Smart energy demand for the sustainable development of energy, water and environment systems. *Smart Energy*, *8*, Article 100091. https://doi.org/10.1016/j.segy.2022.100091

Smart Energy 8 (2022) 100091

Contents lists available at ScienceDirect

Smart Energy

journal homepage: www.journals.elsevier.com/smart-energy

Smart energy demand for the sustainable development of energy, water and environment systems

ARTICLE INFO

Keywords
Energy modelling
Demand response
Sector coupling
Smart energy systems

ABSTRACT

Grounded in the idea of meeting the needs of generations across time, sustainable development bears a close relationship to the way in which humanity consumes energy. Nevertheless, the historic notion that energy demand growth reflects improved living standards, economic development and prosperity are challenged when sustainability constraints and the impact on climate change are considered. As a result, a growing body of scientific research is exploring how energy demand can contribute to the energy transition instead of placing it in peril, by means of greater efficiency, digitalization, connectivity and a holistic approach to planning and management. Over the years, the Conference on Sustainable Development of Energy, Water and Environment Systems (SDEWES) has acted as a forum for scientific discourse in this field, shedding light on nuanced discussions and challenging siloed thinking. This special issue contains a selection of four papers that are focused on smart energy demand, demand response and decarbonization, presented at the 2021 SDEWES Conference (16th SDEWES Conference held in Dubrovnik, Croatia).

1. Introduction

There are two forces shaping the energy demand of the future – the one due to the quest for greater efficiency and reduction of primary energy use and the second due to the quest for smartness and increasing digitalization. In the socio-economic circumstances of the post-pandemic world, the need for both of these forces is greatly emphasized, as we evidence how energy demand affects the markets, energy security and the transition to a low-carbon economy. The scientific literature has shown that adopting a multidisciplinary approach to dealing with this issue by coordinated management and planning across energy sectors, in alignment with the smart energy systems concept, yields greater results in comparison to when solutions are pursued in isolation. This school of thought has been at the core of Conferences on Sustainable Development of Energy, Water and Environment Systems (SDEWES), due to which the Smart Energy journal continues its cooperation with the Conference, initiated with the special issue dedicated to the SDEWES Conferences that took place in 2020. In 2021, the 16th SDEWES Conference was held in during Dubrovnik, Croatia, where hundreds of new contributions were presented, out of which, four papers were included in this special issue of Smart Energy.

2. Smart energy demand for sustainable development

In one of these papers, Wei et al. [1] explores the impacts of building thermal insulation on the energy-related costs and investigate the ability of the building to shift its peak demand through time. The investigation is conducted using dynamic simulations, where the operating set-points of the heating system are determined by a multi-objective model predictive controller seeking to optimize indoor temperature and minimize total energy costs. Based on the results, the authors conclude that heavyweight thermal mass provides greater flexibility and find that insulating houses can simultaneously reduce energy consumption and shift peak demand. This work is part of a continuous thread of SDEWES research in the field of demand response in smart energy systems. Past works on the topic, include Hou et al. [2], where similar findings are obtained when analyzing the space heating in a university building in Norway. It is confirmed that using the thermal mass of the building can act as an effective short-term storage solution for improving the occupants' comfort. The value of demand response was also the focus of Capone et al. [3], which determine the optimal combination of demand shifting and capacity of thermal energy storage in a district heating system or Dorotic et al. [4], which studies the impact of wind penetration on optimal power-to-heat capacities in district heating systems.

While many works on demand response discuss the importance of further investigation of socio-economic considerations, there is a very limited literature addressing this topic. The reason for this is the difficulty of obtaining information on actual equipment ownership, lifestyles of occupants, comfort preferences and attitudes for large sets of households, such as in high rise buildings. This research gap is addressed by Zhang et al. [5], in a paper of this special issue, which studies the relationship between the energy demand and the occupancy of a high rise building in China. The authors survey 112 urban households on questions related to their lifestyles and energy demand, then simulate the energy demand of a case-study skyscraper after which they compare the simulations results to actual energy bills. Their findings show that

https://doi.org/10.1016/j.segy.2022.100091

Available online 7 November 2022

the variations between the energy demand of households are highly dependent on the occupancy patterns and lifestyles and stress the challenge of predicting energy demand, given the stochastic nature of internal heat gains, equipment set points and window opening behavior. The non-trivial impact of occupancy behavior on energy consumption was also highlighted by other SDEWES works in the past, such as [6], where 160 machine learning-based building occupancy prediction studies are reviewed or [7], where a deep learning model is applied for detecting window openings, so as to more effectively manage building ventilation and reduce space heating demand.

