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Polycrisis in the MENA Region
Spotlight on the Water-Energy-Food Nexus

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The UNU CRIS team involved in this exercise brings together a wealth of expertise in the MENA region on climate change, energy, water, and food security. Reinhilde Bouckaert, an expert in the (geo)politics and policies of the energy transition with a focus on the MENA and the EU; Nidhi Nagabhatla, a specialist in water and environmental policy and nexus research; Amal Sarsour, an expert in climate change, food security, and agriculture; and Richard Burchill, a seasoned policy analyst in the MENA region.

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Executive Summary

The Water-Energy-Food (WEF) Nexus in the Middle East and North Africa (MENA) Region provides strategic insights for the region that faces complex interconnected challenges in the water, energy, and food security domain. We call for an integrated approach while explaining how current strategies reveal both limitations and promising opportunities for addressing these critical interdependencies. Governments in the MENA region are gradually recognizing the importance of the WEF nexus approach, but implementation remains limited. Key challenges include: weak coordination across water, agricultural, and energy policy sectors; fragmented policy frameworks; limited understanding of cross-sectoral interactions and climate change policies treated as peripheral rather than core development challenges.

In this context, we aim to 1) answer in how far governments in the MENA region consider the WEF nexus in their strategies and 2) evaluate the potential of integrated approaches to address the polycrisis. We did this by focusing on two case studies, starting from the solution offered to one node of the nexus but strongly related to the others. We try to find out in how far there is as well a focus on the other nodes of the nexus and if integrated approaches could be a solution. We reflect on opportunities and challenges for both countries with conclusions and the way forward. The first case study is on desalination in Jordan to solve its water scarcity. . Jordan has one of the world's highest energy dependencies, and is dependent for 98% of its consumable items on import.

The second case study is on green hydrogen in Algeria. This is a solution for the peak fossil fuel demand expected to be reached before 2030 (International Energy Agency, 2024). This would cause a diminishment of fossil fuel rents on which Algeria depends. Algeria suffers from water and home grown food scarcity, as does Jordan. We conclude by focusing on the nexus approach to effectively address the polycrisis. The MENA region could focus on: a) knowledge integration that bridges data and information gaps in WEF nexus understanding; b) assessment and/or quantify inter-linkages between water, energy, and food sectors towards developing integrated policy approaches; c) in terms of governance and institutional frameworks establish science-based evidence that connects science and policy and creates forums for best practices in nexus governance; d) implement collaborative capacity-building programs.

Regarding case studies, the first case study addresses water scarcity through energy-intensive desalination highlight the interdependence of water and energy sectors. The point in the second case study is to diversify economic strategies as the region will also have to deal with potential reductions in fossil fuel revenues. We anticipate that an integrated WEF nexus approach offers significant advantages to exploring sector-specific trade-offs, enhancing resource efficiency, and supporting sustainable development goals. The region must transition from siloed sector management to an integrated, holistic approach by recognizing the complex interactions between water, energy, and food systems, the region can develop more resilient and sustainable strategies for addressing WEF related challenges.

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Introduction

The Middle East and North African region (MENA) is among the most vulnerable areas to the impacts of climate change (e.g. Chenoweth et al., 2011; Cos et al., 2022). According to the Intergovernmental Panel on Climate Change (IPCC), rising global temperatures, increasing sea levels, shifting precipitation patterns, and the growing frequency of extreme weather events are some of the most significant consequences of climate change (Calvin et al., 2023). The MENA region is particularly susceptible to these effects due to its predominantly arid and semi-arid climate, which is characterized by low rainfall, extreme heat, and dry soil. The IPCC projects that these climatic conditions will intensify throughout the 21st century. Without substantial reductions in greenhouse gas emissions, parts of the MENA region could become uninhabitable before the end of the century (Broom, 2019).

Box 1

The MENA region in this Insight Brief encompasses the following countries: Algeria, Bahrain; Djibouti, the Arab Republic of Egypt, the Islamic Republic of Iran, Iraq, Israel, Jordan, Kuwait; Lebanon, Libya, Morocco, Oman, Palestine, Qatar, Saudi Arabia, the Syrian Arab Republic, Tunisia, the United Arab Emirates, and the Republic of Yemen.

Although the region is often analysed as one, we need to take into account in our analysis the stark differences from the East to the West and from the South to the North. Differences such as environmental gradients, provision of ecosystem services, and the impact of climate change, coupled with significant political, economic, societal, ideological, and religious aspects, affect the region's ability to address crises which will be addressed through our two case studies. Both countries have a different economic and political system, with, for example Jordan being a fossil fuel importer while Algeria is a fossil fuel exporter. Further, the region has been grappling with several enduring conflicts. Recent example is the war of Israel against Palestine encountering accelerated violence. It is also experiencing overlapping aggravating threats with climate change impacts at its core. The MENA is already more vulnerable than many other regions in the world to the consequences of climate change, being called 'a climate hotspot'. High temperatures and heat stress affect human health and increase water and energy demand for cooling and drying conditions, impacting food security with demand expected to continue growing as the population is estimated to surpass 720 million by 2050[1].

Context and Background : Unpacking the Polycrisis

Box 2: What is a Polycrisis?

A polycrisis is the simultaneous occurrence of multiple, interconnected crises that exacerbate each other, creating a complex and compounded impact more significant than the sum of their individual effects. In the context of climate change, polycrisis involves the interplay of environmental, social, and economic challenges that collectively threaten global stability and sustainability.

The MENA region exemplifies a polycrisis scenario, where multiple interconnected crises converge, resulting in a situation significantly more severe than the individual effects of each crisis. This complexity arises from various economic, environmental, social, and political challenges that coincide and reinforce one another. The intricate nature of these crises necessitates integrated responses that address governance and management planning and action (Scott & Gong, 2021). The WEF nexus emphasizes the importance of collaborative and effective coordination frameworks to tackle these multifaceted issues effectively. It stresses the need to steer coordinated efforts with the potential for recovery and improvement via comprehensive strategies that recognize the interdependencies among these crises. In the MENA, climate change exacerbates existing vulnerabilities and creates new challenges. Water scarcity and competition for limited resources can lead to conflicts within and between countries and contribute to political instability. Economic disparities exacerbate the situation, creating conditions that could hinder effective climate adaptation and mitigation targets and goals. For the poor, climate policies prove burdensome without being complemented by measures to offset the costs. Further, lack of access to basic services such as clean water, healthcare, or education, make them more vulnerable to climate impacts and less able to adapt. Social inequality can also fuel political unrest and exacerbate tensions between different groups competing for increasingly scarce resources. As agricultural productivity declines and living conditions deteriorate, people are forced to move in search of better opportunities, increasing pressure on urban areas and neighboring countries.

1 The population increased from about 110 million inhabitants in the 1950s to 507,3 million in 2024 (UNPF, 2024)

The WEF nexus is linked to the SDGs as shown in Figure 1, specifically SDG6 (Clean Water and Sanitation), SDG7 (Affordable and Clean Energy), and SDG2 (Zero hunger) (Guerra, Santa, Neto, 2022; Zhang, Shuai S, Pradhan, Zhao, Fu, 2022). Analysis of the interlinkage between the WEF sectors is fundamental to achieving the SDGs in the region (El-Gafy, 2024).

