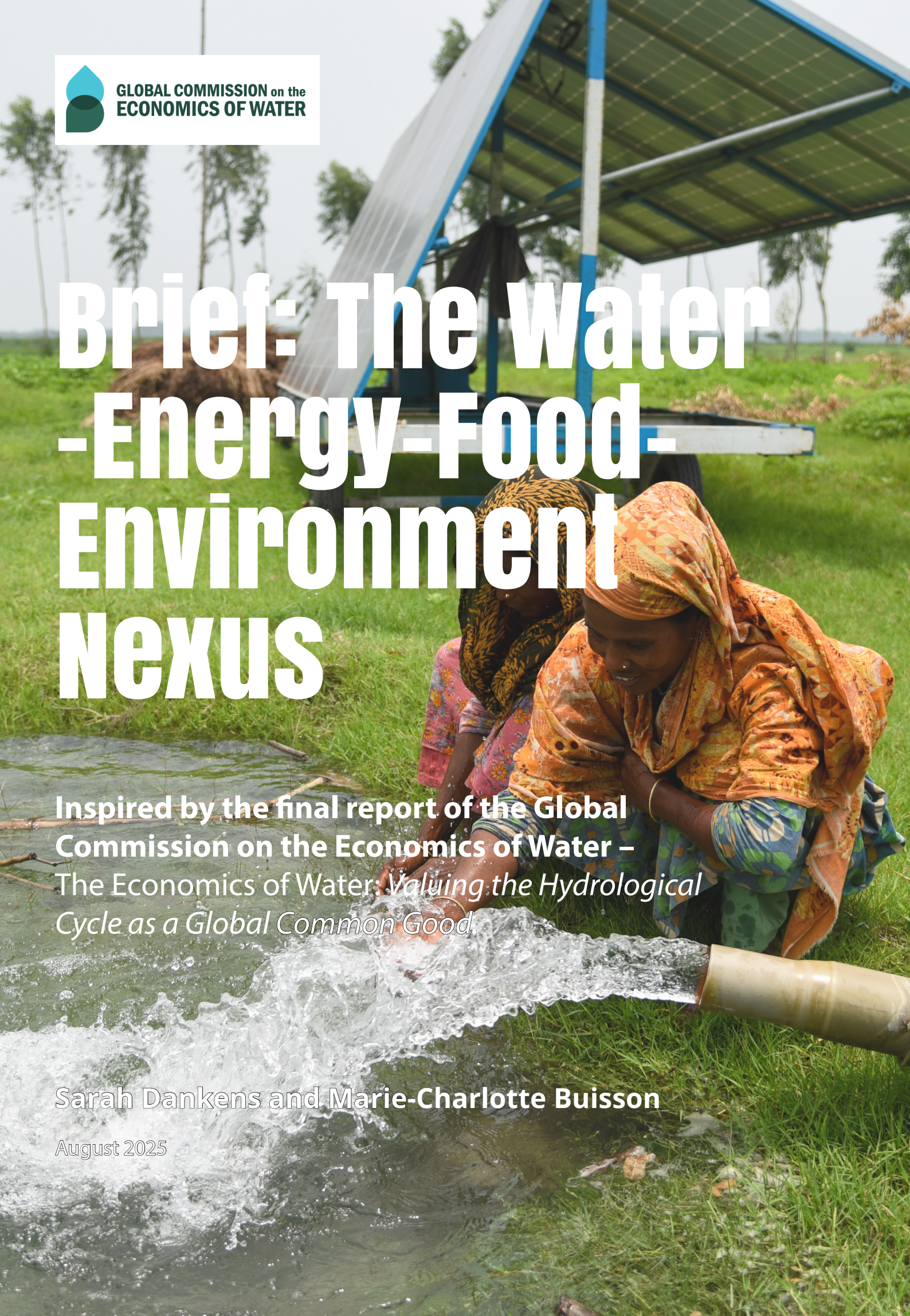

GLOBAL COMMISSION on the ECONOMICS OF WATER

Brief: The Water-Energy-Food-Environment Nexus

Inspired by the final report of the Global Commission on the Economics of Water – The Economics of Water: *Valuing the Hydrological Cycle as a Global Common Good*

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The Global Commission's report sets out the shifts required to drive radical changes in how water is valued, managed, and used. The new economics of water begins by recognizing that the water cycle must now be governed as a global common good, that can only be fixed collectively, through concerted action in every country, collaboration across boundaries and cultures, and for benefits that will be felt everywhere.