Furthermore, a considerable piece of SDEWES research pays special attention to energy demand as a key element of long-term modelling and decarbonization of energy systems, relevant to energy planning [8–10] and modelling gradual transformations of energy systems [11]. This special issue presents the work of Hagos et al. [12], which contributes to the energy planning literature by exploring decarbonization alternatives of a fishery farm. In their study, the authors touch on three important questions – (i) decarbonization of the agriculture sector as one hard-to-decarbonize sector, (ii) decarbonization of islands under lack of grid access and (iii) dealing with uncertainty. Hagos et al. apply the TIMES-HINNØYA energy model, as a demand-driven, stochastic optimization model which accounts for different sources of uncertainty, such as energy storage costs and power grid availability. While the work focuses on a case study in Norway, the applied methods are relevant for other similar cases, where the decarbonization of agriculture demand in areas of weak grid is the prevalent challenge. The findings of [12] are in line with the past works in the field which highlight that decarbonization of islands should adopt a smart energy systems approach [13] and that electrification of other sectors, such as transport and heating maximizes the utilization of renewable energy sources [14].

Finally, in the fourth paper of this special issue, Mauleón [15] presents a statistical model based on the global population and GDP to forecast and simulate global energy demand at distant time horizons, thereby adding new knowledge to previous relevant works such as [16], which studies the relationship between electricity and economic growth for long-term periods. In the analysis of [15], Mauleón compares the obtained forecasts to those of key publications in the literature, showing that if global energy demand development follows historical patterns, it could reach levels notably greater than those required for sustainable, low-carbon development by 2050. Based on these results, in [15], it is concluded that the energy system transition will require changes of lifestyles and demand patterns and that the GDP growth paradigm should likely be replaced by more sustainable metrics, such as the Human Development Index (HDI). It is worth adding that HDI is only one of the relevant metrics. Other metrics, such as the Sustainable Development Goals (SDG) of the United Nations have also been thoroughly evaluated in past SDEWES works. Some examples include: Sebestyén et al. [17], which, based on the data-driven comparative analysis, suggests that the state-of-progress of each of these goals should be individually assessed, Gjorgievski et al. [18] which proposes a methodology for quantification of contributions of climate change mitigation actions to SDGs, Gusheva at al [19]. which applies that methodology to quantify contributions of mitigation policies and measures in waste sector, as well as Gjorgievski at al [20]. which highlights the contributions of SDEWES science to SD Agenda analysing its linkages to the relevant SDGs.

3. Conclusion

The papers enclosed in this special issue demonstrate that the Conferences on Sustainable Development of Energy, Water and Environment Systems continue to be a pillar of support to researchers across the globe, shedding light on original ideas and chartering new research avenues for the scientific community working on the energy transition. The Guest editors believe that these papers will contribute to the incremental knowledge generation process and hope that they will be of interest to the readers of the Smart Energy journal.

References

[1] Wei Z, Calautit J. Investigation of the effect of the envelope on building thermal storage performance under model predictive control by dynamic pricing. Smart Energy 2022;6:100068. https://doi.org/10.1016/j.segy.2022.100068.

[2] Hou J, Li H, Nord N. Nonlinear model predictive control for the space heating system of a university building in Norway. Energy 2022;253:124157. https://doi.org/10.1016/j.energy.2022.124157.

[3] Capone M, Guelpa E, Mancò G, Verda V. Integration of storage and thermal demand response to unlock flexibility in district multi-energy systems. Energy 2021;237. https://doi.org/10.1016/j.energy.2021.121601.

[4] Dorotić H, Ban M, Pukšec T, Duić N. Impact of wind penetration in electricity markets on optimal power-to-heat capacities in a local district heating system. Renew Sustain Energy Rev 2020. https://doi.org/10.1016/j.rser.2020.110095.

[5] Zhang W, Calautit J. Occupancy behaviour and patterns: impact on energy consumption of high-rise households in southeast China. Smart Energy 2022;6:100072. https://doi.org/10.1016/j.segy.2022.100072.

