Challenges of Water-Energy Nexus in BRICS Nations: A Qualitative Approach

Jagdish Prasad Gupta

Abstract: *The water–energy nexus represents a critical interface in global sustainability discourse, reflecting the interdependence between water resources and energy systems. This study examines the structural linkages between water and energy, emphasizing the increasing pressures arising from population growth, urbanization, and climate change. Using a qualitative analytical approach based on secondary data from recent peer-reviewed literature, the paper evaluates sectoral interdependencies, regional disparities, and governance challenges. The findings reveal that energy production remains highly water-intensive, while water supply systems are increasingly energy-dependent, creating a feedback loop of resource stress. The study identifies significant policy fragmentation and institutional gaps, particularly in developing regions. It argues for integrated governance frameworks, technological innovation, and nexus-based policy design to enhance sustainability and resource efficiency.*

Keywords: Water–energy nexus; sustainability; resource governance; water scarcity; energy security; integrated policy

Introduction

Water is essential for socio-economic development for maintaining healthy Eco-system. Worldwide 70 % of fresh water extraction is accounted for by irrigated agriculture, 20 % by industry, and only about10 % by households, hence Water availability for irrigation and food production constitutes one of the greatest pressures on freshwater resources in future. Whereas, water scarcity is an acute situation which world is dealing with specially the developing countries in comparison to developed world. Water scarcity is both a natural and a human-made phenomenon. However, there is enough freshwater on the planet for six billion

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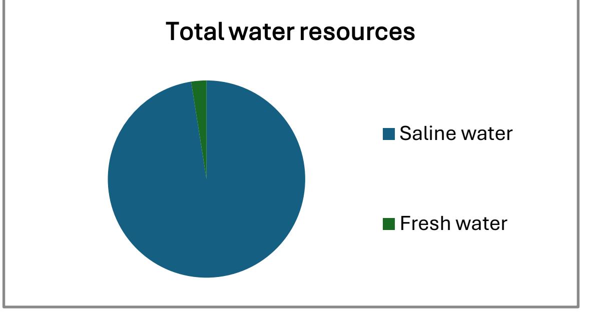
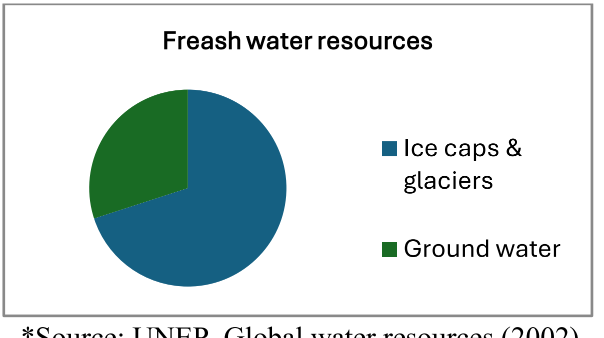
people but it is distributed unevenly and too much of it is wasted, polluted and unsustainably managed. Currently, 1.2 billion people, or almost one-fifth of the world's population, live in areas of physical water scarcity, while another 1.6 billion people, or almost one quarter of the world's population, face economic water shortage (FAO, 2006). Further, studies indicate that by 2025, 800 million people will be living in countries or regions with absolute water scarcity and two-thirds of the world's population could be under severe water stress conditions(FAO, 2006). For example, by 2025, the Middle East and North Africa (MENA) region is set to experience a decline of per capita annual renewable water resources from 750 cubic meters to 500. By contrast, the provisional 2010 Sphere Project standards for water use recommend that the average per capita water consumption range from 7.5 liters to 15 liters per day, which amounts to 2,730 to 5,475 annually (United Nations Office for the Coordination of Humanitarian Affairs (OCHA, 2006).

World without water is unconceivable. About 71% of earth's surface area is covered by water among which 96.5% of water is found in seas and oceans, which is Saline; hence not drinkable. Only about 2.5% of the world's water is fresh water of that, less that 1% is accessible via surface sources and aquifers- the rest is locked up in glaciers and ice caps, or is deep underground (as shown in Figure 1.1).