This policy brief explores the Water-Energy-Food-Environment (WEFE) nexus, emphasizing water's foundational role -- particularly green water, as highlighted by the Global Commission. It identifies key challenges to adopting a nexus approach and outlines pathways toward more systematic and integrated implementation of water, energy, food, and environment considerations across policy, governance, and investment decisions.

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Key messages

Water, energy, food, and environment are deeply interconnected and essential to sustainable development and human well-being. However, growing pressures on natural resources, such as accelerating water depletion and soil moisture loss, rising food insecurity, energy disruptions, and environmental degradation, are threatening progress towards the Sustainable Development Goals.

The Water-Energy-Food-Environment (WEFE) nexus provides an integrated, systematic approach to managing the interconnections between these systems. A nexus approach is a tool that supports multi-sector collaboration while reducing tradeoffs and conflicts, thereby helping to address cross-cutting issues such as food security, climate change, and hydrological imbalances.

The principal challenges to the WEFE nexus approach lie in the siloed responses of governments and investors, as well as perverse economic incentives. Both promote single-sector solutions without considering negative ripple effects in other sectors that harm resilience and resource sustainability.

Implementing the WEFE nexus effectively requires moving beyond siloed approaches and adopting a systems approach, recognizing the interdependence of water, energy, food, and environments. This approach must integrate governance, policy, and investment priorities, while ensuring that efforts to implement the nexus are inclusive and equitable, such that environmental goals align with social and economic development.

Context: Water, energy, food, and environment face intertwined crises

Water, energy, food, and the environment are deeply interconnected and essential for economic development, environmental sustainability, and human well-being.

Energy is required to manage water resources and to support the growth, processing, and distribution of food. At the same time, the environment regulates the water cycles and energy stores necessary for agricultural production. Water – both blue water, the "visible" water extractable from rivers, lakes, and aquifers, and green water, the moisture stored in soils and vegetation – underpins energy production, food security, and healthy environments. Without water, these interconnected systems cannot function.

Disruptions to one system, whether to water, energy, food, or the environment, can have rebound effects across the others. For instance, decreased precipitation and overextraction of water will harm both crop yields and power generation, while energy shortages can disrupt water supply systems and food processing chains. With that, environmental degradation, due to extractive production and land use change, for example, can weaken the very ecosystems that sustain the water, energy, and food production.

The Water-Energy-Food-Environment (WEFE) nexus approach has emerged as an integrated framework that recognizes and optimizes the interdependencies between water, energy, food, and the environment. Utilized as a tool, it encourages cross-sectoral synergies, so that policymakers and other decision-makers may effectively address significant global challenges, such as food security, climate change, and resource scarcity, without creating conflicting outcomes [1, 2].

The Global Commission on the Economics of Water's recommendations – which include transforming food systems, conserving and restoring natural ecosystems, and promoting a circular water economy – acknowledge the interdependence of the WEFE dimensions and recognize blue and green water as foundational pillars for advancing a resilient WEFE approach.

Key challenges and implications

Challenges

Despite advances in technical understanding of nexus interactions, policy, governance, and investment considerations often omit nexus thinking. The section below explores key barriers to implementing the WEFE nexus approach.

a. Weak collective governance undermines the nexus approach:

While the interdependence of the water, energy, and food sectors is widely recognized, actions on the ground remain fragmented. Government and investor responses to these challenges are often siloed, favoring single-issue solutions over an integrated nexus approach, which frequently fail to account for the ripple effects on other sectors.

Regarding investments, current funding, budgeting, and investment models are usually structured around individual sectors, making it challenging to finance integrated solutions that deliver multi-sectoral returns. Financial frameworks not only fail to incentivize cross-sector collaboration, but the resources available for nexus approaches are rarely shared. As a result, nexus-aligned interventions that generate co-benefits across sectors often receive funding from only the primary sector or investor, limiting their broader impact.