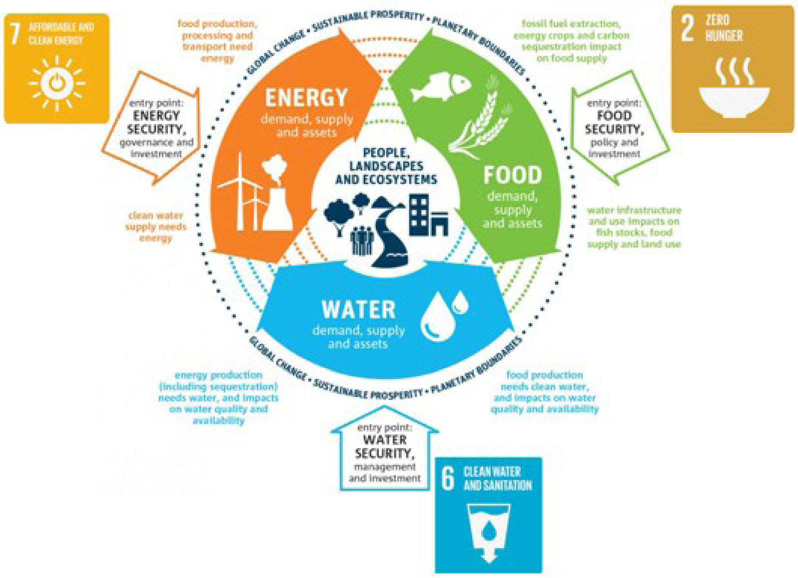

Figure (1): The related SDG's with WEF Nexus (International Water Association, 2018)
Source: International Water Association. (2018). Sustainable development: The water, energy, and food network with minor additions by authors.

The objective and rationale for this assessment

The WEF nexus is a critical framework for policymakers to understand the climate crisis-related impact across overlapping provisioning systems interdependencies of water resources, energy generation, and food production. This nexus is particularly vulnerable in the MENA due to the region's arid climate, limited water resources, and heavy reliance on fossil fuels. This assessment focuses on two cases, one on water in Jordan and one on energy in Algeria, which are intertwined with the WEF nexus and climate security issues. We aim to provide evidence through these examples that these three nodes strongly hinge together when focusing on solutions for the polycrisis. The aim is to determine how far the solutions provided for one node in Jordan and Algeria consider the other nodes of the WEF Nexus. This approach offers a promising framework for addressing the intertwined challenges of climate change. However, it also requires overcoming significant barriers, such as managing competing resource demands, addressing data gaps, and fostering cross-sectoral governance. By leveraging synergies and promoting technological innovation, the WEF Nexus can offer substantial opportunities to develop sustainable and adaptive strategies that address the climate crisis and the needs of vulnerable populations.

> **Box 3: Four Challenges of the WEF Sectors in MENA Region**
> The principal factors contributing to the growing demand for and misuse of water, energy, and food resources in MENA region are urbanization, population growth, unsustainable agricultural practices, and poor governance.

Decoding Water in the WEF Nexus

The MENA region is witnessing a surge in water demand due to population growth, urbanization, and economic development. However, the water supply is dwindling due to climate change, over-exploitation of groundwater, and pollution. Despite being home to only 6% of the global population, the region receives only 2% of the world's renewable fresh water. By 2030, annual water available per capita in the region is expected to fall below the absolute water scarcity threshold of 500 cubic meters per person. By 2040, around one-fifth of all countries will confront chronic water scarcity, with this region being the most severely affected. With the current water management strategies, a conservative estimate suggests an annual additional 25 billion cubic meters of water will be needed by 2050. Arid conditions, low rainfall, and high evaporation rates characterize the geographic location of most MENA countries. This leads to limited natural water resources and a higher impact on climate change. Climate change leads to rising temperatures, heat waves, extended periods of extreme heat, changing precipitation patterns, rising sea levels, and increased evaporation rates, contributing to decreased water availability and competition for water resources. According to the World Bank (2018) assessment, climate-related water scarcity could cause economic losses in the region of 6–14 percent of GDP by 2050. Extreme weather events' increased frequency and intensity are straining infrastructure, livelihoods, agricultural output, and human lives.

Food and water shortages have reached critical levels, resulting in national and regional security implications. Reduced rainfall and increased drought conditions contribute to the expansion of desert areas and the degradation of fertile land, posing significant challenges to agriculture, food security, and ecosystem health. Low-lying areas and coastal cities are particularly vulnerable to the impacts of sea-level rise, storm surges, and saltwater intrusion, threatening livelihoods and economic activities. The resulting decline in food security, rising food prices, and increased import dependence intensify the region's vulnerabilities. Moreover, climate change disrupts ecosystem services, affecting biodiversity and ecological balance. Changes in temperature and precipitation patterns lead to habitat loss, species migration, and the proliferation of invasive species, which, in turn, compromise crucial ecosystem services.

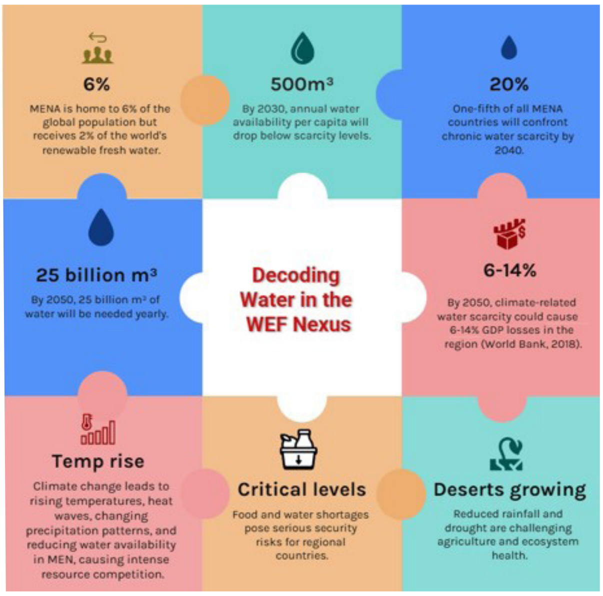

Figure (2): Decoding Water in WEF nexus in MENA Region
Source: created by the author

Box 4: Opportunities to address the escalating water security concerns in the region

Opportunities include tackling the integrated challenges by exploiting multiple ways to increase water efficiency. There is a need to design context-specific climate action strategies and adequately addressing critical technological gaps and institutional and governance blind spots. These include improving transboundary water relations to alleviate conflicts, reducing reliance on depleting groundwater supplies, ensuring access to safe and clean water for all populations, smart practices for managing agricultural water demand, and expanding adaptation efforts to combat the water-related impacts of climate change. Renewable sources such as seawater can play a significant role in addressing the challenges of pollution and overuse. Advancing research in desalination is crucial to make it affordable and sustainable, as the region currently relies on energy-intensive desalination techniques with a high carbon footprint contributing to climate change. Carbon emissions are associated with pumping, treating, and transporting water, contributing to the overall

Photo: AI-generated visual to demonstrate intelligent agriculture practices that can help in managing water use efficiency
Immediately available solutions, as well as long-term resilience-building efforts, need to be implemented. A shift towards sustainable water management is imperative. There is insufficient emphasis on reducing water losses and implementing efficiency measures to conserve water. Historically, the region's response has been to increase water supply by constructing dams, tapping into groundwater, and expanding desalination capabilities. However, this approach has overlooked critical efficiency (such as ageing dams, cost of maintenance etc and governance (multilevel, centralized versus decentralized) issues, making it fiscally and environmentally unsustainable. The unsustainable groundwater extraction has allowed policymakers to delay essential water management and service reforms. Additionally, the unchecked water withdrawal and brine discharge from desalination plants degrades marine ecosystems. The region's increasing reliance on importing virtual water—water embedded in commodities like cereals—further exposes countries to supply shocks, as evidenced by recent conflicts such as the war in Ukraine. The institutions responsible for allocating water, particularly between agricultural and urban demands, remain highly centralized. This centralization underscores the urgent need for more participatory, integrated approaches in water management. Part of the solution could be focusing on low-carbon energy, smart technologies such as advanced membranes, and using renewable energy for desalination and wastewater treatment. This transition is crucial for building a resilient and sustainable future.