Figure 1.1: World water resources





*Source: UNEP, Global water resources (2002)

Above mentioned figure illustrates that only 1% of total available water is usable water, which consumes for drinking, irrigation, industrial and other purposes. The replenishment of freshwater depends on evaporation from the surface of the oceans. About 80 per cent of all precipitation falls on the oceans and the remaining 20% on land. The difference between precipitation on land surfaces and evaporation from those surfaces (Total falls on oceans minus total evaporation) is run-off and ground water recharge which is approximately 47000 km3 annually (UNEP, 2002). Concerns about water have reached to mainstream media, highlighting the significant threat to the availability of the water at the global and regional level. In fact, economic growth will also soon constrained by water shortages, affecting the reliable production of energy particularly in the developing countries. Hence, the global debate is going not only about water security or water scarcity in isolation. Instead, it is about the WEN, that is, the links among water and energy. For instance, in Asia, the extraordinary growth of industrialization and urbanization pushes the demands for energy, but expanding power production will be limited by water availability.

Increasingly, it is recognized that water scarcity directly affects energy production systems. Thermal power plants require substantial quantities of water for cooling, hydropower depends entirely on water availability, and fossil fuel extraction involves water-intensive processes (Macknick et al., 2012; Byers et al., 2018). Consequently, water constraints can significantly limit energy generation capacity, particularly in rapidly developing regions (van Vliet et al., 2012, Rosanti, 2025).

At the same time, the provision of water services is highly energy-dependent. Energy is required for groundwater extraction, pumping, treatment, desalination, and distribution (Plappally & Lienhard, 2017; Siddiqi & Anadon, 2011). In water-scarce regions, such as parts of the Middle East, energy-intensive desalination has become a primary strategy for ensuring water supply, thereby increasing dependence on energy systems (Weinthal & Sowers, 2020, Al-Saidi & Elagib, 2017). This reciprocal relationship between water and energy has led to the emergence of the water–energy WEN (WEN) as a critical analytical framework (Endo et al., 2015; Liu et al., 2018).

The increasing scarcity of natural resources has thus necessitated a shift from sector-specific management approaches toward integrated frameworks. The WEN represents one such paradigm, emphasizing the interdependence between water and energy systems (Rasul, 2015, Endo et al., 2018). Water is indispensable for energy production, including thermal cooling, hydropower, and fuel extraction, while energy is essential for water extraction, treatment, and distribution (Dai et al., 2017, Macknick et al., 2012).

Global demand for both resources is rising due to population growth, urbanization, and industrialization. These trends are particularly pronounced in emerging economies, where infrastructure expansion intensifies resource pressures (Byers et al., 2018; Parkinson et al., 2019). Climate change further exacerbates these challenges by altering hydrological cycles and energy demand patterns, thereby increasing uncertainty and vulnerability in both sectors (van Vliet et al., 2012; Liu et al., 2018).

Recent scholarship identifies the WEN as central to sustainable development transitions, particularly in achieving resource efficiency and resilience (Helerea et al., 2023). However, despite its conceptual relevance, implementation remains limited due to governance fragmentation, institutional silos, and lack of policy coherence across sectors (Weinthal & Sowers, 2020, Al-Saidi & Elagib, 2017). In this context, the WEN moves beyond a purely technical understanding of resource interdependencies to encompass governance, policy, and sustainability dimensions (Endo et al., 2017; Liu et al., 2018). The WEN approach highlights the need for integrated resource management strategies that address trade-offs and synergies across sectors (Rasul, 2015; Yillia, 2016). It also underscores the importance of institutional coordination, technological innovation, and policy reform in ensuring long-term resource security (Dai et al., 2017; Byers et al., 2018). Thus, the transition from a water scarcity discourse to a WEN-based framework reflects a broader shift in sustainability thinking one that recognizes the interconnected nature of resource systems and the necessity of holistic governance approaches (Liu et al., 2018; Endo et al., 2015).

In light of these interdependencies, the present study seeks to critically examine the WEN by situating it within the broader context of resource scarcity, climate change, and sustainability transitions. Building on the empirical patterns observed in energy use across water extraction, treatment, transportation, and domestic consumption, as well as water intensity across diverse energy production systems, the paper investigates how these bidirectional linkages generate systemic pressures across sectors and regions. It specifically aims to (i) analyse sectoral interactions across agriculture, industry, and energy production, highlighting the trade-offs between water-intensive energy systems and energy-intensive water services; (ii) assess regional variations in water withdrawals and energy demand, with particular attention to rapidly developing regions such as Asia and resource-constrained regions such as Africa; and (iii) examine governance and institutional challenges, including policy fragmentation and inefficient resource allocation, that constrain effective WEN management. By integrating these analytical dimensions, the study contributes to advancing WEN-based thinking and proposes pathways for more coherent, adaptive, and sustainable policy frameworks to ensure long-term water and energy security.

