Water–Energy–Food Nexus for Agro-Industrial Companies

Subjects: Engineering, Environmental
Contributor: Fernando Caixeta, André M. Carvalho, Pedro Saraiva, Fausto Freire

The water–energy–food (WEF) nexus approach is gaining attention due to the challenge of better managing natural elements. Agro-industrial companies, given their environmental impacts, need to take sustainability into proper account. One important sustainability management concept used nowadays is the so-called water–energy–food (WEF) nexus. It means that the aforementioned elements are intrinsically managed together, and one action in one direction can affect both of the others. As a result, these three issues should be considered in an integrated manner because they are connected, and their utilization may expose important tradeoffs.

Keywords: Water-Energy-Food nexus ; excellence models ; agro-industrial companies ; decision-support tool

1. Introduction

Sustainability actions are urgent in the face of the quick depletion of natural resources that are essential for humankind. There is a lack of adequate access to water, energy, and food resources for a substantial percentage of the global population: Despite efforts within the past 15 years, 800 million people are still considered food insecure, an equal number has no access to safe drinking water, and 1.2 billion people lack access to electricity [1]. In the face of this reality, new practices are needed transversally, and all industrial sectors benefit from focusing on impacts on environmental, social, and economic results. Many industries and sectors recognize the importance of better managing the aforementioned natural resources [2][3][4]. Nevertheless, the agro-industrial sector deserves to be highlighted, as it requires a huge contribution of those natural resources [5][6] and has high pollution emissions rates [7].

Given that, the good practices of natural resource management should be stimulated to overcome unsustainable practices in the agro-industrial area. In this sense, quality management (QM) could be used since it presents a framework that organizations are already familiar with and has proved to be valuable when adapted to new technologies [8]. Among them, one particular scope is business excellence models (BEMs), a framework that oversees all activities and tasks needed to maintain the desired level of performance in an organization and relate it to its external environment [9]. Given that, this approach provides the methods (tools, processes, metrics, and indicators) to do so [10]. Accordingly, and in principle, BEMs offer a useful toolset to also oversee the pursuit of organization-wide sustainability [8][11].

In this context, one important sustainability management concept used nowadays is the so-called water–energy–food (WEF) nexus. It means that the aforementioned elements are intrinsically managed together, and one action in one direction can affect both of the others [12][13]. As a result, these three issues should be considered in an integrated manner because they are connected, and their utilization may expose important tradeoffs [14]. Identifying and evaluating tradeoffs and synergies is essential for integrating other perspectives. Nevertheless, there is no clear framework to measure and assess the quality of processes and operations related to the deployment of the principles behind the WEF nexus [15]. The incorporation of the WEF nexus into an enterprise-level model is essential for integrating sustainability into efficient planning, development, and monitoring, but also for policymaking in key WEF-productive sectors of the economy [15][16].

2. Water, Food, and Energy Systems and the WEF Nexus

Concerns about water, food, and energy systems are rapidly growing due to differing regional availabilities and their impact on the interdependences amongst themselves [15][17]. WEF elements are essential for human life, sustainable development, and social equality [18]. In this sense, ensuring their security is a crucial activity concerning every individual worldwide.

Given that, the need for the integrated analysis of natural elements is not a novelty in the scientific literature. In this sense, some authors affirmed that WEF elements should be evaluated in an integrated manner. This concept is considered the first attempt at this new approach [19][20][21][22]. However, the WEF nexus concept was only launched in 2011, when it was incorporated into an international discussion on sustainable development by the Stockholm Environment Institute [12] and the World Economic Forum [13]. According to Hoff [12], the WEF nexus implies that water availability, energy production/consumption, and food security are inextricably linked. Consequently, actions in any one area have impacts on the others [18]. In addition, the World Economic Forum [13] affirms that focusing on the joint promotion of food security, in addition to water and energy accessibility, is the meaning of nexus thinking. These interlinkages, and the criticality of the scarcity of any of the three resources and its impact on the others, emphasize the need to manage them jointly and more efficiently [23].

Such a nexus approach can support the transition to implement the Sustainable Development Goals (SDGs)—Agenda 2030 [24]. In this sense, scientific literature has plenty of studies linking WEF nexus implementation with the SDGs, performing better in regional sustainability [25], for legal challenges [26], and for rural communities [27], among other uses. Furthermore, this addition should reduce environmental impacts and generate additional benefits that outweigh the integration across sectors, enhancing, for instance, circular economy implementation [28]. Such gains should appeal to national interest and encourage governments, private sectors, and civil society to engage [29]. In practical terms, this approach can represent the action required in bioeconomy to implement real solutions in sustainability actions [30].

