The Water–Energy–Food Nexus Index

Subjects: Anthropology | Area Studies

Contributor: David Natcher

The water–energy–food (WEF) Nexus Index is a quantitative measure and representation of country-level WEF security based on 21 water, energy, and food security indicators. The WEF nexus has emerged as a leading tool for assessing integrated resource management strategies and for monitoring progress towards the WEF-related Sustainable Development Goals. A notable outcome of WEF nexus research has been the calculation of the global WEF Nexus Index, which provides a quantitative ranking of country-level WEF security for 170 nations.

WEF Nexus Index

1. Introduction

Over the past decade, the water–energy–food (WEF) nexus has emerged as a leading tool for assessing integrated resource management strategies and for monitoring progress towards the WEF-related Sustainable Development Goals (SDGs 2, 6, and 7). The WEF nexus is a method of examining and evaluating WEF resources as a holistic, interconnected system rather than three independent, disjointed sectors. A considerable body of scholarship now exists on the WEF nexus [1][2][3][4][5][6], which has lent important insight into the inherent linkages and interdependencies that exist between WEF systems [7][8]. Between 2008–2019 alone, 396 papers were published on the WEF nexus, many of which highlight the need for the multicentric treatment of WEF systems [9]. A notable outcome of WEF nexus research has been the calculation of the Global WEF Nexus Index. The WEF Nexus Index integrates data from 21 selected indicators to determine a quantitative ranking of country-level WEF security. These rankings, which include 170 nations, are used to assess national-level progress toward achieving the WEF-related SDGs [10][11].

2. The WEF Nexus Index

The WEF Nexus Index is a quantitative measure and representation of country-level WEF security based on 21 water, energy, and food security indicators. These 21 indicators were determined following a global assessment of water, energy, and food-related databases and were selected based on relevance, data availability, and reliability [11]. Among the 21 indicators that were selected, 7 are used to measure water security, 6 represent energy security, and 8 are used to assess food security (**Table 1**).

Water Indicators	Energy Indicators	Food Indicators
Water Access	Energy Access	Food Access

Water Indicators	Energy Indicators	Food Indicators
1. Percentage of people using at least basic drinking water services.	8. Access to electricity (% of population).	14. Prevalence of undernourishment (%).
2. Percentage of people using at least basic sanitation services.	9. Renewable energy consumption (% of total energy consumption).	15. Percentage of children under 5 affected by wasting.
3. Degree of integrated water resource management implementation.	10. Renewable electricity outputs (% of electricity output).	16. Percentage of children under 5 who are stunted.
	11. CO_2 emission per capita.	17. Prevalence of obesity in the adult population (18 and older).
Water Availability	Energy Availability	Food Availability
4. Annual freshwater withdrawals.	12. Electric power consumption (kWh per capita).	18. Average protein supply (gr/caput/day).
5. Renewable internal freshwater resource per capita.	13. Energy imports (net % of energy use).	19. Cereal yield (kg/ha).
6. Environmental flow requirements.		20. Average dietary energy supply adequacy.
7. Average precipitation (mm/yr.).		21. Average value of food production ($/capita).

Table 1. Indicators used in the WEF Nexus Index [11].

The WEF Nexus Index was developed in accordance with the Joint Research Centre's Competence Centre on Composite Indicators and Scoreboards (JRC:COIN) [12]. The analytical framework for the WEF Nexus Index consists of three equally weighted sub-indexes, or "pillars", each one representing a WEF sector. The equal weighting of each pillar reflects the multicentric nature of the WEF nexus by ensuring that each resource sector has equal importance in the calculation of the overall index [10]. Within each WEF pillar are two equally weighted sub-pillars representing access and availability. The access sub-pillar refers to equitable access to and distribution of WEF resources, whereas the availability sub-pillar relates to the physical availability of the resource itself [11]. Each sub-pillar then contains a subset of indicators representing access to or availability of its corresponding WEF resource (**Table 1**).

To calculate WEF Nexus Index values, the indicator data were first normalized using the min–max method. Following this method, the country *i*'s normalized value for indicator *j* would be calculated as

$$x_{ij}^{norm} = \frac{x_{ij}^{obs} - x_j^{min}}{x_j^{max} - x_j^{min}} \times 100 \quad (1)$$

(1)

where the superscript *obs* indicates the observed value for country *i* and the superscripts *max* and *min* denote the maximum and minimum values of indicator *j* among the sample. This procedure converts data to a uniform, unitless scale from 0–100 so that it may be aggregated across indicators [13]. Each sub-pillar (*SP*) is then calculated as the weighted arithmetic average of its normalized indicator values,

$$SP_i = w_j x_{ij}^{norm} + \cdots + w_n x_{in}^{norm}, \quad (2)$$

(2)

where w_j is the assigned weight of indicator *j*, *n* is the number of indicators within the sub-pillar, and the sum of w_j through w_n for each sub-pillar is one. The WEF pillar scores are then calculated as the arithmetic average of their underlying access and availability sub-pillars. For example, the water pillar (*WP*) for country *i* would be calculated as

$$WP_i = \frac{SP_{Access,i} + SP_{Availability,i}}{2} \quad (3)$$

(3)

The WEF Nexus Index (*WNI*) for the country *i* can then be calculated as the arithmetic average of its water pillar, energy pillar (*EP*), and food pillar (*FP*) scores:

$$WNI_i = \frac{WP + EP + FP}{3} \quad (4)$$

(4)

