Water-Energy-Food Nexus in Water Scarce Regions (A WEF Nexus Perspective from the Arab Region)

Khaled AbuZeid, PhD, PE, PMP

Introduction

The Arab region is among the most water-stressed areas in the world, with renewable water resources per capita averaging less than 500 cubic meters annually—well below the international water scarcity threshold. Simultaneously, the region's growing populations, rising food demands, expanding energy needs, and exposure to climate change amplify the pressures on already limited resources. Addressing these interconnected challenges requires a Water-Energy-Food Nexus (WEF Nexus) approach, which recognizes the interdependencies between sectors and advocates for integrated, cross-sectoral policy responses.

This paper presents policy recommendations for governments, private sector actors, and civil society stakeholders in the Arab region to operationalize the WEF Nexus, drawing on evidence from the regional context, including resource limitations, wastewater challenges, desalination dependence, energy transitions, and transboundary water disputes.

Safeguarding Non-Renewable Groundwater through Strategic Allocation

Non-renewable fossil groundwater currently sustains drinking water supply and agriculture in ten Arab countries, with extraction exceeding 100% of renewable water sustainability thresholds. Present policies often allocate high-quality fossil groundwater for agriculture, which consumes large volumes at low economic returns.

Policy Recommendations:

- Prioritize the strategic use of fossil groundwater for domestic and drinking purposes, where energy for treatment costs are lower (≈0.48 kWh/m^3) compared to future alternatives when needed such as desalination (2.58–8.85 kWh/m^3).
- Couple this with the systematic reuse of generated wastewater for agriculture, which requires comparatively modest energy inputs (1.0–2.5 kWh/m^3).
- Enforce groundwater abstraction regulations, including licensing and monitoring, to ensure sustainable withdrawals.

This policy shift extends the lifespan of fossil aquifers, secures safe water for human needs, and creates a reliable secondary source for agriculture through treated wastewater.

Scaling Up Wastewater Reuse and Energy Recovery

The region produces approximately 24 billion cubic meters of municipal and industrial wastewater annually, yet only about 61% is treated safely. Low levels of reuse reflect high energy costs for treatment and distribution, alongside weak regulatory and financial frameworks.

Policy Recommendations:
- Expand public-private partnerships (PPP) for wastewater treatment and reuse projects, providing incentives such as tax exemptions, guaranteed off-take agreements, and low-interest financing.
- Invest in biogas recovery during wastewater treatment to offset operational energy costs and create circular economy opportunities.
- Establish national water reuse standards and guidelines that harmonize quality requirements for agricultural, industrial, and landscape irrigation uses.

By integrating wastewater into the resource portfolio, Arab countries can simultaneously enhance water availability, reduce pollution, and generate renewable energy.

Optimizing Desalination within the Energy-Water Nexus

The Arab region hosts over 60% of the world's desalination capacity, producing more than 7 BCM/year. While desalination provides critical water security, it is highly energy-intensive, creating dependencies on fossil fuels and increasing carbon footprints.

Policy Recommendations:
- Gradually transition desalination plants to run on renewable energy sources, especially solar and wind, reducing water-energy trade-offs.
- Develop regional centers of excellence to improve brine management technologies, minimizing ecological damage to coastal ecosystems.
- Incorporate desalination expansion into nationally determined contributions (NDCs) to align with climate goals and attract climate finance.

Desalination should remain a key water security instrument but requires technological innovation, renewable integration, and governance reforms to reduce long-term costs and impacts.

Mainstreaming Energy-Efficient Water for Food Policies

Agriculture consumes more than 80% of the region's freshwater, while irrigation modernization often prioritizes water savings without accounting for higher energy inputs. Policies that increase irrigation efficiency through pressurized systems may inadvertently raise energy consumption, undermining sustainability.

Policy Recommendations:
- Adopt a dual-efficiency framework—evaluating irrigation policies based on both water savings and energy intensity.
- Promote reuse of agricultural drainage water and surface water pumping (≈0.37 kWh/m^3) as cheaper energy alternatives to groundwater pumping (≈0.48 kWh/m^3).
- Support solar-powered irrigation to reduce fossil fuel dependency in rural agriculture while putting the right regulations in place to avoid over abstraction of groundwater.
- Encourage the introduction of virtual water trade policies, strategically importing water-intensive crops while focusing domestic production on higher-value, less water-intensive commodities.

A WEF Nexus perspective ensures that agricultural modernization contributes to food security without undermining energy and water security.