To address the MENA's water challenges, six strategies for addressing the water component of the WEF nexus in the MENA Region are outlined in Figure (3) below.

Expand the number of desalination plants to counteract the decreased availability of conventional water sources	repair and upgrading of outdated and deteriorated water infrastructure, in order to enhance the overall efficiency and effectiveness of the water distribution network.	Combines high-tech solutions, such as virtual water, with traditional methods of saving water to counteract the increased water demand
Involves adopting a package of demand-pull regulations and supply-push incentives to combine irrigation with currents of acceptable water quality.	Implementing institutional development policies to improve soil information.	Implement cooperation agreements among all the countries of the MENA region, especially those in the Middle East, which are particularly water scarce.

Figure (3): Six strategies for addressing the water component of the WEF nexus in the MENA Region

Case Study: Water Crisis in Jordan, Is Desalination a Fitting Strategy?

Jordan, a country in the Middle East region, is one of the countries with the lowest renewable water resources per capita in the world. Jordan ranked the second poorest country regarding water challenges in 2017, with only 100 m3 per capita per year (Al-Addous et al., 2023; Al-Kharabsheh, 2020). The per capita share of water resources has decreased drastically from 429.9 cubic meters (1977) to 94 cubic meters (2018) (Hussein, 2018; Knoema, 2022). It is expected to decrease further by about 90 cubic meters, putting Jordan in a water scarcity situation (Shamout, 2023). Jordan's water resources are estimated at a long-term average of 8191 MCM/year; groundwater accounts for about 61% of the water supply.

Water scarcity threatens Jordan's development, with approximately 93.5% of the country receiving less than 200 mm of rainfall and only 0.7% of the country receiving more than 500 mm of annual rainfall (Qtaishat, 2020). This has been identified as the minimum amount required for social and economic development (Lange 2019). The water scarcity in Jordan is perpetuated by many factors, including rapidly increasing population growth, the unprecedented influxes of refugees into Jordan, inadequate management practices leading to high levels of non-revenue water, recurrent and lengthy droughts, and excessive groundwater extraction (Brückner et al. 2021, Hussein, Natta, Yehya, Hamadna, 2020). The predicted decrease in precipitation and unsustainable urbanization drive increased demand for water, energy, and food (Awadh, Al-Mimar, and Yaseen, 2021). This leads to overconsumption of natural resources and declining renewal rates in Jordan (Bdour et al., 2022). Water scarcity hinders economic growth and the government's ability to ensure access to clean water and protect human health. The availability of water resources in Jordan poses a significant challenge to human health, sustainable development, food security, and the broader economy (Al-Saidi, 2020; Irshaid, 2020; Al-Taani, Nazzal, and Howari, 2021). This will have a particularly detrimental impact on the Mediterranean region (Leal Filho & Manolas, 2022).

Since the mid-1990s, financing constraints have been a major problem facing Jordan's energy and water supply sectors. The development of a comprehensive strategic plan for the water sector, encompassing management, infrastructure, and financial reforms, is imperative in addressing Jordan's water challenges (Al-Kharabsheh, 2020; Jeuland et al., 2023). While the private sector has played a significant role in both energy for water supply and water supply production and supply in various countries, including Jordan, their involvement has been limited in number and scope to date (Awaad et al., 2020; Chenoweth and Al-Masri, 2021). The government of Jordan initiated the establishment of a series of independent power producers in the mid-1990s, with the objective of addressing the escalating electricity demands of a rapidly expanding economy. Foreign and local private investors demonstrated considerable interest in these projects (Alterman, Hall and Todman, 2021). The challenges experienced by Jordan's energy sector are multifaceted, with constraints on its water supply being a salient issue.

The allocation of desalinated water for electricity consumption, however, gives rise to new financial barriers. The operation of companies is contingent upon a reliable and continuous water supply, yet in Jordan, the provision of this essential service is under the jurisdiction of the state-owned water department. The absence of a clearly defined policy framework governing the pricing of water property ownership has also given rise to a number of issues. In addition, the local infrastructure landscape is characterized by the inadequate placement of critical projects, including the foundations for power networks, roads, and water and sewage systems. This has contributed to delays in capital projects. Finally, the appraisal and partnership contracts were lengthy and led to uncertainties (Al-Muqdadi et al., 2021; Chenoweth, RA Al-Masri, 2021; Schuetze and Hussein, 2023).

Innovative methods of generating financial capital by utilizing public-private partnerships to bridge financing constraints have been developed (Chenoweth and Al-Masri, 2021). Jordan's water sector strategy is heavily reliant on public-private partnerships (PPPs) as a transformative mechanism for addressing systemic financial and infrastructural constraints. The country's innovative approach to water management demonstrates a strategic framework for mobilising private sector expertise and capital. Despite the implementation of measures to address water stress, including the construction of new dams and water conservation initiatives, water stress remains a significant problem. This necessitates the development of a comprehensive strategy that includes both short-term demand-side interventions and long-term supply-side reforms (Al-Addous et al., 2023).

In 2006, the Government of Jordan awarded a 25-year build-operate-transfer (BOT) contract to Samra wastewater treatment plant company (WWTP). It is the first BOT and public-private partnership in the country. The project directly addresses Jordan's capacity to address its severe water deficit of about 450 cubic meters annually and thus, its growth capacity. When completed the As-Samra wastewater treatment plant will be the largest facility of its kind in the country. The Multilateral Investment Guarantee Agency (MIGA) has supported two phases of the project by providing equity investment guarantees to the project financiers. The first phase ran from 2006 to 2015 and the expansion phase of the project now seeks to meet local demand post 2015 (Matar, 2013) .