Similarly, policy frameworks tend to focus on individual sectors at national or regional levels while neglecting local realities – this is especially true concerning managing shared or transboundary resources. This sectoral approach often leads to conflicting priorities, such as when a government allocates water for hydropower without considering the needs of downstream irrigation or expands renewable energy infrastructure without assessing the strain on municipal water systems [3].

The concurrent groundwater and food security crises in Iran offer a compelling case study illustrating the collective action failures that result from siloed approaches. In an effort to enhance national food security and self-sufficiency following the Iranian Revolution, the government implemented energy subsidies for irrigation, high tariffs on grain imports, and price guarantees on wheat. While these measures successfully boosted food production, they led to widespread overextraction of groundwater, including from over 800,000 unlicensed wells. Political reluctance to enforce water limits, coupled with increased production of water-intensive crop choices due to the price inelasticity of water demand, further entrenched unsustainable practices [2]. Today, the country's food production is dependent on the overextraction of groundwater.

The Iran case highlights the risks of siloed policymaking: misalignments across sectors produce tradeoffs instead of co-benefits, thereby sidelining environmental considerations, in this case, water resources, and undermining long-term resilience across all WEFE systems. As a result, broader goals that connect multiple sectors – such as healthy diets, climate-resilient livelihoods, or the protection of vital ecosystem services – remain unrealized. This lack of collective governance and investment efforts is a global issue. Across both high- and low-income countries, sector-specific policies and investments continue to dominate, creating barriers to collaboration and integrated resource management.

b. Perverse economic incentives contribute to WEFE nexus failures:

Subsidies in food, energy, and water remain a major source of misalignment in the WEFE nexus, as they frequently create counterproductive economic incentives. Although subsidies are usually designed to make food, fuel, or water more accessible, they can lead to unintended consequences regarding resource use, such as encouraging water-intensive crop production, land conversion, or promoting inefficient energy or water use. Rather than supporting integrated, resource-efficient solutions, these financial incentives perpetuate overuse and pollution, encourage unsustainable practices, disrupt green water flows, and further complicate efforts to implement a cohesive nexus strategy.

India, for example, has emerged as a prime example of how perverse energy subsidies have contributed to groundwater depletion and overall failure of the WEFE nexus. Starting in the 1960s, electricity subsidies enabled pro-poor irrigation and food security. However, over time, these policies – coupled with guaranteed crop procurement and fertilizer subsidies for water-intensive crops such as wheat and rice – reinforced water- and energy-intensive practices, ultimately driving many electricity utilities to bankruptcy. Since then, efforts to reform through direct regulation or subsidy rationalization have stalled, mainly due to political resistance and bureaucratic inertia. Instead, most states have pursued indirect strategies focused on limiting fiscal losses and safeguarding water access during droughts, without addressing the deeper structural misalignments across the WEFE nexus [2].

Alternatively, in the Czech Republic, the government subsidized the afforestation of unproductive and unprofitable agricultural land. A 2021 study demonstrated that this intervention led to improved soil water retention and lower surface temperatures compared to when the land was used for agriculture, illustrating how economic incentives can support soil health and green water management with minimal trade-offs in food production [4].

c. Institutional and technical gaps hinder operationalization of the WEFE nexus:

Effectively operationalizing the WEFE nexus requires translating the integrated concept into actionable policies, investment decisions, and governance practices. This is inherently complex due to the interdependence and competing demands of the sectors involved. To date, data gaps, differing policy priorities, and limited stakeholder coordination hinder integrated planning. Power imbalances among actors, especially in transboundary contexts, can intensify trade-offs and coordination challenges, while both local and national institutions often lack the capacity or political will to assess interlinkages or apply nexus tools effectively. The absence of reliable and harmonized cross-sectoral data results in siloed measurement tools, making the holistic implementation of the WEFE nexus challenging.

d. Green water is insufficiently valued in WEFE policy and planning frameworks:

Green water is fundamental to the resilience of land-based ecosystems and underpins the energy demands and water productivity of the agriculture sector. Green water is the primary source of moisture for rainfed agriculture, which accounts for over 60% of the world's food production [5]. Managing green water effectively strengthens synergies across the nexus by enhancing food security, lowering energy needs, sustaining ecosystems, and improving overall water availability.