Literature Review

The WEN has emerged as a critical interdisciplinary framework that integrates resource management, sustainability science, and policy analysis. While early studies primarily focused on technical interdependencies between water and energy systems, recent scholarship has expanded the scope to include governance, socio-economic, and environmental dimensions. This shift reflects a broader recognition that resource challenges are not merely technological but deeply embedded in institutional and policy contexts (Endo et al., 2017; Rasul, 2016).

Interdependence of Water and Energy Systems

A central theme in the literature is the increasing interdependence between water and energy systems. Water is essential for energy production processes such as cooling in thermal power plants, hydropower generation, and fossil fuel extraction, while energy is required for water extraction, treatment, and distribution. Dai et al. (2017) provide a global assessment of this interdependence, demonstrating how water constraints can significantly affect energy production capacity. Similarly, Macknick et al. (2012) highlight the water intensity of various electricity generation technologies, emphasizing the vulnerability of energy systems to water scarcity. Recent studies further underscore that this interdependence is intensifying due to rising demand and climate variability. Byers et al. (2018) argue that climate change will exacerbate water stress, thereby constraining energy systems, particularly in developing regions. These findings reinforce the need to view water and energy not as isolated sectors but as interconnected systems requiring integrated management.

Emergence of WEN-Based Sustainability Theoretical Frameworks

Further, the evolution of WEN-based frameworks as tools for sustainable resource management. The WEN has been increasingly integrated into broader sustainability paradigms, including the water–energy–food (WEF) nexus. Liu et al. (2018) argue that nexus approaches provide a holistic framework for addressing complex resource interdependencies and achieving sustainable development goals. Helerea et al. (2023) extend this perspective by examining the nexus in the context of energy transitions. Their study highlights that while renewable energy systems reduce carbon emissions, they also introduce new water demands and trade-offs, thereby complicating sustainability outcomes. Similarly, Yupanqui (2025) emphasizes that integrated nexus frameworks are essential for identifying synergies and trade-offs across sectors, particularly in resource-constrained environments. These studies collectively demonstrate that WEN thinking has evolved from a conceptual framework to a practical tool for sustainability planning. However, its implementation remains uneven across regions and sectors.

Governance Fragmentation and Institutional Challenges

A third critical theme is the role of governance and institutional structures in shaping WEN outcomes. Despite the recognition of interdependencies, water and energy systems are often governed by separate institutions, leading to fragmented policy frameworks and inefficient resource use. Weinthal and Sowers (2020) highlight how governance fragmentation exacerbates resource vulnerabilities in water-scarce regions, particularly in the Middle East, where energy-intensive desalination creates dependency loops. Similarly, Al-Saidi and Elagib (2016) argue that institutional silos and lack of policy coordination are major barriers to effective WEN implementation. Endo et al. (2015) further emphasize that successful WEN governance requires integrated institutional frameworks that facilitate coordination across sectors. Without such frameworks, policy interventions may lead to unintended consequences, such as increased energy demand for water supply or over-extraction of water due to energy subsidies.

Climate Change, Urbanization, and Nexus Pressures

Another emerging theme is the impact of global drivers such as climate change and urbanization on the WEN. These factors are intensifying resource demand and increasing system vulnerabilities. Van Vliet et al. (2012) demonstrate that climate change can significantly affect water availability, thereby reducing the efficiency of thermal power plants and disrupting energy supply systems. Similarly, Rosanti, (2025) highlight how urbanization and economic growth increase both water and energy demand, creating additional pressure on already stressed systems. Dahiya (2025) further argues that these pressures are particularly acute in developing economies, where infrastructure limitations and governance challenges amplify resource constraints. This underscores the need for adaptive and resilient WEN-based strategies.

Need for Integrated and Adaptive Resource Management

There is a dire need emphasizes for integrated and adaptive approaches to resource management. Scholars argue that traditional sectoral approaches are inadequate for addressing the complexities of the WEN. Rasul (2015) advocates for integrated policy frameworks that align water, energy, and food systems to achieve sustainability goals. Similarly, Yillia (2016) highlights the importance of identifying trade-offs and synergies to optimize resource use. Recent studies also emphasize the role of technological innovation and data-driven decision-making in improving WEN governance (Helerea et al., 2023). However, these approaches must be complemented by institutional reforms and policy coherence to be effective.