[6] Zhang W, Wu Y, Calautit JK. A review on occupancy prediction through machine learning for enhancing energy efficiency, air quality and thermal comfort in the built environment. Renew Sustain Energy Rev 2022;167:112704. https://doi.org/10.1016/j.rser.2022.112704.

[7] Tien PW, Wei S, Liu T, Calautit J, Darkwa J, Wood C. A deep learning approach towards the detection and recognition of opening of windows for effective management of building ventilation heat losses and reducing space heating demand. Renew Energy 2021;177. https://doi.org/10.1016/j.renene.2021.05.155.

[8] Dedinec A, Markovska N, Taseska V, Kanevce G, Bosevski T, Pop-Jordanov J. The potential of renewable energy sources for greenhouse gases emissions reduction in Macedonia. Therm Sci 2012;16:717–28.

[9] Ćosić B, Markovska N, Taseska V, Krajačić G, Duić N. Increasing the renewable energy sources absorption capacity of the Macedonian energy system. J Renew Sustain Energy 2013;5. https://doi.org/10.1063/1.4812999.

[10] Ćosić B, Markovska N, Taseska V, Krajačić G, Duić N. The potential of GHG emissions reduction in Macedonia by renewable electricity. Chem Eng Trans 2011;25. https://doi.org/10.3303/CET1125010.

[11] Herc L, Pfeifer A, Duic N. Optimization of the possible pathways for gradual energy system decarbonization. Renew Energy 2022;193:617–33. https://doi.org/10.1016/j.renene.2022.05.005.

[12] Hagos DA, Liu Y, Huang L. Investigating alternative power supply solutions under long term uncertainty for offgrid-offshore fish farm: the case of Hinnøya island, Norway. Smart Energy 2022;7:100078. https://doi.org/10.1016/j.segy.2022.100078.

[13] Calise F, Duic N, Pfeifer A, Vicidomini M, Orlando AM. Moving the system boundaries in decarbonization of large islands. Energy Convers Manag 2021:234. https://doi.org/10.1016/j.enconman.2021.113956.

[14] Groppi D, Nastasi B, Prina MG, Astiaso Garcia D. The EPLANopt model for Favignana island's energy transition. Energy Convers Manag 2021:241. https://doi.org/10.1016/j.enconman.2021.114295.

[15] Mauleón I. A statistical model to forecast and simulate energy demand in the long-run. Smart Energy 2022;7:100084. https://doi.org/10.1016/j.segy.2022.100084.

[16] Koščak Kolin S, Karasalihović Sedlar D, Kurevija T. Relationship between electricity and economic growth for long-term periods: new possibilities for energy prediction. Energy 2021;228. https://doi.org/10.1016/j.energy.2021.120539.

[17] Sebestyén V, Abonyi J. Data-driven comparative analysis of national adaptation pathways for Sustainable Development Goals. J Clean Prod 2021;319. https://doi.org/10.1016/j.jclepro.2021.128657.

[18] Gjorgievski VZ, Mihajloska E, Abazi A, Markovska N. Sustainable development goals—climate action nexus: quantification of synergies and trade-offs. Clean Technol Environ Policy 2022;24:303–13.

[19] Gusheva E, Gjorgievski V, Grncarovska TO, Markovska N. How do waste climate policies contribute to sustainable development? A case study of North Macedonia. J Clean Prod 2022:354. https://doi.org/10.1016/j.jclepro.2022.131572.

[20] Gjorgievski VZ, Markovska N, Pukšec T, Duić N, Foley A. Supporting the 2030 agenda for sustainable development: special issue dedicated to the conference on sustainable development of energy, water and environment systems 2019. Renew Sustain Energy Rev 2021:143. https://doi.org/10.1016/j.rser.2021.110920.

Vladimir Z. Gjorgievski
Faculty of Electrical Engineering and Information Technologies, University Ss. Cyril and Methodius in Skopje, North Macedonia

Natasa Markovska
Research Center for Energy and Sustainable Development, Macedonian Academy of Sciences and Arts, Skopje, North Macedonia

Brian Vad Mathiesen
Department of Planning, Aalborg University, Aalborg, Denmark

Neven Duić*
Department of Energy, Power Engineering and Environment, Faculty of Mechanical Engineering and Naval Architecture, University of Zagreb, Zagreb, Croatia

* Corresponding author.
E-mail address: Neven.Duic@fsb.hr (N. Duić).