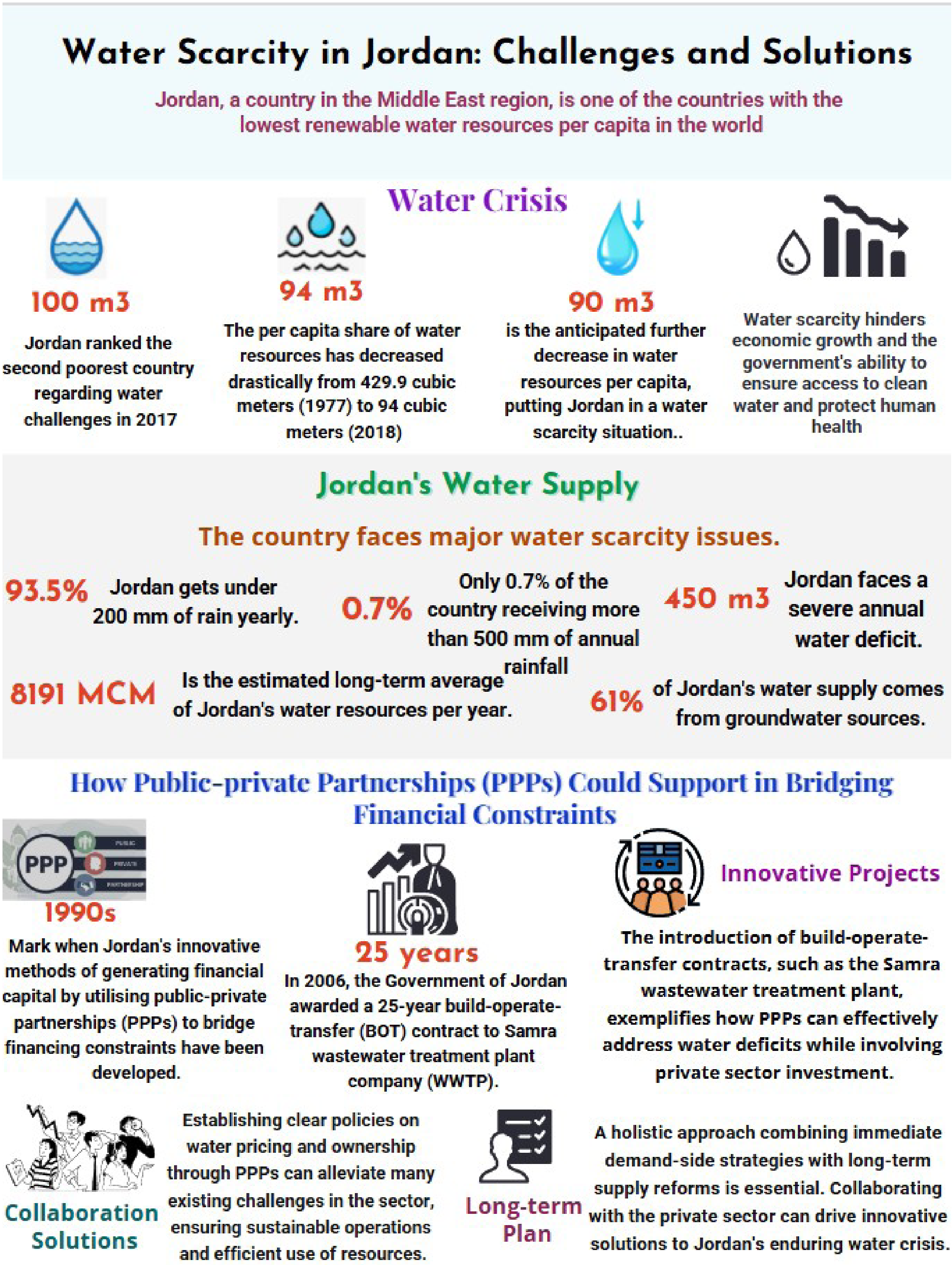

Figure (4): Water scarcity in Jordan and how public-private partnerships could support in bridging financial constraints

As-Samra Wastewater Treatment Plant expansion: A landmark PPP project with total investment: $223 million (including $93 million from MCC, $110 million from private sector, $20 million from Jordanian Government) to increased wastewater treatment capacity and treat 70% of national wastewater and it chieved 78% energy self-sufficiency through biogas and hydropower

Build-Operate-Transfer (BOT) project structures with involvement of international investors like Morganti, Suez Environment Syndicated financing from local Jordanian banks

Targeted infrastructure development in water, energy, and utilities sectors with WEF approach

Future PPP Potential and strategy encompasses:
- Planned PPP projects worth 42 billion USD over next decade
- Focus on water desalination, clean energy, infrastructure
- Targeting private sector investment in critical national infrastructure
- Addressing water scarcity through innovative technological interventions

PPP approach demonstrates a platform for leveraging private sector capital and expertise to overcome national resource constraints, and could positioning Jordan as a regional leader in sustainable water management strategies.

Desalinated Water Opportunities in Jordan

Jordan's water security strategy represents an approach to addressing critical water scarcity through innovative desalination technologies, particularly brackish water reverse osmosis (BWRO). The Ministry of Water and Irrigation (MWI) has strategically positioned itself by leveraging public-private partnerships through Build-Operate-Transfer (BOT) implementation models, transforming water infrastructure development into a dynamic, adaptable ecosystem of technological intervention (Komendantova et al., 2020; Miklyaev et al., 2024; Qtaishat, 2020). Brackish water desalination emerges as a pivotal solution, characterized by its remarkable 95% water purification efficiency and potential to optimize operational expenses while expanding water access to inland regions (Bdour et al., 2022) . With a 1-10 g/L salinity range, these technologies enable water extraction from diverse sources, including naturally salty aquifers, river systems, industrial wastewater, hydraulic fracturing return flows, irrigation channels, and cooling water systems. (Pan et al., 2020). The strategic implementation framework prioritizes technological innovation, environmental sustainability, and economic efficiency. By deploying inland brackish water desalination facilities, Jordan is not merely intending to solve immediate water challenges but establishing a comprehensive, forward-looking water security paradigm. This approach integrates advanced technological solutions, minimizes environmental footprints, and creates a resilient infrastructure that adapts to evolving regional water dynamics ((Jones et al., 2019).
The result is a water management that framework positions Jordan at the forefront of global water security innovation, demonstrating how strategic technological interventions can transform fundamental resource challenges into opportunities for sustainable development.

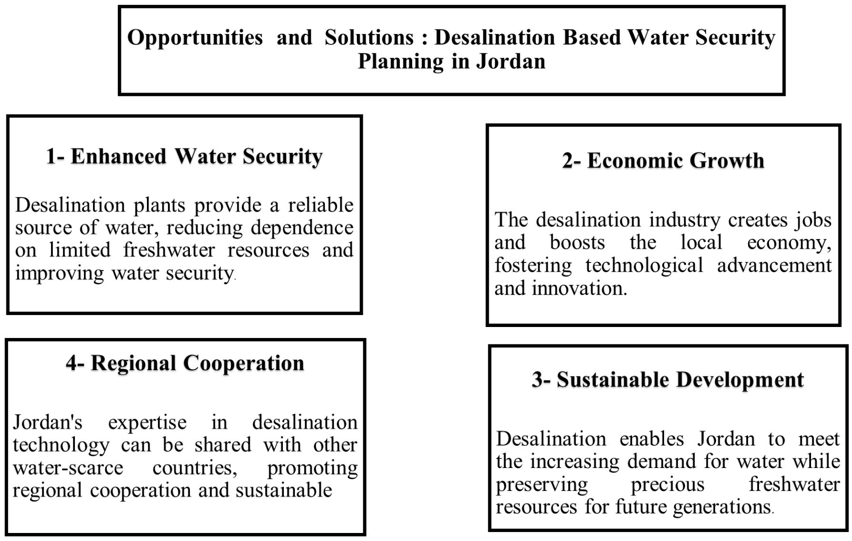

Figure (5): provides a summary of the potential for the utilization of desalinated water in Jordan.

Desalinated water challenges in Jordan

Jordan confronts an unprecedented water scarcity crisis characterized by extreme resource limitations and complex technological challenges. With annual water availability plummeting to merely 90-97 cubic meters per person—dramatically below the 500 cubic meters sustainability threshold—the country faces multifaceted environmental and economic challenges. The water sector is critically constrained by 97% energy import dependency, high desalination costs, and significant greenhouse gas emissions from water production technologies(Salameh and Al-Alami, 2021; Qtaishat, 2020). . Agricultural sectors consume over 50% of freshwater resources, while brackish water reverse osmosis (BWRO) desalination processes impose substantial energy requirements and environmental burdens. The Jordanian government's 2023-2040 National Water Strategy strategically addresses these challenges through integrated water resource management, groundwater preservation, exploration of non-traditional water sources, and aggressive water loss reduction targets. By targeting non-revenue water losses and implementing innovative conservation technologies, Jordan aims to mitigate its water security risks. The strategy emphasizes a holistic approach that interconnects water management, energy consumption, and environmental sustainability, recognizing that technological innovation and strict resource management are crucial for national resilience. Renewable energy integration, optimized desalination plant operations, and careful ecosystem monitoring are key components of this comprehensive water security framework, designed to protect Jordan's economic and environmental future.

However, also desalination presents significant challenges and environmental concerns (Al-Addous et al., 2023). The key elements summarized in Figure 4 demonstrate the challenges. The water concerns Jordan faces mostly revolve around securing energy supplies, given that the nation relies on imports for around 97% of its energy supply (Bdour et al., 2022). The implementation of brackish water reverse osmosis (BWRO) desalination has a high energy requirement for moving feedwater through membranes, evaporating water, or chemically separating feedwater salts (Curto, Franzitta, and Guercio, 2021; Esmaeilion,2020; Panagopoulos, 2021). This results in greenhouse gas (GHG) emissions, elevated power expenses, fossil fuel use, and brine discharge, which can impact land, air, and water (Al-Kharabsheh, 2020). The energy demand and environmental impact influence the sustainability and practicality of desalination systems(Al-Kharabsheh, 2020; Miklyaev et al., 2024; Al-Obaidi et al., 2018).