Thus, the above literature review highlights that despite significant advancements in understanding the WEN there is a limited comparative regional analysis that captures variations in WEN dynamics across different socio-economic contexts. Additionally, integration of governance and institutional frameworks into WEN studies remains insufficient. Lastly, there is a lack of policy-oriented research that translates theoretical insights into actionable strategies. This study addresses these gaps by combining global analysis with governance perspectives and providing policy-relevant insights, particularly in the context of developing economies.

Methodology

This study adopts a qualitative research design grounded in the systematic analysis of secondary data to examine the structural interdependencies of the WEN. Given the interdisciplinary nature of the WEN spanning environmental systems, technological processes, and governance frameworks the use of secondary data enables a comprehensive and integrative assessment of global trends, sectoral linkages, and regional disparities. The study draws on a curated body of literature comprising Scopus-indexed and ABDC-listed journal articles published between 2016 and 2025, complemented by authoritative institutional reports and datasets from organizations such as the International Energy Agency, World Bank, and UN Water. The reliance on recent peer-reviewed scholarship ensures methodological rigor and enhances the relevance of the analysis in the context of evolving sustainability challenges (Helerea et al., 2023,; Weinthal & Sowers, 2020,).

To systematically interpret the collected data, the study employs a thematic analysis approach, which facilitates the identification and synthesis of recurring patterns across diverse sources. Key themes explored include the dependence of energy systems on water resources, the energy intensity of water supply systems, regional inequalities in resource distribution, and governance-related challenges affecting WEN management. Thematic analysis is particularly suited for interdisciplinary sustainability research, as it allows for the integration of qualitative insights across multiple domains and scales (Endo et al., 2015). Through this approach, the study captures the complexity of interactions between water and energy systems while maintaining analytical coherence.

In order to deepen the analysis, the study further incorporates a sectoral perspective, examining how WEN dynamics manifest across key sectors such as agriculture, industry, and energy production. This sectoral analysis enables the identification of critical trade-offs and synergies, particularly in contexts where water-intensive energy production and energy-intensive water supply processes intersect. Such an approach is consistent with existing literature that highlights the importance of sector-specific assessments in understanding resource interdependencies and sustainability outcomes (Dai et al., 2017).

Complementing the sectoral analysis, a comparative regional framework is employed to assess variations in water withdrawal and energy demand across major global regions, including Asia, Africa, Europe, and North America. This comparative approach is essential for identifying region-specific vulnerabilities and understanding how socio-economic, climatic, and infrastructural factors shape WEN dynamics. Previous studies have demonstrated that regional disparities play a critical role in determining resource stress and sustainability pathways (Byers et al., 2018,; Parkinson et al., 2019). Furthermore, the study integrates a policy and governance analysis to examine institutional arrangements and regulatory frameworks influencing WEN management. This includes an evaluation of key challenges such as institutional fragmentation, lack of policy coherence, and inefficient resource pricing mechanisms. Such governance-related factors are widely recognized as major barriers to the effective implementation of WEN-based approaches, particularly in developing regions (Weinthal & Sowers, 2020; Al-Saidi & Elagib, 2016).

By incorporating governance analysis, the study moves beyond a purely technical understanding of the WEN and highlights the importance of institutional coordination and policy integration. Conceptually, the research is anchored in the WEN framework, which conceptualizes water and energy systems as interconnected and mutually dependent. This framework provides a holistic lens for analysing feedback loops, trade-offs, and synergies between resource systems, and is increasingly recognized as a critical tool in sustainability science and integrated resource management (Liu et al., 2018; Rasul, 2015). It enables the study to align its analytical components sectoral, regional, and governance dimensions within a unified theoretical structure.

Despite its comprehensive scope, the study is subject to certain limitations. The reliance on secondary data restricts the ability to validate findings through primary empirical evidence, and the analysis is inherently dependent on the availability and quality of existing literature. While this approach allows for broad generalizations and comparative insights, it may overlook localized variations and context-specific dynamics. Future research could address these limitations by incorporating primary data collection, case study approaches, and quantitative modeling techniques to enhance the empirical robustness and policy applicability of WEN research.

Results and Discussion

As for the earlier, parts of the research articles it is known that energy is vital to the provision of water as energy is needed to extract ground water, collect, transport and treat it. This relationship between two resources is known as the WEN.

