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The water-energy-food nexus approach from a security perspective

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Abstract:

To meet the demand for the resources needed to sustain this population increase, it is estimated that food production will have to increase by 60%, energy consumption by 80% and water needs by 55% worldwide.

Major macro trends taking place in the 21st century, coupled with an increasingly uncertain geopolitical landscape, are putting huge pressure on the water-energy-food nexus. There are an ever increasing number of actors demanding greater quantities of these resources and there may be tensions and incompatibilities that break the harmony there must be between the management of water, energy and food from the standpoint of sustainable development.

Keywords

Water-energy-food nexus, GHGs, climate change, renewable energies…

El enfoque nexo agua-energía-alimentos: tensión, sostenibilidad y conflictos

Resumen:

Para satisfacer la demanda de recursos necesarios para sustentar este incremento poblacional se estima que la producción de alimentos tendrá que aumentar en un 60%, el consumo de energía en un 80% y las necesidades de agua en un 55% a nivel mundial.

Las principales tendencias macro que están teniendo lugar en el siglo XXI junto con un panorama geopolítico cada vez más incierto están ejerciendo mucha presión sobre el nexo agua-energía-alimentos. Cada vez hay más actores que demandan mayores cantidades de cada uno de estos recursos y pueden existir tensiones e incompatibilidades que hagan romper la armonía que debe existir entre la gestión del agua, la energía y los alimentos desde el punto de vista del desarrollo sostenible

Palabras clave:

Nexo agua-energía-alimentos, GEI, cambio climático, energías renovables.

Introduction

It is estimated that the world's population will reach some nine billion people. To meet the demand for the resources needed to sustain this population increase, it is estimated that food production will have to increase by 60%, energy consumption by 80% and water needs by 55% globally[1].

To address this challenge, in 2011 the World Economic Forum proposed strategies to strengthen the sustainable use of water, energy and agricultural resources in the context of climate change[2]. The concept of the water-energy-food nexus (WEF) came about as a holistic approach to address today's sustainable development challenges.

The environmental component has subsequently been added. Healthy ecosystems are a prerequisite for the sustainability of all the above and are negatively affected if water, energy or food are used unsustainably. To this effect, the water-energy-energy-food nexus is also known as the water-energy-food-ecosystems (WEFE) nexus to explicitly recognise its environmental dimension. Over the past ten years, this new approach has become a key framework for addressing complex resource and development challenges.[3]

Among the water, energy and food sectors there are interconnections that are multidimensional[4]. Water plays a key role in energy production, for example, in the extraction and capture of energy resources such as fossil fuels. Water is a component of the power generation process like in thermal power plants and is also used as cooling systems in them and in nuclear power plants. Water is also the raw material for hydropower and is key to the production of biofuels. Water availability is therefore an increasingly important measure for assessing the physical, economic and environmental viability of energy projects[5]. Water consumption in the global power sector will potentially increase by up to 50% by 2050, compared to the 2020 level[6]. This figure gives an idea of the challenge we face.

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[1] https://www.waterfootprint.org/event/water-energy-food-nexus-symposium-2023/
[2] https://www3.weforum.org/docs/WEF_WI_WaterSecurity_WaterFoodEnergyClimateNexus_2011.pdf
[3] https://www.gwp.org/en/sdg6support/iwrm-support/themes/water--energy--food--ecosystems-nexus/what-is-the-wefe-nexus/
[4] https://www.gwp.org/en/GWP-Mediterranean/WE-ACT/Programmes-per-theme/Water-Food-Energy-Nexus/
[5] https://www.energynews.es/el-sector-de-la-energia-debera-lidiar-con-los-problemas-de-agua/
[6] Lohrmann, A., Farfan Orozco, F., Lohrmann, C., Fritz Kölbel, J., & Pettersson, F. (2023). Troubled waters: Estimating the role of the power sector in future water scarcity crises. Energy, 282, Article 128820. https://doi.org/10.1016/j.energy.2023.128820

The relationship between energy and water is also a two-way street. To this effect, energy is needed to process and distribute water, treat wastewater, pump groundwater and desalinate seawater.