Jordan's water-energy sustainability strategy represents a critical paradigm shift in addressing national resource challenges through innovative, environmentally conscious solutions. By integrating cutting-edge desalination technologies with renewable energy frameworks, the country is in pioneering phase to holistic approach that simultaneously tackles water scarcity, energy dependency, and ecological preservation. The nation's strategic vision focuses on minimizing environmental footprints while developing robust water infrastructure, particularly through solar-powered desalination technologies and advanced brine discharge management techniques. The transformative approach centers on leveraging renewable energy sources to power water production, with potential carbon dioxide reductions approaching 1,289,600 kg over project lifetimes and renewable energy payback periods as short as 1.1 years.

Photovoltaic brackish water reverse osmosis (PV-BWRO) technologies emerge as a cornerstone strategy, enabling 300 million cubic meters of water production capacities annually with minimal ecological disruption. By prioritizing partnerships with innovative technology providers and developing integrated renewable energy infrastructure, Jordan is repositioning water security from a challenge to an opportunity for technological innovation and environmental stewardship.The Aqaba-Amman Water Desalination and Conveyance Project epitomizes this comprehensive approach, demonstrating how strategic water management can address national resource constraints while maintaining ecological integrity. This model promises to mitigates immediate water scarcity challenges and establishes a sustainable blueprint for water-energy nexus management in water-stressed regions, balancing technological innovation, economic resilience, and environmental conservation(Al-Kharabsheh, 2020; Awaad et al., 2020; Saidan et al., 2020)

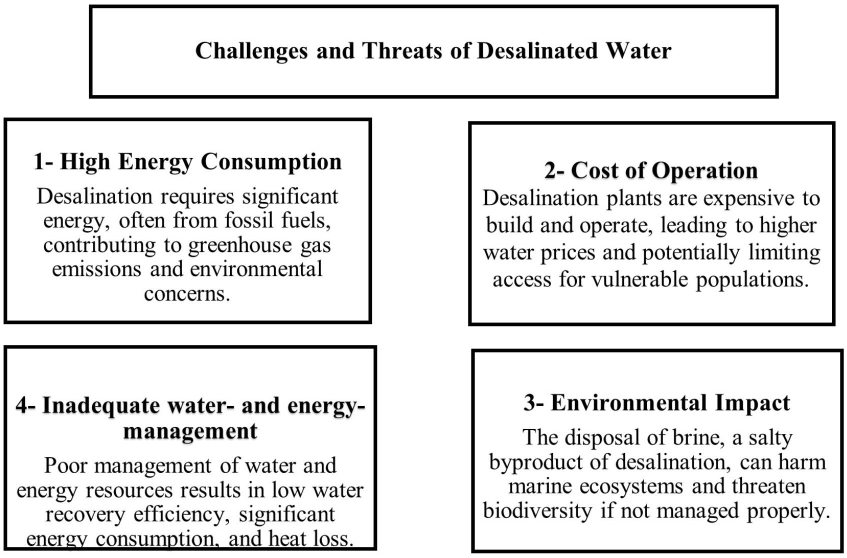

Figure (6): provides a summary of the challenges and threats of the utilization of desalinated water in Jordan.

Decoding energy in the WEF nexus

Regions grappling with an increase in temperature due to climate change, burgeoning populations, and diminishing freshwater resources result in a surging energy demand. The imperative for space cooling and the vital process of water desalination primarily drives this elevated energy need. This confluence of factors is particularly salient in the MENA region, as highlighted in reports such as the International Energy Agency's (IEA) 2018 analysis and research by Healy et al. (2015) and Siddiqi and Anadon (2011). Currently, the MENA region's energy provisions are reliant on fossil fuels. However, limiting the global average temperature increase to as close to 1.5° Celsius as possible, as laid down in the 2015 Paris Agreement, implies leaving almost 40% of 'developed reserves' of fossil fuels unextracted (Trout et al. 2022). Under a business-as-usual scenario, continued high rates of greenhouse gas emissions, of which more than two-thirds are related to the fossil fuel sector, would create intolerable heat and humidity combinations within the current century (Pal and Eltahir 2016). The MENA region, with its fossil fuel exporting states, faces a dilemma. On the one hand, these states are interested in the decarbonization agenda to combat climate change and protect their territories. On the other hand, decarbonization could severely impact their oil-dependent economies and political systems (Krane 2020).

Further, generating conventional energy in hydrocarbon-fired power plants requires water. In contrast, pumping water from underground aquifers, water treatment, and transport in distribution networks requires significant energy. This water competes with the agriculture and food sector, which will only become more severe with the warming up of the region. Further, countries in the region have historically provided subsidies for energy consumption, including fossil fuels. While intended to support communities, fossil fuel subsidies can potentially hinder energy efficiency as well as renewable energy investments. To address the MENA's energy challenges, we propose a multifaceted strategy outlined in Figure 7 below.

Figure (7): Five key aspects to address the MENA's energy challenges.

Green hydrogen production could be part of the solution and is seen by many as an enabler of transitioning to a decarbonized economy based on sustainable energy systems (Olabi et al., 2023). Further, it supports the SDGs of clean energy for all (SDG 7), climate change (SDG 13), and clean water (SDG 6). The example below of Algeria reflects the focus on the hydrogen sector and its challenges in the nexus. Algeria possesses significant renewable energy resources, particularly solar and wind power. Leveraging these resources to produce green hydrogen presents a compelling opportunity. Algeria can produce green hydrogen in significant quantities by investing in electrolysis infrastructure and utilizing excess renewable energy capacity. This offers a strategic opportunity to position itself as a critical player in the global green economy by focusing on producing green hydrogen. This green hydrogen can be used to attract hard to decarbonize sectors creating a whole new industry in Algeria.

Case study: Hydrogen in Algeria, Evolving Pathway to Energy Security?

Algeria faces significant vulnerability to climate variations, particularly with the recurring droughts that result in water shortages and poor harvests. Moreover, desertification encroaches on approximately 20 million hectares of arid and semi-arid steppe regions (Huebner and Fadhil Al-Quraishi 2024). The primary driver of this degradation is a combination of climatic factors and human activities (Sahnounea et al. 2013). Additionally, in recent years, the country has experienced destructive floods triggered by torrential rains, resulting in loss of life, extensive property damage, and displacement of families. Projections for 2030 indicate that climate change will likely bring rising temperatures, some reduction in precipitation, and more frequent episodes of drought and heavy rain spells. These changes may, in turn, lead to a shift in bioclimatic zones toward increased aridity (MedECC 2020). In Algeria, about 90% of the population lives in northern urban cities, where problems with rising sea levels due to climate change are also a concern. Further, these cities already suffer from the so-called urban heat island effect, whereby increased urban expansion and concentrated human activity result in increased warming and heat stress, a matter of concern across the MENA region (Tzyrkalli et al., 2024). This will augment the need for substantial electricity for space cooling to maintain comfortable indoor conditions. However, the current energy production from fossil fuels requires vast amounts of the already limited available water for production processes, including the extraction and refining of fossil fuels (Sahnounea et al. 2013), demonstrating the need to address the WEF nexus.