Energy is needed for ground water extraction; consequently the amount depends on the distance (or depth) from the water source. The process of water treatment also consumes extensive amount of energy to treat brackish, saline & waste water for human & industrial usage through filtration, such as in Australia and Middle East. Water supply to the scarcer (drought prone) areas through transportation also consumes the energy. The following below mentioned (Table 1.1) elaborates the usage of energy in water extraction, treatment and other processes.

Table 1.1: Usage energy in water sector

Energy Usage in	Detail
Extracting water	• Drinking water • Irrigation • Industrial purposes
For water treatment	• Pump & process water • Energy is used to pump wastewater to the treatment plant, and to aerate and filter it at the plant.
Transportation	• Supplying • Distribution • Storage
Domestic purposes	• Washing • Cooking • Cooling

*Source: IEA report "Water for energy" (2012)

Water is ubiquitous in energy formation processes. The production of **oil** requires water in various stages, as show in (Table 1.2) for drilling, hydraulic fracturing & other purposes. Oil is the fossil fuel with highest energy production rate and Asia accounts for almost 40% of the water consumption for oil production (World Energy Council et al., 2010), which will increase further due to growth in population. Almost with the source of world's 40% electricity generation the **coal** is considered as the second most source of primary energy, hence requires water for coal cutting & dust suppression in mining. Coal washing also consumes additional water to increase its quality, which consequently affects the ground & surface water quality through run off from mine. Bio fuels require water for irrigating feedstock crops and for fuel conversion. Water usage for irrigation depends on the crop & region, where it grown, also on the raining pattern of the area.

Water is required for almost all types of electricity generation. **Hydro power** is well known for water consumption in generation process. UNECO-IHE report titled "The water footprint of electricity from hydropower" (June, 2011) states that "the hydropower is a large consumptive user of water. The amount of water lost through evaporation annually from the reservoirs is equivalent to 10% of the global blue water footprint related to crop production". **Thermal power** plants generate about 75% of the electricity produced in the world (IEA, 2012). They needs water mainly for cooling per unit of energy produced, Hence, considered as the larger user of water; in Europe, it accounts 43% of fresh water extraction & in USA, responsible for nearly half of all withdrawals ("Water and Energy Nexus: Challenges, Solutions and United Nations Initiatives," 2014).

Concentrating solar power commonly known as 'solar thermal' concentrates solar rays to produce steam to power turbines and consumes water primarily for producing steam & cleaning solar panels. CSP consumes approximately five times more water per unit energy that a gas- fired plant, two times more than a coal fired plant & 1.5 times more than a nuclear plant ("Water and Energy Nexus: Challenges, Solutions and United Nations Initiatives," 2014). Similarly wind power requires water to keep turbine clean

Thus, with expected increase in population combined with the growth in economies by 2030 water consumption would increase, while energy demand from hydropower and other renewable energy resources will rise by 60% (WWAP, 2009). These issues are interconnected – increasing agricultural output, for example, will substantially increase both water and energy consumption, leading to increased competition for water between water-using sectors.

Below mentioned (Table 1.2) illustrates the detail usage of water in primary energy production and power generation.

Table 1.2: Usage of water in energy

Water usage in	Detail	
primary energy production	Coal	• Cutting and dust suppression in mining and hauling. • Washing to improve coal quality. • Re-vegetation of surface mines.

		• Long-distance transport via coal slurry.
	Oil and gas	• Drilling, well completion and hydraulic fracturing. • Injection into the reservoir in secondary and enhanced oil recovery. • Oil sands mining and in-situ recovery. • Upgrading and refining into products.
	Biofuels require water	• Irrigation for feedstock crop growth. • Wet milling, washing and cooling in the fuel conversion process.
Power Generation	Thermal power plants(fossil fuel, nuclear and bio energy)	• Boiler feed, i.e. the water used to generate steam or hot water. • Cooling for steam-condensing. • Pollutant scrubbing using emissions-control equipment.
	Hydropower	• Electricity generation. • Storage in a reservoir (for operating hydro-electric dams or energy storage).

	Concentrating solar power and geothermal	• System fluids or boiler feed, i.e. the water used to generate steam or hot water. • Cooling for steam-condensing.
	Wind power	• Turbine cleaning

*Source: IEA report "Water for energy" (2012)

As almost all energy generation processes require significant amount of water, and water requires energy for transport and treatment, proves that these two natural resources are linked.