However, green water management is often undervalued and overlooked, while reliance on and overextraction of blue water increases – for instance, through irrigation for agricultural production – resulting in exacerbating the negative environmental and resource pressures associated with blue water use. Green water is neither extracted, priced, nor stored through traditional infrastructure. Despite its critical importance, the result is that green water is largely absent in most water allocation policies, investment plans, and regulatory frameworks. Consequently, efforts to adopt a WEFE nexus approach often fall short, missing both the essential role of green water and the multiple benefits that its effective management can provide.

Risks of inaction and call to action

The pressures across the WEFE nexus framework are intensifying. Climate change is exacerbating droughts, floods, and extreme weather events, disrupting crop production and straining water and energy systems. Rapid population growth and urbanization are driving up demand for food, water, and electricity, while global dietary shifts toward meat and processed foods are increasing pressure on land and freshwater resources. With that, food and energy production are highly water-intensive: Agriculture is the largest consumer of global freshwater resources and accounts for approximately one-quarter of all energy used globally [6]. In transboundary river basins, competing national interests over shared water bodies are heightening tensions and threatening long-term cooperation and sustainability.

The consequences of failing to take collective, integrated action across the WEFE nexus are no longer hypothetical: they are unfolding in real time, with severe impacts. Fragmented responses and siloed decision-making not only exacerbate these challenges but also undermine global commitments to the Sustainable Development Goals (SDGs), including zero hunger, access to clean water, affordable energy, and climate action. Millions of people still face hunger, poverty, and limited access to essential services, all of which are clear signs that current systems are falling short of delivering on global goals.

More specifically, the fallout from these nexus failures disproportionately affects vulnerable populations, including women, low-income communities, and smallholder farmers, who are most directly reliant on natural resources for their livelihoods. When siloed approaches and uncoordinated investment and governance strategies exacerbate the intertwined crises of the WEFE nexus, these groups are hit hardest by water shortages, food insecurity, and unreliable energy access, thereby deepening social and economic inequalities.

Recommendations and pathways for action

The WEFE nexus framework presents a powerful alternative to fragmented and siloed strategies. By treating water, energy, food, and the environment as one unified system, the nexus makes it possible to develop solutions that reduce risks, minimize tradeoffs, and strengthen resilience and equity for both people and the planet.

Effectively optimizing the WEFE nexus approach begins with **acknowledging the intricate links between water flows, environment, energy, and food production** – and recognizing the resilience of the global hydrological cycle as a global common good since it underpins each of the activities in the nexus. Doing so requires a shift toward a new model of water economics which places equal weight on environmental sustainability, social equity, and economic efficiency – commonly referred to as the "3Es." Although often seen as competing priorities, these goals must now be advanced together, through measures such as appropriate water pricing, setting absolute resource limits, and promoting sustainable food and land management.

To fully capture water's value within the WEFE nexus, **it is essential to incorporate green water dynamics into planning and decision-making frameworks**. Strengthening the management of green water can significantly boost the overall impact of the nexus approach. By improving water use efficiency, lowering the energy intensity of agriculture, and supporting ecosystem health, it ultimately contributes to greater food security.

Tackling the challenges that underpin the WEFE nexus demands a fundamental rethinking of existing approaches to policymaking and investment. It is no longer sustainable to manage these dimensions in silos. Instead, it is necessary to not only recognize but also integrate into decision-making processes the interconnected services these systems provide.

In light of these considerations, **integrated, cross-sectoral action across governance structures, policy agendas, and investment portfolios is essential** (Box 1). Adopting a systems approach requires that policy and investment decisions are made collaboratively and designed to integrate water, energy, food, and environmental considerations across all levels of governance, including transboundary, national, regional, and local systems. Doing so necessitates capacity building, system-wide transformation in institutional and governance structures, and the establishment of a framework for cross-sectoral coordination and dialogue. As part of these efforts, green water considerations must be systematically integrated in nexus tools and paired with spatially tailored strategies that promote soil moisture retention and enhance long-term ecological resilience.

At the core of this approach is a **focus on the people and communities that steward the WEFE nexus systems.** Development must be grounded in the needs and knowledge of local communities, especially those who are most vulnerable, such as women, smallholder farmers, and marginalized groups. **Policies and investments should prioritize inclusive participation to** ensure that the benefits of WEFE interventions are just and equitable. In this way, efforts to build environmental resilience must therefore be pursued alongside, not at the expense of, inclusive socio-economic development [3].