Many scientific articles have tried to express some practical examples of how to implement this methodology. Saladini et al. [25] selected 12 indicators to monitor the Mediterranean area called the Partnership for Research and Innovation in the Mediterranean Area, based on the Sustainable Development Goals, which can be directly related to boosting sustainable business innovation [31]. Hussien et al. [32] assessed the impact of WEF elements using a risk-based method. Bijl et al. [33] showed differences in physical trade production, distance, and volume using indicators. Karan et al. [34] created indices based on the UN-Habitat's City Prosperity Index that specifically integrate the nexus-relevant indices into a weighted equity index. El-Gafy [35] proposed six indicators in order to quantify the nexus as a strategic tool applied to crop production. AbdelHady et al. [36] proposed three output indicators, agriculture, aquaculture, and net energy production, to assess the value of different ecosystem health conditions under three water management scenarios.

Additionally, managing water, energy, and food without efficient and synergistic actions may increase the risk of shortages. Consequently, one opportunity to improve the sustainable use of these sources is investigating the integration of the water–energy–food nexus with quality and business excellence initiatives.

3. Quality, Excellence, and Sustainability

Given the mentioned scientific gap in integrating the WEF nexus with the principles of quality and excellence, the use of BEMs has been considered. This decision is based on the understanding that these frameworks offer a clear opportunity for the development of a quality and continuous improvement mindset that can be aligned with needs and the best sustainability practices [8][37][38]. Regarding the agro-industrial sector, they are aligned with a major impact [39], and their actions can be responsible for proper natural resource management [40]. In this sense, excellence initiatives center on meeting stakeholders' needs and expectations, widening previous scopes of quality-oriented initiatives [41] and focusing on creating sustainable value for all "interested" parties. They have been used by organizations worldwide to improve their performance and achieve improved business results.

Excellence models are most widely used by organizations for self-assessment and improvement, including targeting sustainability [38], with companies opting to adapt and customize them in search of competitive advantages [42]. They promote a longitudinal management philosophy, highlighting a set of principles that orient managers' and associates' behaviors in the long-term, fostering continuous improvement [43]. BEMs focus on offering insights for organizations to manage processes, tools, or techniques, both old or new, with the goal of building value from new opportunities and achieving superior organizational results [44].

However, and regardless of their extensive use, there is still limited integration of the topic of environmental sustainability in excellence frameworks, in this particular case tackling the use of the WEF nexus approach. Despite other scientific authors cited in this research showing a growing pressure for the development of new models, the truth is that economic, social, and environmental sustainability are still often left outside of the scope of some major excellence models [45], although this situation is also changing. Thus, research on business and operational excellence does not usually include a clear focus on environmental sustainability.

Accordingly, there is a clear aim for promoting specific models for the deployment of sustainability-focused excellence in different industrial sectors. In the specific scope of this work—focusing on water, energy, and food as critical issues and looking specifically at the agro-industrial sector—this model proposes to integrate excellence and sustainability because of the WEF nexus.