On the basis of current scenario, it is estimated that the global demand for both water & energy would increase due to growth in population and other economic factors occurring in developing countries, especially in Africa & Asia, making it even scarcer that it already is in many regions of the world. As shown in Table 1.3, more than 60% of all water is withdrawn in Asia, more than 10% are withdrawn by Europe and North America, and around 5% is withdrawn by Latin America and the Caribbean, and even less in Africa.

The below mentioned table illustrates the total water withdrawal region wise

Table 1.3 Total water withdrawals

Regions	**Countries**	**Population(million)**	**Total water withdrawal (bill m3/yr)**	**Water withdrawal (m3/per person)**
Africa		860.1	214.9	249.8
	Northern Africa [1] (2000)	149.0	93.9	630.5
	Sub-Saharan	711.0	120.9	170.1

[1] Northern Africa: Egypt, Libya, Algeria, Tunisia, and Morocco

	Africa (2000)			
Asia		3,761.2	2,407.2	640.0
	China(2000)	1,293.2	630.4	487.44
	India(2000)	1,078.1	645.9	599.06
	Middle East[2] (2000-2006)	191.5	214.3	1,119.09
	Other Asia[3] (2000)	1,198.4	916.6	764.84
Europe		808.4	428.4	529.9
	EU-27 (2000)	483.5	260.7	539.25
	Russia (2001)	145.3	66.2	455.49
	Other Europe (2000)	179.6	101.5	565.11
Latin America and the Caribbean(LAC)		431.5	188.0	435.6
	Brazil(2000)	179.1	59.3	331.06
	Other LAC (2000)	252.4	188.0	509.81
North America		427.3	597.8	1398.7
	USA(2000)	294.0	473.6	1610.7
	Canada (2000)	31.3	46.0	1468.0
	Mexico (2000)	102.0	78.2	766.6
World		6,290.0	3,836.3	609.9

*Source: World Energy Council report "Water for energy" (2010)

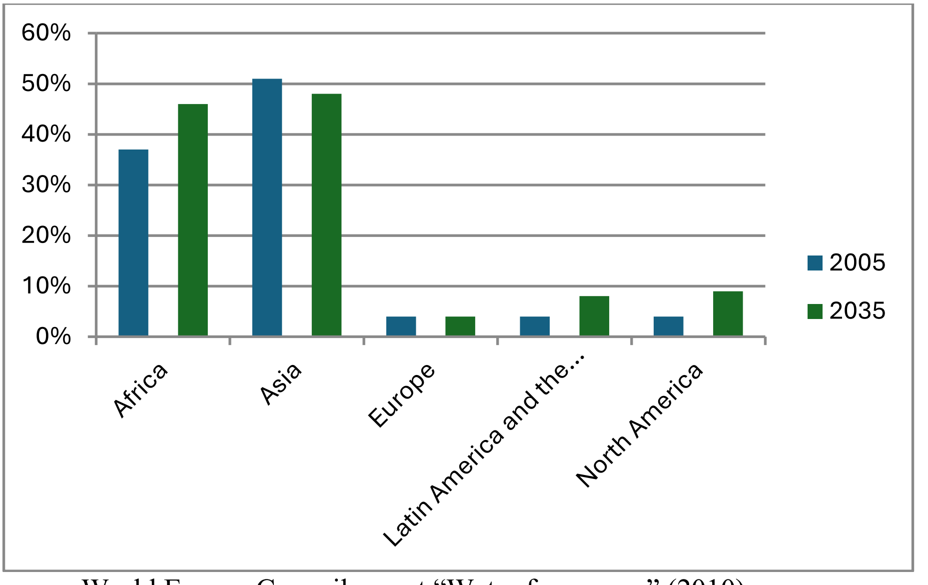
[2] Middle East: Syria, Iraq, Iran, Lebanon, Israel, Jordan, Saudi Arabia, Yemen, Oman, United Arab Emirates, Bahrain, Qatar, Kuwait.
[3] Other Asia incl. Australia, New Zealand etc.

According to recent report of UN water, it is estimated that 85% of the world population lives in the driest half of the planet, 783 million people do not have access to clean water and almost 2.5 billion do not have access to adequate sanitation. About 66% of Africa is arid or semi-arid and more than 300 of the 800 million people in sub-Saharan Africa live in a water-scarce environment. Figure 1. 2 show the total consumption of water in primary energy production along with electricity generation in selected regions. Africa being a second most populated continent in the world withdraws 37% of its available water for energy production and predictions are that this will further increase by 9% in 2035 due to increase in production, infrastructural growth in health sector, transportation, power development and population.