Water is also the main resource in the entire food supply chain. In turn, intensive agricultural production is increasingly affecting water quality. Energy is also an essential component of food production from pumping water to processing, transporting and refrigerating food. Energy is also linked to food through the production of fertilisers.

In recent years, the rise of biofuels and the installation of renewable energies on land that was traditionally agricultural are causing land use changes with implications for food production.

All economic activity depends on the physical environment around it, and especially on the interconnection between the three essential resources: water, energy and food. From an economic perspective, the nexus approach has largely promoted a holistic approach to thinking about sustainable development initiatives, especially in relation to cleaner and more efficient production processes in the agriculture, water and energy sectors[7].

In this context, the nexus is a useful tool for detecting the economic risk of resource scarcity, optimising investments and resource use, and for assessing the effects of economic policies or shocks such as climate change.[8]

Aside from the economic one, this nexus is studied from other perspectives. For example, for the FAO: "*The water-energy-food nexus is about understanding and managing often competing interests while ensuring the integrity of ecosystems*. *The result of this process is a conceptual approach that revolves around the complex and interrelated uses of water, energy and food"*[9]*.*

However, when attempting to study this nexus in a specific region, it must be recognised that it is more than a biophysical system; it is also a multi-scale fusion of people, institutions and infrastructure, influenced by history and a particular context.[10]

7 https://journals.sagepub.com/doi/10.1177/14649934231162220?icid=int.sj-abstract.similar-articles.7
8 https://link.springer.com/article/10.1007/s10668-022-02877-4
9 https://www.fao.org/land-water/water/watergovernance/waterfoodenergynexus/en/
10 Hejnowicz A.P. "Appraising the Water-Energy-Food Nexus From a Sustainable Development Perspective: A Maturing Paradigm?" Earth's Future. Volume10, Issue12 December 2022

The major macro trends taking place in the 21st century together with an increasingly uncertain geopolitical landscape are putting this nexus under huge pressure. An increasing number of actors are demanding greater quantities of each of these resources and there may be tensions and incompatibilities that break the harmony there must be between water, energy and food management from the point of view of sustainable development.

Pressures on the water-energy-food nexus

Population growth

According to UN data, by mid-November 2022 the world's population will reach 8 billion, which is more than three times the mid-20th century figure. This growing trend will continue in the coming years because the world population is estimated to increase by almost 2 billion people from today's 8 billion to 9.7 billion in 2050, with a peak of around 10.4 billion by the mid-2080s[11].

This increase will occur heterogeneously across the globe. More than half of global population growth between now and 2050 is expected to take place in Africa. Sub-Saharan Africa is expected to double its population this year.

While the population there must cope with poor living conditions, in other regions of the world such as Asia, the upper-middle income population is experiencing a considerable boom[12]. This increase is associated with higher consumption of water, energy and food, and a growing market for consumer goods, including technology and automotive goods. In the particular case of China, meeting the needs of its growing middle class is a challenge that has far-reaching consequences for the country's future[13]. Agricultural investments in other countries[14], genetic manipulation to obtain larger livestock[15] and the

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[11] https://www.un.org/es/global-issues/population

[12] Bonnet, A. and A. Kolev (2021), "The middle class in Emerging Asia: Champions for more inclusive societies?", OECD Development Centre Working Papers, No. 347, OECD Publishing, Paris, https://doi.org/10.1787/93af380b-en.

[13] https://www.wilsoncenter.org/sites/default/files/media/documents/publication/WATER%20ENERGY%20FOOD%20ROADMAP.pdf

[14] https://www.gro-intelligence.com/insights/a-look-at-chinese-investment-in-african-agriculture

[15] https://www.lavanguardia.com/internacional/20191007/47854982630/cerdos-gigantes-china-granjas-peste-porcina.html

hoarding of fish resources[16] are some examples of the strategies China is implementing to ensure food security for its population.