References

1. Scanlon, B.R.; Ruddell, B.L.; Reed, P.M.; Hook, R.I.; Zheng, C.; Tidwell, V.C.; Siebert, S. The food-energy-water nexus: Transforming science for society. Water Resour. Res. 2017, 53, 3550–3556.
2. Clift, R. Climate change and energy policy: The importance of sustainability arguments. Energy 2007, 32, 262–268.
3. Schoenherr, T.; Talluri, S. Environmental sustainability initiatives: A comparative analysis of plant efficiencies in Europe and the US. IEEE Trans. Eng. Manag. 2013, 60, 353–365.
4. Yeung, S.M. UNSDGs and future quality management—Social policy for developing sustainable development mindset. Corp. Gov. Sustain. Rev. 2019, 3, 26–34.
5. Viles, E.; Santos, J.; Muñoz-Villamizar, A.; Grau, P.; Fernández-Arévalo, T. Lean-green improvement opportunities for sustainable manufacturing using water telemetry in agri-food industry. Sustainability 2021, 13, 2240.
6. Adelodun, B.; Kareem, K.Y.; Kumar, P.; Kumar, V.; Choi, K.S.; Yadav, K.K.; Yadav, A.; El-Denglawey, A.; Cabral-Pinto, M.; Son, C.T.; et al. Understanding the impacts of the COVID-19 pandemic on sustainable agri-food system and agroecosystem decarbonization nexus: A review. J. Clean. Prod. 2021, 318, 128451.
7. Karwacka, M.; Ciurzyńska, A.; Lenart, A.; Janowicz, M. Sustainable Development in the Agri-Food Sector in Terms of the Carbon Footprint: A Review. Sustainability 2020, 12, 6463.
8. Fonseca, L.; Amaral, A.; Oliveira, J. Quality 4.0: The efqm 2020 model and industry 4.0 relationships and implications. Sustainability 2021, 13, 3107.
9. Carvalho, A.M.; Sampaio, P.; Rebentisch, E.; Carvalho, J.A.; Saraiva, P. Operational excellence, organisational culture and agility: The missing link? Total Qual. Manag. Bus. Excell. 2019, 30, 1495–1514.
10. Isaksson, R. Excellence for sustainability–maintaining the license to operate. Total Qual. Manag. Bus. Excell. 2019, 32, 489–500.
11. Siltori, P.F.S.; Simon Rampasso, I.; Martins, V.W.B.; Anholon, R.; Silva, D.; Souza Pinto, J. Analysis of ISO 9001 certification benefits in Brazilian companies. Total Qual. Manag. Bus. Excell. 2020, 32, 1614–1632.
12. Hoff, H. Understanding the Nexus: Background Paper for the Bonn2011 Nexus Conference; Stockholm Environment Institute: Stockholm, Sweden, 2011; pp. 1–52.
13. World Economic Forum. Water Security: The Water-Food-Energy-Climate Nexus: The World Economic Forum Water Initiative; Island Press: Washington, DC, USA, 2011.
14. Taniguchi, M.; Endo, A.; Gurdak, J.J.; Swarzenski, P. Water-Energy-Food Nexus in the Asia-Pacific Region. J. Hydrol. Reg. Stud. 2017, 11, 1–8.
15. Purwanto, A.; Sušnik, J.; Suryadi, F.X.; de Fraiture, C. Water-energy-food nexus: Critical review, practical applications, and prospects for future research. Sustainability 2021, 13, 1919.
16. Botai, J.O.; Botai, C.M.; Ncongwane, K.P.; Mpandeli, S.; Nhamo, L.; Masinde, M.; Adeola, A.M.; Mengistu, M.G.; Tazvinga, H.; Murambadoro, M.D.; et al. A review of the water-energy-food nexus research in Africa. Sustainability 2021, 13, 1762.
17. Leung Pah Hang, M.Y.; Martinez-Hernandez, E.; Leach, M.; Yang, A. Designing integrated local production systems: A study on the food-energy-water nexus. J. Clean. Prod. 2016, 135, 1065–1084.
18. Daher, B.T.; Mohtar, R.H. Water-energy-food (WEF) Nexus Tool 2.0: Guiding integrative resource planning and decision-making. Water Int. 2015, 40, 748–771.
19. Koutsoyiannis, D.; Makropoulos, C.; Langousis, A.; Baki, S.; Efstratiadis, A.; Christofides, A.; Karavokiros, G.; Mamassis, N. HESS opinions: "Climate, hydrology, energy, water: Recognizing uncertainty and seeking sustainability". Hydrol. Earth Syst. Sci. 2009, 13, 247–257.
20. Hülsmann, S.; Sušnik, J.; Rinke, K.; Langan, S.; van Wijk, D.; Janssen, A.B.; Mooij, W.M. Integrated modelling and management of water resources: The ecosystem perspective on the nexus approach. Curr. Opin. Environ. Sustain. 2019, 40, 14–20.
21. Benson, D.; Gain, A.K.; Rouillard, J.J. Water governance in a comparative perspective: From IWRM to a "nexus" approach? Water Altern. 2015, 8, 756–773.

22. Roidt, M.; Avellán, T. Learning from integrated management approaches to implement the Nexus. J. Environ. Manag. 2019, 237, 609–616.

23. Weitz, N.; Strambo, C.; Kemp-Benedict, E.; Nilsson, M. Closing the governance gaps in the water-energy-food nexus: Insights from integrative governance. Glob. Environ. Chang. 2017, 45, 165–173.

24. UN. 2030 Agenda for Sustainable Development; United Nations: New York, NY, USA, 2015; Volume 16301.

25. Saladini, F.; Betti, G.; Ferragina, E.; Bouraoui, F.; Cupertino, S.; Canitano, G.; Gigliotti, M.; Autino, A.; Pulselli, F.M.; Riccaboni, A.; et al. Linking the water-energy-food nexus and sustainable development indicators for the Mediterranean region. Ecol. Indic. 2018, 91, 689–697.