Algeria has agreed upon official plans to take action against climate change. In 2016, Algeria ratified the Paris Climate Agreement by presidential decree, confirming its Nationally Determined Contribution (NDC). The NDC foresees a reduction of 7% by 2030 compared to the reference scenario using only national means and a reduction of up to 22% if the country were to benefit from significant international support. At the same time, the NDC emphasizes the importance of adaptation, in particular, to strengthen the resilience of ecosystems to extreme phenomena (floods and drought) and to guarantee better control of the risks of natural disasters linked to climate change. The expected results of the NDC include an adaptation of the institutional and regulatory framework to climate change, the strengthening of institutional and human capacities in the field, including for the management of extreme climatic events, the establishment of a monitoring and early warning system, and the development of regional and local plans for adaptation to climate change. In 2019, Algeria produced its first National Climate Plan, which the Government Council validated the same year. This document outlines the recommended measures and the critical intervention sectors to deal with climate issues in the short and medium term. Mitigation includes the energy sector, while adaptation, water resources, and agriculture are mentioned. Per these indications, Algeria presented in 2021 a project to the Green Climate Fund to realize a National Plan for adaptation to the effects of climate change, the implementation of which is planned[3] over three years. At the research level, the 2021 National Research Plan defines three major areas considered priorities for the[4] government, two of which, namely food security and energy security, are closely linked to the country's climate challenges[5].

Although Algeria made several plans to address climate change, the numbers do not add up. Algeria's current energy system is 99% dependent on fossil fuels. CO2 emissions by sector are distributed in Algeria as follows: energy 75% (including 46% for energy consumption, 20% for the production, processing, and transport of hydrocarbons, and 8% for the liquefaction of natural gas); agriculture, land use change, and forestry 11%; waste and industrial processes 10% (including 95% in the form of methane from landfills and 5% from the cement industry in the form of CO2). However, solutions do exist. Algeria is a vast country geographically located in the solar belt, with many windy areas, making investing in renewable energy capacity a 'no regret option'. The external demand for renewable energy electricity and green hydrogen is expected to grow immensely from other regions less endowed with solar energy, such as the EU, opening up a new export market. Currently importing more than 80% of Algeria's fossil fuels, the EU has doubled its import targets to 10 million tonnes of green hydrogen per year by 2030 from three major hydrogen corridors, the Mediterranean, the North Sea area, and as soon as conditions allow Ukraine. This offers enormous potential for Algeria to transition away from its heavy reliance on fossil fuels. Around 60% of Algeria's fiscal revenues come from hydrocarbons, amounting to 95% of its export revenue.

Green hydrogen opportunities in Algeria

Algeria announced in 2021 that it wants to sell green hydrogen instead of natural gas to Spain and Italy in 2030, using the same pipelines to take leadership over the green hydrogen market. The production of green ammonia, using green hydrogen in its production process, could increase the sustainable production of fertilizer, which is one of the essential elements in improving agricultural production and food security. This could replace the chemical fertilizers sector in Algeria, which is heavily reliant on fossil fuels. Further, it has a positive impact on good health and well-being. With minimal to zero gas emissions, green hydrogen is considered an environmentally friendly energy carrier and a step forward towards low levels of air and water pollution. Further, renewable energy sources are more dispersed, creating local opportunities in furthering the greening of the energy supply. The hydrogen opportunities for Algeria are shown in figure 6 below.

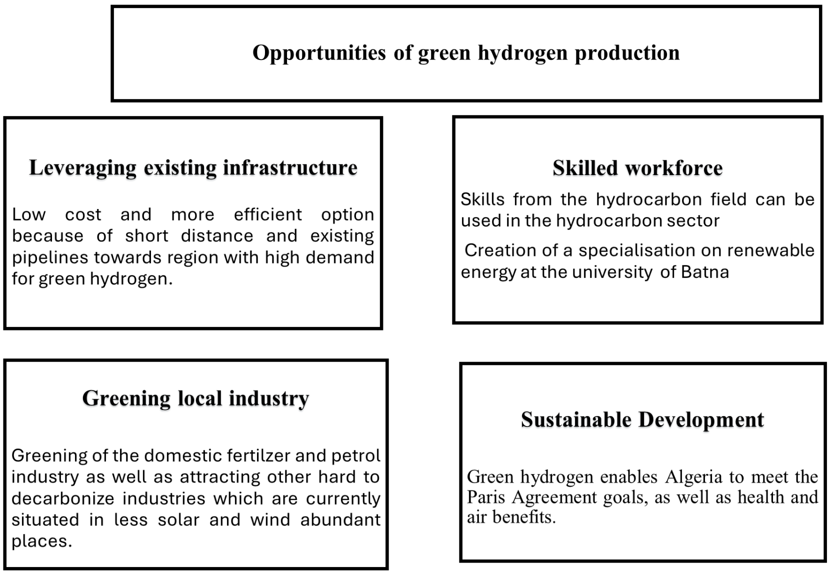

Figure (8): provides a summary of the potential for green hydrogen in Algeria.

Green hydrogen challenges in Algeria

However, we also need to consider the potential adverse side effects of the investment in green hydrogen. Electrochemical water electrolysis is used to develop a green hydrogen economy. This process demands significant highly purified water throughout the whole process. Algeria has recently seen protests against shale gas extraction due to heavy pollution, contamination, and depletion of local water supplies needed for agriculture. With the prospects of increased pressure on water resources because of high population growth and climate change impacts, more attention should be paid to the scarce water resources available before investing in energy plants. It is inconsistent with noticing that when energy production, and in this case, more specifically, hydrogen production, is investigated, it is not yet a standard practice to take into account the impact on water availability (e.g., Brändle et al. 2021, Heinemann and Mendelevitch, 2021, van Wijk and Wouters 2021; Olabi et al. 2023. Further, scholars have warned about the inefficiency of using green hydrogen as the production process causes significant energy losses. Furthermore, refurbishing pipelines for green hydrogen could conflict with the natural gas business model and green hydrogen exports if the same pipelines are used. Low-cost domestic natural gas and experience in CCS technology could lead to an interest in exporting blue hydrogen if business-case transport options exist. Transporting hydrogen via pipeline without refurbishing the pipelines damages the pipes and the electronic equipment. The density of hydrogen would require tripling the energy used, and thus, the cost of pumping it through the pipelines would be high. There will also be high fugitive emissions. Shipping is not yet the solution either. Shipping green hydrogen by sea takes three times the energy required to liquefy it compared to natural gas, while the same tanker volume would only carry 27% of the energy. Also, 0.2% of the hydrogen would boil off daily while shipped (Olabi et al. 2023).

Northern African countries must work together and fulfill their own green electricity needs before focusing on inefficient use of their green electricity to produce hydrogen for export. Algeria has not yet taken up high shares of renewable energy resources, despite a renewable energy law created in 2004 and ambitious renewable energy plans that have existed since 2011. According to data from IRENA (2020), Algeria is far behind its neighbors in terms of renewable energy used for electricity generation. Further, the electricity grid infrastructure is poorly developed both regionally and within Algeria. This should be a priority to overcome the intermittency of renewable energy sources. Further, green hydrogen needs cheap and constant electricity, which is costly with site-specific renewables to be cost competitive. Next, Algeria is an autocratic state with low regulatory quality, high corruption levels, and an unattractive investment climate.