Increased urbanisation

According to UN estimates, 60% of the population will live in cities. Furthermore, 75% of the world's primary energy and 80% of the world's food is consumed in urban areas [17].

Ninety-five per cent of this urban expansion of the world's population will occur in developing countries[18], where the urban population is expected to grow from 56% of the world's total in 2021 to 68% in 2050. This growth will occur in cities where the population lives in informal settlements with no or restricted access to basic services such as drinking water, sanitation, electricity and waste management.

UN-Habitat's World Cities Report 2022 estimates that India's urban population will rise to 675 million by 2035, the second highest behind China's one billion. By 2030, half of all Africans will live in cities, while almost two-thirds of the country’s urban population already lives in slums with poor access to safe drinking water.

Climate change

The first approximation of the influence of climate change on the water-energy-food nexus is based on the consequences of direct impacts due to altered temporal and geographical precipitation patterns, increased temperatures and rising sea levels. These impacts alter countries' ecosystems and can jeopardise the proper functioning of critical infrastructure. To cite some examples, saline intrusion in Egypt could lead to the loss of crops in the Nile Delta[19]. For its part, in Africa, where 60-100% of the population depends on agriculture, a 1°C rise in temperature could cause 10-30% crop losses, leading to food security situations[20].

Moreover, water in aquifers is consumed at a faster rate than it is replenished. The increased use of more efficient irrigation systems, such as pumping systems, requires higher energy consumption. Moreover, obtaining fresh water via a desalination process

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[16] https://www.nytimes.com/interactive/2022/09/26/world/asia/china-fishing-south-america.html
[17] https://www.mdpi.com/2073-445X/11/9/1569
[18] https://www.un.org/sustainabledevelopment/cities/
[19] https://earthobservatory.nasa.gov/images/149183/the-nile-deltas-disappearing-farmland#:~:text=About%2015%20percent%20of%20Egypt%27s,UN%20Food%20and%20Agriculture%20Organization.
[20] https://www.nature.com/articles/s41598-019-49167-0

is the most expensive and energy-intensive option for water treatment. At the current rate of consumption, this situation will only get worse. By 2025, two-thirds of the world's population could face water scarcity[21].

The second approach to the influence of climate change on the water-energy-food nexus could be from a mitigation point of view. Climate policies are intrinsically linked to energy and economic policies.

Ambitious greenhouse gas emission reduction targets are being imposed to avoid a 2°C global temperature rise. Most powers are committed to achieving climate neutrality by 2050, and to achieve this, all economic sectors must be involved to some degree in decarbonisation.

These mitigation policies are prompting significant progress towards the use of renewable energy - in the case of the EU also encouraged by the search for greater energy security since the war in Ukraine - and changing the way populations consume. These measures have direct implications for the management of the water-energy-food nexus.

Innovative projects are currently being developed to try to achieve symbiosis between these sectors. In terms of the relationship with food production, there is both good and bad news. On the one hand, there is the development of agrovoltaics, i.e. using photovoltaics on agricultural crops to produce more efficient irrigation systems[22], while on the other, the rise of renewables means that farmers are finding it more profitable to rent their land for solar panels than to cultivate it, which could lead to a decrease in agricultural products on the market.

In water-scarce countries, the provision of cheap energy for pumping groundwater for irrigated agriculture could lead to groundwater depletion and loss of water quality, with potentially serious consequences for those who have come to rely on groundwater irrigation[23].