Asia has the highest water withdrawal of the world's region (51%, as shown in graph 1.1), owing to its geographical condition, irrigation patter & large population. Maximum water withdrawal due to urbanization and industrialization results in water scarcity in the area and simultaneously affects the ground water quality also. Studies also predicted that 30 years down the lane the consumption of water will be reduced from 51% to 48% for the reason that if the same pace is maintained there will be no water left at all, also the cost will increase three times than today inferences can be drawn from Saudi and Australia (Dziuban, 2025).future Europe with the majority of developed countries, where people can afford energy on efficient technology and decrease water extraction for energy production stands at 4% (as shown in graph1.2) and assumes to be at same level for next 15 years. Latin America and the Caribbean has the second largest hydropower technical potential of all regions in the world – about 20% (of which almost 40% is in Brazil) or approximately 700 GW ("Water and Energy Nexus: Challenges, Solutions and United Nations Initiatives," 2014). The study assumes that demand for water withdrawal would rise by 4% in 2035. North America being a developing state also assumes to increase their water withdrawal rate by 5% in 2035.

Figure 1.2 illustrates the percentage of water requirement in energy processes; the assumption is made on the basis of the data available

Graph 1.2: Percentage of Water requirement in energy processes



*Source: World Energy Council report "Water for energy" (2010)

As population and economies grow many regions of the world experience water and energy security challenges that water withdrawals (FAO, 2009). Further, over 1.3 billion people worldwide still lack access to electricity; most of them reside in sub-Saharan Africa and East-Asia (IEA,2012). About 2.8 billion people live in areas of high water stress and 1.2 billion live in areas of physical scarcity. It is estimated that by 2030, nearly half of the world's population will be living in areas of high water stress affecting energy and food security (Rodriguez et al., 2013). must be addressed now. During the next 20 years, cities in developing countries will have to meet the demand of 70 million more people each year (United Nations, n.d.-b). Recent FAO estimates show that by 2050, feeding a planet of 9 billion people will require a 60 percent increase in agricultural production and a 6 percent increase in already-strained

According to recent estimates from the World Energy Council, emerging economies like China, India, and Brazil will double their energy consumption in the next 40 years. By 2050, Africa's electricity generation will be seven times as high as it is today. Similarly, in Asia, primary energy production will almost double, and electricity generation will more than triple by 2050 (National Intelligence Council et al., 2012). And in Latin America, increased production will come from non-conventional oil, thermal, and gas sources and the amount of electricity generated is expected to increase fivefold, tripling the amount of water needed (National Intelligence Council et al., 2012). The increased demand for energy will put additional pressure on already constrained water resources. The 2012 UN Water Report surveyed more than 125 countries on this topic and found that the problem of water for energy was high or very high on the list of priorities in 48 percent of the countries surveyed

Conclusion

The findings of this study reaffirm that the WEN is characterized by deep structural interdependencies that span across extraction, treatment, transportation, and consumption processes within the water sector, as well as across diverse energy production systems. As demonstrated in the analysis, energy is indispensable at every stage of water provisioning from groundwater extraction and wastewater treatment to distribution and domestic use while water remains equally critical for energy generation processes, including thermal cooling, hydropower, fossil fuel extraction, and biofuel production. These interdependencies create a reinforcing feedback loop, intensifying resource pressures under conditions of rapid population growth, urbanization, and economic expansion. The regional analysis further highlights significant disparities in water withdrawals and energy demands, with Asia accounting for the largest share due to its demographic and developmental characteristics, while regions such as Africa face compounded challenges of water scarcity and energy poverty. The evidence also suggests that future increases in energy demand particularly in emerging economies will exacerbate water stress, thereby intensifying competition across sectors such as agriculture, industry, and domestic use. Importantly, the study reveals that these challenges are not merely technical but are deeply rooted in governance and institutional fragmentation. Sectoral silos, inefficient resource pricing, and lack of integrated policy frameworks continue to hinder effective WEN management. In this context, the paper concludes that achieving sustainable water and energy security requires a paradigm shift toward integrated governance approaches that align technological innovation with institutional coordination and policy coherence. Such approaches are essential for addressing trade-offs, optimizing resource use, and ensuring long-term sustainability in an increasingly resource-constrained world.

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