Integrating Renewable Energy into Water Systems

Energy transitions in the Arab region can unlock co-benefits for water and food security. Solar panels on reservoirs and canals, in-stream turbines, and mini-hydropower installations on drainage outfalls exemplify low-impact synergies.

Policy Recommendations:
- Support solar floating PV projects on reservoirs to reduce evaporation losses while generating renewable energy.
- Encourage civil society and private sector investment in small-scale renewable projects linked to wastewater, cooling water, or irrigation outfalls.
- Develop supportive regulatory frameworks for distributed energy generation that reduces water intensity compared to fossil fuel extraction and refining.

Such policies enhance resilience by reducing water consumption in the energy sector and lowering greenhouse gas emissions.

Accounting for Water in Green Hydrogen Strategies

Emerging hydrogen strategies in the region focus on energy transition but often overlook water requirements which is especially important in freshwater scarce countries. Producing 67 liters of liquified green hydrogen requires one cubic meter of freshwater, and desalination for this purpose can consume up to 3 kWh/m^3. The net energy return is

currently negative when accounting for desalinated water input to produce electricity from green hydrogen as 67 liters of green hydrogen would produce only 0.134 kWh.

Policy Recommendations:
- Make water requirement assessments mandatory in all national hydrogen strategies.
- Explore hybrid models that integrate renewable desalination, wastewater reuse, and brine valorization for hydrogen production.
- Caution private investors and governments against large-scale hydrogen expansion without resolving the water-energy trade-off.

The following applications ensures that hydrogen ambitions may not inadvertently worsen freshwater scarcity concerns associated with desalination needs:

Green hydrogen may be useful in high-temperature industrial processes, where direct electrification is impractical—such as steel, cement, and ammonia production.

Aviation and maritime transport using green hydrogen, provides high energy density without the weight penalties of batteries.

Cross-border energy trade in green hydrogen enables export of renewable energy without extending grid infrastructure or suffering transmission losses.

Long-duration and seasonal storage of green hydrogen stores surplus renewable power over weeks or months, unlike batteries with shorter cycles.

Remote and off-grid regions can use green hydrogen which offers mobile and flexible energy delivery where grid access is limited or expensive.

Fertilizer and chemical synthesis can use green hydrogen to replaces grey hydrogen in producing urea, methanol, and other key agricultural inputs.

Addressing Transboundary Water-Energy-Food Nexus

Sixty percent of renewable surface water in the Arab region originates outside national borders, making cooperation critical. The case of the Grand Ethiopian Renaissance Dam (GERD) illustrates how unilateral upstream hydropower development can undermine downstream food and energy security.

Policy Recommendations:
- Strengthen regional governance mechanisms under frameworks such as the Arab Water Council and All-Inclusive River Basin Organizations to manage transboundary trade-offs.
- Institutionalize civil society participation in transboundary negotiations to ensure accountability and local perspectives.
- Develop basin-wide agreements that balance upstream energy security with downstream water and food security.

A cooperative transboundary Nexus framework can transform potential conflicts into opportunities for joint investments and benefit-sharing.

Leveraging Strategic Virtual Water Trade for Food Security

The Arab region imported 329 BCM of virtual water through food trade in 2019, underscoring dependence on global markets. While food self-sufficiency is politically attractive, it is not always feasible or sustainable for most water scarce countries.

Policy Recommendations:
- Institutionalize virtual water accounting in national agricultural and trade policies to guide crop choices and import strategies.
- Promote regional trade integration to diversify sources of food imports and reduce exposure to global market shocks.
- Invest in strategic food reserves to buffer against disruptions in international trade.

Well-assessed virtual water trade should be recognized as a legitimate and strategic tool for food security rather than viewed as a vulnerability.

Conclusion

The Arab region's water, energy, and food insecurities are deeply intertwined. Pursuing siloed sectoral policies leads to short-term gains but long-term vulnerabilities. The WEF Nexus approach offers governments and stakeholders a framework to optimize resource use, reduce trade-offs, and build resilience, albeit when formulating energy transition policies.

Key recommendations include:
- Safeguarding fossil groundwater for drinking purposes and maximizing wastewater reuse;
- Expanding desalination sustainably with renewable energy;
- Pursuing dual water-energy efficiency in agriculture;
- Embedding water considerations into energy transitions, including hydrogen strategies;
- Enhancing transboundary WEF Nexus cooperation; and
- Embracing virtual water trade as a strategic tool.

Operationalizing these policies requires not only government action but also private sector innovation and civil society engagement. Water Scarce regions should benefit from the Arab region experience whose future depends on integrating water, energy, and food security planning under a shared, cross-sectoral vision that ensures resilience against climate change, population growth, and geopolitical risks.