[21] https://www.worldwildlife.org/threats/water-scarcity
[22] https://www.innozar.es/instalaciones-agricolas-rentables-sostenibles-bombeo-solar/
[23] https://www.fao.org/land-water/water/watergovernance/waterfoodenergynexus/en/

Regarding biofuels, the impact on food systems needs to be studied with great caution. Biofuels could provide up to 27% of the world's transport fuel by 2050[24]. According to the IEA roadmap, 3 billion tonnes of biomass per year will be needed by 2050 to produce the forecast amount of biofuels. This would mean one billion tonnes of biomass waste and residues, which would need to be complemented by the production of around 100 million hectares of land, some 2% of the total land for agricultural[25]. The water footprint of this type of energy could be 70 to 400 times larger than the water footprint of conventional fossil energy sources[26].

As far as the promising green hydrogen is concerned, the production of one tonne of hydrogen through electrolysis used to require an average of nine tonnes of water, while most modern water purification and treatment systems require around two tonnes of impure water to produce one tonne of purified water, i.e. one tonne of hydrogen actually needs not nine but 18 tonnes of water. Taking losses into account, the ratio is closer to 20 tonnes of water for every tonne of hydrogen[27]. The cost of water supply, storage and purification is a significant cost that needs to be addressed at source and could become a limiting factor for the development of green hydrogen.

Ammonia is beginning to be considered as a clean energy source to decarbonise the shipbuilding sector. The International Renewable Energy Agency (IRENA) estimates that green and blue ammonia production (gas production with carbon capture) for the world to achieve the objective of a maximum rise in temperature of 1.5°C will total 688 Mt in 2050[28]. Currently, 80% of ammonia is used in fertiliser production[29]. This increase in ammonia demand for energy should not jeopardise fertiliser supply and food production. If the price of fertilisers becomes too expensive, as seen recently because of the war in

[24] https://www.iea.org/news/biofuels-can-provide-up-to-27-of-world-transportation-fuel-by-2050-iea-report-says-iea-roadmap-shows-how-biofuel-production-can-be-expanded-in-a-sustainable-way-and-identifies-needed-technologies-and-policy-actions

[25] Ibid

[26] https://www.researchgate.net/publication/274427873_The_Water_Demand_of_Energy_Implications_for_Sustainable_Energy_Policy_Development

[27] https://elperiodicodelaenergia.com/el-hidrogeno-verde-y-la-crisis-del-agua/

[28] https://www.ammoniaenergy.org/articles/new-irena-report-decarbonising-shipping-by-2050/

[29] https://www.health.ny.gov/environmental/emergency/chemical_terrorism/ammonia_tech.htm#:~:text=How%20is%20ammonia%20used%3F,pesticides%2C%20dyes%20and%20other%20chemicals.

Ukraine[30], farmers will not be able to afford to fertilise their fields with a consequent reduction in crop yields.

The green transition needed to meet climate commitments also requires certain critical minerals, such as cobalt, rare earths and lithium, the extraction and processing of which are concentrated in certain parts of the world. Freshwater consumption in mining represents only a small proportion of total global and even national water use. However, on regional and local scales, mining can generate significant impacts on freshwater resources, particularly when water consumption exceeds carrying capacities defined by the amount of water available, and given environmental water requirements[31].

To meet climate targets, the food sector is also undergoing a major transformation. The livestock sector is increasingly being questioned for its contribution to greenhouse gas emissions, and for the amount of water associated with livestock farming. Given the increase in the world's population and its food needs, the challenge is to obtain the necessary protein via other means. Synthetic meat[32], the consumption of insects[33] and the rise of fish farms[34] seem to be viable options to meet the food needs of the world's population.

The digital world

The initial concept of sustainable development of the water-energy-food nexus was approached from a perspective of the influence of climate change on the three sectors. While this phenomenon is considered one of the biggest systemic risks, it is also worth considering the impact of a trend that has increased dramatically in recent years, namely the digitalisation of society. The world's population is growing and needs resources, but so does data, mainly energy and water - and at an exponential rate and speed.