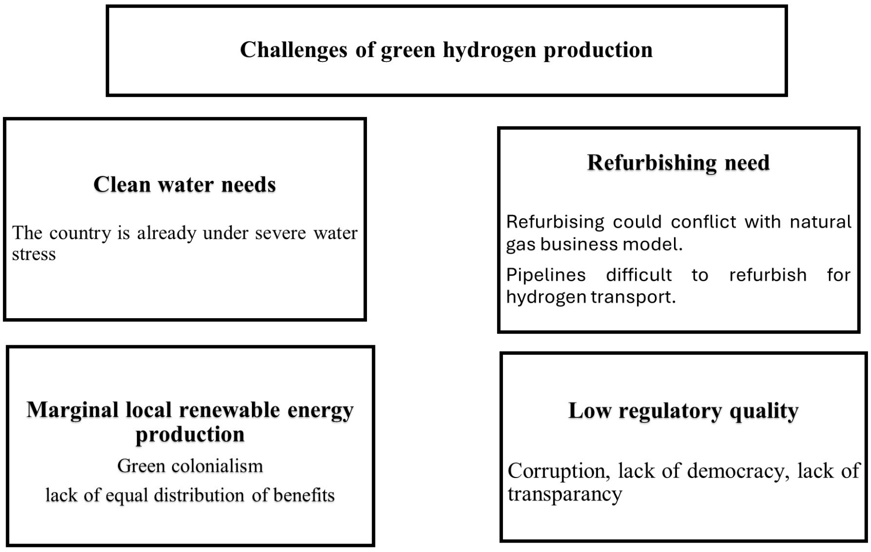

Figure (9): provides a summary of the challenges to green hydrogen production in Algeria.

To seize the opportunities and overcome the challenges in developing a green hydrogen sector, Algeria must adopt a multifaceted approach that aligns with both its climate adaptation goals and its economic ambitions. Firstly, Algeria can leverage its abundant renewable energy resources, particularly solar and wind power, to reduce its dependence on fossil fuels and enhance energy security. By focusing on the development of renewable energy infrastructure, such as expanding solar and wind capacity and modernizing the electricity grid, Algeria can mitigate the intermittency of renewable sources and provide reliable energy for green hydrogen production. Investing in green hydrogen infrastructure, including the refinement of electrolyzers and water management systems, would be essential, but should be approached with caution, given the country's water scarcity issues. A comprehensive water management strategy, ensuring the availability of purified water without exacerbating current shortages, must accompany the scaling-up of hydrogen production.

Furthermore, to tap into the growing global market for green hydrogen, Algeria could improve its regulatory environment by enhancing transparency and attracting foreign investment. This would address the current barriers posed by high corruption levels and the unattractive investment climate. In doing so, Algeria could position itself as a leader in the green hydrogen market, particularly in Europe, where demand is projected to surge. Collaborating with regional partners in North Africa to ensure that green electricity is prioritized for domestic needs before exporting hydrogen would also be crucial to maintaining local energy security.

However, Algeria's path forward must also involve careful consideration of the environmental, social, and economic implications of its green hydrogen ambitions. A focus on integrating green hydrogen into local industries—such as agriculture, by replacing fossil-fuel-based fertilizers with green ammonia—could enhance food security and provide a direct benefit to Algerian society. Additionally, ensuring that investments in green hydrogen do not undermine the country's ability to meet its domestic energy needs or worsen existing water stress will be critical to ensuring that the transition is sustainable. Through coordinated planning, strategic investment, and cross-sector collaboration, Algeria has the potential to create a thriving green hydrogen economy that serves both its climate adaptation goals and economic diversification efforts, while also contributing to regional energy stability.

Five recommendations for Addressing the Energy Component of the WEF Nexus

First, water efficiency standards should be implemented throughout the value chain when creating an enabling framework for a renewable energy and green hydrogen sector. Water and energy could work in perfect nexus with green hydrogen plants.

Second, choosing a hybrid approach wherein green electricity production is preferred over water-intensive energy production systems could help exemplify environmental stewardship. On one hand, it will help mitigate the pressure on water resources, a precious commodity in many arid regions. Conversely, support for the country's commitment to sustainable practices aligns with efforts to combat climate change and conserve vital resources.

Third, access to capital while ensuring the proper investment framework is essential to achieve a clean, just energy transition, which is still lacking in parts of the MENA region. The capital cost for the global South, including some MENA countries, is still far higher for renewable energy than in the North (UNEP 2022).

Fourth, alignment with SDG 7, 'access to clean energy sources for all' should be put forward. The MENA region should first invest in its clean energy to fulfill its needs. Fossil fuel exporting countries should use fossil fuel export income to finance this transition. Further, producing green hydrogen locally offers a distinct economic self-sufficiency advantage for importing fossil fuel countries. States can reduce their dependence on foreign hydrogen imports by harnessing renewable resources within their borders or in the larger region. This approach can help bolster energy security and retain valuable capital within the domestic economy, spurring local industry and job creation.

Fifth, investing in a local, new economy would benefit a region with high youth unemployment. It could help foster the growth of a green energy sector, attract investment, and nurture local expertise. Creating an enabling environment, including good governance such as regulatory quality, political stability, and control of corruption, plays a pivotal role.

Photo: AI-generated visual to demonstrate WEF nexus (water-food-energy needs are managed in an integrated manner for the well-being of people and communities)

Decoding food in the WEF Nexus

The crises experienced in water and energy compound the MENA region's food security challenges. Climate change and water scarcity critically impact food production in MENA, a region already characterized by arid conditions and limited water resources. According to the United Nations Food and Agriculture Organization (FAO), the Middle East is one of the most water-stressed regions globally, with many countries relying heavily on finite groundwater sources. Climate change exacerbates this situation by increasing temperatures and altering precipitation patterns, leading to more frequent and severe droughts. These changes directly affect the availability of water for irrigation, which is crucial for agriculture. Water scarcity and challenges faced in obtaining water require energy-intensive solutions, further exacerbating the polycrisis being experienced. The current situation has been significantly worsened by geopolitical conflicts that have led to increases in food prices and supplies. Further, the fossil gas used to make fertilizers for plants' nutrition could be replaced by green hydrogen. This would reduce the carbon intensity of the farming industry in order to contribute less to climate change at the origin of temperature rise. The rise in temperatures also clearly affects agricultural output. The primary impact is an ever-increasing need for water in agricultural practices. In the region, the already stretched water access means farmers must either invest in more water for irrigation—often an unsustainable option—or face reduced crop yields. The increase in irrigation also leads to higher energy demands, and not all parts of the region have easy or affordable access to energy supplies. Many countries in the region are withdrawing water at unsustainable rates, leading to the over-extraction of aquifers (World Bank Group, 2018, 2). As groundwater levels drop, the cost of accessing water increases, placing additional financial burdens on farmers. Moreover, over-extraction often degrades groundwater quality, which can lead to soil salinization. This process reduces soil fertility, further diminishing agricultural productivity and threatening the livelihoods of those dependent on farming.

Integrated strategies for water management, energy supply, and climate adaptation are necessary. Greater attention is paid to sustainable agricultural practices, such as adopting drought-resistant crop varieties, improving irrigation techniques that use water more efficiently, and upgrading machinery. As the MENA region is facing similar challenges, regional cooperation on water management is necessary. Many of the region's water resources are transboundary, but governments continue to focus on their own national needs. By working together, Middle Eastern countries can develop more resilient agricultural systems that are better equipped to withstand the impacts of climate change and water scarcity, ultimately improving food security for their populations. More integrated national and regional strategies are also needed as the resulting pressures within the WEF nexus exacerbate social tensions and contribute to migration to cities. This, in turn, can strain urban infrastructure and services, creating a cycle of vulnerability and instability that can only be addressed through integrated responses.

Food security in Jordan is, as with the rest of the MENA region, a critical and pressing issue. Unfortunately, Jordan faces a range of further pressures in this area as it has a primarily arid climate with limited agricultural land, is resource-poor, and is experiencing increasingly frequent climate-related detrimental events. Jordan's economy has struggled and experienced high levels of unemployment and is struggling to stimulate growth and innovation. A further pressing matter is the large number of refugees Jordan is hosting, which places greater demands on water, electricity, and food supplies. Jordan is one of the most water-scarce countries in the world, which severely hampers its agricultural production. With only a tiny fraction of the land being arable and suitable for farming, the country heavily relies on food imports to meet the needs of its population. This dependence on imports makes Jordan highly vulnerable to global fluctuations in food prices and fertilizers, with frequent supply chain disruptions further complicating efforts to ensure consistent and affordable access to food for all its citizens.