26. Olawuyi, D. Sustainable development and the water-energy-food nexus: Legal challenges and emerging solutions. Environ. Sci. Policy 2020, 103, 1–9.

27. Cansino-Loeza, B.; Tovar-Facio, J.; Ponce-Ortega, J.M. Stochastic optimization of the water-energy-food nexus in disadvantaged rural communities to achieve the sustainable development goals. Sustain. Prod. Consum. 2021, 28, 1249–1261.

28. Parsa, A.; Van De Wiel, M.J.; Schmutz, U. Intersection, interrelation or interdependence? The relationship between circular economy and nexus approach. J. Clean. Prod. 2021, 313, 127794.

29. Garcia, D.J.; You, F. The water-energy-food nexus and process systems engineering: A new focus. Comput. Chem. Eng. 2016, 91, 49–67.

30. D'Adamo, I.; Gastaldi, M.; Morone, P.; Rosa, P.; Sassanelli, C.; Settembre-Blundo, D.; Shen, Y. Bioeconomy of Sustainability: Drivers, Opportunities and Policy Implications. Sustainability 2022, 14, 200.

31. Merino-Saum, A.; Baldi, M.G.; Gunderson, I.; Oberle, B. Articulating natural resources and sustainable development goals through green economy indicators: A systematic analysis. Resour. Conserv. Recyc. 2018, 139, 90–103.

32. Hussien, W.A.; Memon, F.A.; Savic, D.A. A risk-based assessment of the household water-energy-food nexus under the impact of seasonal variability. J. Clean. Prod. 2018, 171, 1275–1289.

33. Bijl, D.L.; Bogaart, P.W.; Dekker, S.C.; van Vuuren, D.P. Unpacking the nexus: Different spatial scales for water, food and energy. Glob. Environ. Chang. 2018, 48, 22–31.

34. Karan, E.; Asadi, S.; Mohtar, R.; Baawain, M. Towards the optimization of sustainable food-energy-water systems: A stochastic approach. J. Clean. Prod. 2018, 171, 662–674.

35. El-Gafy, I. Water-food-energy nexus index: Analysis of water-energy-food nexus of crop's production system applying the indicators approach. Appl. Water Sci. 2017, 7, 2857–2868.

36. AbdelHady, R.S.; Fahmy, H.S.; Pacini, N. Valuing of Wadi El-Rayan ecosystem through water-food-energy nexus approach. Ecohydrol. Hydrobiol. 2017, 17, 247–253.

37. Rivera, D.E.; Piferrer, M.R.T.; Mundet, M.H.B. Measuring territorial social responsibility and sustainability using the EFQM excellence model. Sustainability 2021, 13, 2153.

38. Henríquez-Machado, R.; Muñoz-Villamizar, A.; Santos, J. Sustainability through operational excellence: An emerging country perspective. Sustainability 2021, 13, 3165.

39. Rajakal, J.P.; Ng, D.K.S.; Tan, R.R.; Andiappan, V.; Wan, Y.K. Multi-objective expansion analysis for sustainable agro-industrial value chains based on profit, carbon and water footprint. J. Clean. Prod. 2021, 288, 125117.

40. Amoriello, T. Sustainability: Recovery and Reuse of Brewing-Derived. Sustainability 2021, 13, 2355.

41. Klefsjö, B.; Bergquist, B.; Garvare, R. Quality management and business excellence, customers and stakeholders: Do we agree on what we are talking about, and does it matter? TQM J. 2008, 20, 120–129.

42. Carvalho, A.M.; Sampaio, P.; Rebentisch, E.; Saraiva, P. Operational excellence as a means to achieve an enduring capacity to change—Revision and evolution of a conceptual model. Procedia Manuf. 2017, 13, 1328–1335.

43. Miller, R.D.; Raymer, J.; Cook, R.; Barker, S. The Shingo Model for Operational Excellence; Logan, U., Ed.; Utah State University: Logan, UT, USA, 2013.

44. EFQM. EFQM Model for Business Excellence. 2003. Available online: https://efqm.org/ (accessed on 2 December 2021).

45. Asif, M.; Searcy, C.; Garvare, R.; Ahmad, N. Including sustainability in business excellence models. Total Qual. Manag. Bus. Excell. 2011, 22, 773–786.