Global internet traffic increased by 23% in 2021[35] By 2025, the amount of global data is expected to increase to more than 180 zettabytes. Considering demographic and technology trends, projections show that by 2023, 5.3 billion people will have access to the Internet and approximately 29.3 billion devices will be connected, with access speeds

[30] https://www.maritimeoptima.com/blog/will-the-ammonia-shipping-market-boom
[31] https://www.mdpi.com/2079-9276/10/12/120
[32] https://www.labiotech.eu/in-depth/cultured-meat-industry/
[33] https://www.fao.org/edible-insects/en/
[34] https://www.hsph.harvard.edu/christopher-golden/research-projects/fisheries-and-food-security/
[35] https://www.iea.org/reports/data-centres-and-data-transmission-networks

increasing to an average of 110Mbps by 2023[36]. Mobile data traffic is also expected to continue its rapid growth to quadruple by 2027, and 5G's share of mobile data traffic is expected to increase to 60% by the same year, up from 10% in 2021. Although 5G networks are expected to be more energy efficient than 4G, the assessment of their impact is still uncertain[37]. Managing this level of data expansion and processing poses significant challenges not only in terms of technology and operations, but also in terms of sustainability, as data centres are driving up energy and water consumption.

According to a recent scientific study, in the OECD-Europe area, the amount of data is estimated to reach 225 BS compared to 86EB in 2020, which will lead to an increase in energy consumption from 29.8 TWH in 2020 to 112TWh in 2030. In terms of water consumption associated with this data, the figures would be significant since a consumption of 145.2 million^{m3} is projected to reach 546.7 million^{m3} in 2030[38].

The rise of artificial intelligence has implications for water resources. Its impact is beginning to be assessed as the figures are starting to be significant. By way of example, it is estimated that asking 20-20 questions to ChatGPT consumes half a litre of water[39].

In light of these figures, technology giants are investing in the development of new clean energy generation and developing new technologies and operational efficiencies to make data centres more water efficient[40].

Final considerations

Demand for water, energy and food is increasing globally at unprecedented levels. A number of factors are putting pressure on these three resources: global population growth, rapid urbanisation, changing diets, economic growth, climate change and technological challenges.

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[36] https://digitalinfranetwork.com/talks/the-pathway-to-net-zero-water-data-centres/meeting-growing-demands-without-causing-further-harm-to-our-planet/
[37] https://www.iea.org/reports/data-centres-and-data-transmission-networks
[38] Farban J. and Lohrmann A. "Gone with the clouds: Estimating the electricity and water footprint of digital services in Europe". *Energy conversion and management, 290 (2023)*
[39] https://www.euronews.com/green/2023/04/20/chatgpt-drinks-a-bottle-of-fresh-water-for-every-20-to-50-questions-we-ask-study-warns
[40] https://about.fb.com/news/2021/08/restoring-water/

An integrated approach to these three sectors allows for an understanding of the complex interrelationships between them. Given the limited nature of these three resources, management as a nexus makes it possible to consider the impact of a given decision in one sector on the others.

To meet growing global demand, natural resources are under increasing pressure. There is growing evidence of a strong link between conflicts, both national and international, and resources such as food, energy and water and their interconnections.

Although from the outset the management of the water-energy-food nexus has been approached from the point of view of the sustainability of economic development, it is appropriate to start looking at the relationship between these resources from a security point of view, especially when the relationship between them is becoming increasingly strained. Inappropriate prioritisation of the use of these resources has the potential to exacerbate conflict situations in any region of the world, not just those particularly vulnerable to climate change.

Peace is characterised by a capacity to manage conflict, not to repress it[41]. In a context of increasing resource demands, a proper understanding of the water-energy-food nexus at global level and in specific contexts could be the basis for avoiding conflict situations or helping to resolve them.

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41 https://www3.weforum.org/docs/WEF_GAC_NaturalRiches_ResponsibleNaturalResourceManagementConflictCountries_Report_2013.pdf