To combat food insecurity, Jordan has implemented strategies such as promoting sustainable agriculture, improving water management, and seeking international assistance. A UNDP project is working at the community level by supporting entrepreneurial water security efforts involving the host communities and refugee populations. (UNDP, 2021). The main challenge to initiatives such as these is scaling them up nationally and ensuring the projects remain sustainable. These efforts face significant obstacles due to resource constraints nationally and regional instability. Long-term solutions depend on regional cooperation and international support to help Jordan overcome its structural challenges and ensure a stable and secure food supply for its population. The WEF nexus ensures that food security must be addressed and not marginalized when discussing water or energy matters.

Food security in Algeria is also problematic for many of the same reasons faced by Jordan and the MENA region. Despite having vast land resources, Algeria's agricultural sector faces numerous obstacles, including water scarcity, soil degradation, and limited arable land. The Sahara Desert covers most of the country, leaving only a tiny percentage suitable for farming. This geographical constraint, coupled with inconsistent rainfall and outdated farming techniques, hampers domestic food production, making it difficult for Algeria to achieve self-sufficiency in essential food staples. Also a significant refugee population in the western part of the country, which is one of the most protracted refugee crises in the world, require high levels of international support to meet food requirements (WFP, 2019). Plus, the country's heavy dependence on food imports to meet domestic demand further exacerbates its food security challenges with imports > half of its food needs, particularly wheat, a staple in the Algerian diet. This dependency makes Algeria vulnerable to global food price fluctuations and supply chain disruptions. The country's reliance on hydrocarbon exports to finance these imports also ties its food security to the volatile global energy market. Economic

downturns, like those caused by falling oil prices, directly impact the government's ability to subsidize food and maintain stable prices, leading to increased food insecurity among the population.
The initiatives launched to mitigate these issues to boost domestic agriculture, improve water management, and reduce import reliance. The government has invested in modernizing agriculture, expanding irrigated areas, and encouraging the cultivation of drought-resistant crops (WFP, 2024). However, these efforts face challenges such as bureaucratic inefficiencies, corruption, and the slow pace of reform. Addressing food security in Algeria requires a multi-faceted approach that includes agricultural improvements, economic diversification, better resource management, and enhanced social safety nets to protect vulnerable populations from food-related crises (UNESCWA, 2021). The WEF nexus perspective could facilitate integrated approaches that lead to more effective ways of providing energy and water on a sustainable basis, supporting food security. As a tangible example, if Algeria can develop its green hydrogen output, it will be able to produce greener fertilizers at a lower cost, benefitting farmers.

Way Forward for Managing the WEF Nexus

The polycrisis in the MENA region, driven by climate change, underscores the urgent need for integrated solutions that address the interdependencies across the WEF nexus. By adopting a holistic approach, the region can enhance its resilience and sustainability in the face of complex and interconnected challenges. Addressing multifaceted challenges requires robust regional and global cooperation and comprehensive strategies. Equally, extensive efforts are needed to achieve effective governance at the national and local levels. The nexus approach identifies the need for integrated working across government departments and ensures policy implementation, ideas, and impacts beyond the particular ministry. In the MENA region, national governments are very much centralized, which has the potential for effective governance across ministries. However, too often, it results in varying interests competing for limited resources. While it is not possible to deny, as Allouche et al. (2019) express, that "water, food, energy, and the environment somehow encapsulate some of the world's most pressing problems, and that governance is a key part of the problem as well as the solution," how to bring about effective governance to address the nexus, remains elusive.

Mitigation efforts, such as reducing greenhouse gas emissions and transitioning to clean, renewable energy sources, are essential to curb the impacts of climate change. Equally important are adaptation measures, including innovative water management strategies, climate-resilient agriculture, coastal protection, and ecosystem restoration. These actions are vital for enhancing resilience and minimizing the vulnerabilities of the MENA region. However, measures like this, on their own, are not impactful. There are trade-offs to be managed as attention to one element of the nexus has a knock-on effect on the others. Seeing how each part of the nexus relies upon and is impacted by the other parts is an essential step forward. It is necessary to institutionalize thinking about the WEF nexus across government structures at both the national and global levels so that actions consider the holistic nature of the problems being faced. Focusing attention on mitigation and adaptation also needs to ensure all stakeholders are involved in planning and implementation, in particular at the local level where the WEF nexus most clearly manifests itself.

The complex interplay of environmental, economic, and social factors in the MENA region has created a polycrisis that poses significant challenges to stability and meeting sustainability targets. The repercussions of water stress conditions, increased often polluting energy resources, and reduced agricultural output due to climate change highlight the urgent need for substantial investments in adaptation and mitigation measures. As some national budgets in the region are strained under these challenges, slow economic growth can lead to a vicious cycle of crisis and response, further destabilizing regional stability. However, in this area of transition, with the evolving landscape of WEF partnerships, a critical avenue emerges for addressing these interrelated challenges. Understanding these interlinkages is important to foster a more equitable and sustainable approach to WEF security, particularly as the pressures of climate change intensify.

The WEF nexus requires an integrated way of working across government ministries. In turn, there must be clear leadership to ensure government action is directed at addressing the WEF nexus and not about the siloed interests of a particular ministry. The high levels of cooperation and collaboration needed within governments are also critical to promote cooperation among MENA nations, strong support, which is pivotal in achieving these objectives. To this end, we outline five key strategies.
First, **leveraging opportunities and discussing benefits** is crucial. The WEF security-focused economy presents numerous

opportunities for the region to tackle the polycrisis while generating benefits for all stakeholders. Regional energy security and water management partnerships can be mutually beneficial, particularly for shared water systems. These collaborations must be managed carefully to ensure equitable resource distribution, mitigate environmental impacts, and protect vulnerable communities. Sustainable and just partnerships are essential for building resilience, and these principles should be central to any regional or sub-regional strategy.

Second, **social justice and community resilience** must be prioritized. Despite including WEF nexus considerations in regional strategy, there is a notable absence of binding mechanisms to ensure equitable outcomes. The risk of excluding local populations from decision-making processes concerning WEF security is significant. For instance, developing energy security through green hydrogen initiatives raises critical issues of dependency and fair benefit distribution. Addressing these concerns is vital for fostering community resilience and ensuring social justice.

Third, establishing **institutional structures and standards** focused on the WEF nexus is a positive development in many MENA countries. However, the region's polarization regarding resource exploitation underscores societal concerns about equity and sustainability. Transparent communication and stakeholder engagement are essential to navigate these complexities. The dynamics within selected countries highlight the need for inclusive and democratic processes to govern emerging WEF pathways effectively.

Fourth, integrating WEF issues into the **global governance agenda** is necessary. Despite existing bilateral and multilateral partnerships, the lack of a clear timeline for achieving sustainability goals presents challenges. Resource scarcity, exacerbated by climate change, increases competition and perpetuates inequalities, particularly as the Global North relies on imports from the Global South for energy and food security. Without clear national and regional guidelines, advancing the WEF agenda through transparent governance remains a formidable task.

Finally, addressing **uncertainties and fostering future dialogues** is crucial for the future of WEF security in the MENA region. The ongoing transition brings with it many uncertainties and resistance. Open dialogues, transparent decision-making, and clear sustainability standards are essential. While there is optimism about green hydrogen's potential, it is imperative to consider the social and environmental implications, especially as technology develops. Further, cooperation between states on innovative approaches may be limited with differing socio-economic and political systems. A collective approach that addresses uncertainties and promotes ongoing dialogue will be vital for navigating the complexities of WEF security and achieving a sustainable future.

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