Based on these calculations, the WEF Nexus Index for Canada is 75.51 (out of 100), making it the fifth most WEF-secure country (N = 170) [11]. Canada's water pillar value was calculated to be 68.50, which ranks 42nd globally. Canada scores high for providing basic access to drinking water and safely managed sanitation services but had a relatively low score for average annual precipitation. Canada's energy pillar value was 84.81, which ranked it as being the 3rd most secure. Canada's high energy score is attributed to the universal access to electricity and being a net exporter rather than importer of energy. However, Canada's energy score is negatively influenced by relatively low renewable energy consumption and higher than average CO_2 emissions. Last, Canada's food pillar was calculated to be 73.22, ranking it 13th worldwide. This score is attributed in part to Canada having a low

prevalence of undernourishment and children less than five years of age who are affected by wasting or stunting. However, this value is offset by high rates of obesity in the adult population.

The WEF Nexus Index serves as a useful mechanism for policymakers to assess how well their respective countries are meeting WEF security benchmarks, which WEF sectors are more or less secure, and how their scores compare to others, either globally or in their respective regions. **Table 2** shows the WEF Index and resource pillar scores for the top five ranked nations.

Table 2. Top five ranked nations in the WEF Nexus Index [11].

Country	Global Ranking	Index Score	Water	Energy	Food
Norway	1st	80.9	79.1	93	70.5
New Zealand	2nd	77.3	79.1	74.6	78.2
Sweden	3rd	76.9	78.2	82.3	70.1
Iceland	4th	76.6	79.4	93.2	57.2
Canada	5th	75.5	68.5	84.8	73.2

References

1. Liu, Q. Interlinking climate change with water-energy-food nexus and related ecosystem processes in California case studies. Ecol. Process. 2016, 5, 389.
2. Endo, A.; Tsurita, I.; Burnett, K.; Orencio, P.M. A review of the current state of research on the water, energy, and food nexus. J. Hydrol. Reg. Stud. 2017, 11, 20–30.
3. Fader, M.; Cranmer, C.; Lawford, R.; Engel-Cox, J. Toward an Understanding of Synergies and Trade-Offs Between Water, Energy, and Food SDG Targets. Front. Environ. Sci. 2018, 6, 112.
4. Mainali, B.; Luukkanen, J.; Silveira, S.; Kaivo-Oja, J. Evaluating Synergies and Trade-Offs among Sustainable Development Goals (SDGs): Explorative Analyses of Development Paths in South Asia and Sub-Saharan Africa. Sustainability 2018, 10, 815.
5. Kulat, M.I.; Mohtar, R.H.; Olivera, F. Holistic Water-Energy-Food Nexus for Guiding Water Resources Planning: Matagorda County, Texas Case. Front. Environ. Sci. 2019, 7, 3.
6. Natcher, D.; Ingram, S. A Nexus Approach to Water, Energy, and Food Security in Northern Canada. Arctic 2021, 74, 1–11.

7. Bhaduri, A.; Ringler, C.; Dombrowski, I.; Mohtar, R.; Scheumann, W. Sustainability in the water–energy–food nexus. Water Int. 2015, 40, 723–732.
8. Biggs, E.M.; Bruce, E.; Boruff, B.; Duncan, J.M.; Horsley, J.; Pauli, N.; McNeill, K.; Neef, A.; Van Ogtrop, F.; Curnow, J.; et al. Sustainable development and the water–energy–food nexus: A perspective on livelihoods. Environ. Sci. Policy 2015, 54, 389–397.
9. Han, X.; Zhao, Y.; Gao, X.; Wang, Y.; Jiang, S.; Zhu, Y.; An, T. The historical footprint and future challenges of water-energy-food nexus research: A bibliometric review towards sustainable development. Environ. Rev. 2021, 29, 260–276.
10. Simpson, G.B.; Jewitt, G.P.W.; Badenhorst, J. Development of Water-Energy-Food Nexus Index and Its Application to South Africa and the Southern African Development Community; WRC Report no. 2959/1/19; Water Research Commission: Pretoria, South Africa, 2020; ISBN 978-0-6392-0113-9. Available online: http://wrcwebsite.azurewebsites.net/wp-content/uploads/mdocs/2959_final.pdf (accessed on 7 June 2021).
11. Simpson, G.; Jewitt, G.P.W.; Becker, W.; Badenhorst, J.; Neves, A.; Rovira, P.; Pascual, V. The Water-Energy-Food Nexus Index; Jones & Wagener: Sandton, South Africa, 2020; Available online: https://doi.org/10.31219/osf.io/tdhw5 (accessed on 7 June 2021).
12. Saisana, M.; Alberti, V.; Alvarez, M.; Becker, W.; Caperna, G.; Cocco, C.; Damioli, G.; De Pedraza, P.; Del Sorbo, M.; D'Hombres, B.; et al. Joint Research Centre: Competence Centre on Composite Indicators and Scoreboards. In Proceedings of the 16th JRC Annual Training on Composite Indicators and Scoreboards, Ispra, Italy, 5–9 November 2018.
13. OECD. Handbook on Constructing Composite Indicators: Methodology and User Guide; Organisation for Economic Co-operation and Development: Paris, France, 2008.