Perhaps most importantly, the ambition should go beyond simply balancing competing demands on resources and should **move toward solutions that generate co-benefits**, such as enhancing food security, environmental preservation, and clean energy generation. Integrating the WEFE nexus into policies and investments can support sustainable development while safeguarding natural resources and promoting equitable access to them.

Box 1: Policy approaches to the WEFE nexus

Multistakeholder Platforms in Pakistan: In Pakistan, the CGIAR initiative on NEXUS Gains developed a multistakeholder platform to address key challenges in groundwater governance. By uniting a range of stakeholders, including farmers, civil society, academia, the private sector, and government representatives, the initiative facilitated meaningful collaboration and dialogue on local groundwater management. This approach strengthened and ensured greater alignment between grassroots efforts and provincial policies, while enhancing accountability across sectors that typically operated in silos [7].

Multi-sectoral institutional reform in Sri Lanka: In Sri Lanka's Mahaweli River Basin, which supports over 40% of the country's agriculture and over 50% of its hydropower – policies regarding energy, agriculture, water, and the environment were fragmented, resulting in resource conflicts and poor climate resilience. The Mahaweli Authority of Sri Lanka (MASL) helped shift the region to a coordinated, cohesive approach to advance WEFE nexus outcomes. The approach fostered inter-agency coordination, shared data tools, and stakeholder engagement to balance the needs of agriculture, energy, water, and the environment. Key reforms, such as joint planning, environmental flow rules, and synchronized hydropower and irrigation schedules, reduced resource conflicts, improved climate resilience and crop productivity, and enhanced basin-level governance.

Enablers for action

The section below outlines enablers for driving action around the WEFE nexus:

a. **Financing for the Nexus Transition:** Accelerating the shift toward integrated WEFE systems requires mobilizing innovative financing (Box 2). Governments and public institutions can drive investment by deploying blended finance strategies, which share risks and rewards among sectors and industries, including the public sector, private companies, and philanthropic actors, to enhance the viability and equity of projects.

   Upfront investments in capacity building, technology, and infrastructure will be necessary to implement nexus approaches. For this reason, financial risk mitigation tools, such as innovative insurance products, cost-sharing schemes, and multi-sector partnerships, can help farmers, utilities, and energy producers manage risks as they transition to more integrated methods. Additionally, economic incentives such as Payments for Ecosystem Services (PES) can encourage preserving ecosystem functions and valuing the natural capital across the nexus.

Box 2: Financial innovations to implement the nexus:

Nexus assessments for investment portfolios in South Africa: In Southern Africa, the Southern African Development Community (SADC) piloted financial innovations that integrate water, energy, and food goals. By running nexus portfolio assessments to identify multi-benefit projects, including solar irrigation, wastewater reuse, and sustainable forestry, in shared basins such as the Incomati-Maputo and Orange-Senqu, the SADC promoted cross-sectoral investments that enhance regional resource security, climate resilience, and sustainable development [8].

Solar pump subsidy schemes in Rajasthan, India: In response to persistent groundwater depletion, inefficient electricity subsidies, and inconsistent irrigation access, the Government of Rajasthan launched a solar pump subsidy scheme to promote sustainable water and energy use in agriculture. The scheme reduced groundwater overuse by linking irrigation to solar power availability, while promoting renewable energy and enhancing food production through more reliable irrigation. By replacing electricity subsidies with capital support for solar infrastructure and enabling farmers to sell excess energy, the scheme encouraged more efficient irrigation, reduced dependency on grid electricity, and enhanced crop productivity through reliable irrigation. Collaboration across water, energy, and agriculture departments ensured the alignment of sustainability goals, thereby achieving multiple ecosystem co-benefits, including reduced emissions, water conservation, greater food security, and improved farm resilience and income [10].

b. **Harnessing Data Across the WEFE Nexus:** Effective management of the WEFE nexus requires robust, transparent, and integrated data spanning water – both blue and green – energy, and food systems. A lack of evidence and existing data gaps, including siloed reporting on energy and agriculture, reinforce divisions among sectors and scales, thereby weakening decision-making and strategic planning [3]. Developing a unified nexus data infrastructure, with cross-sector, systems-level indicators (e.g., water and energy footprints, resource productivity, ecosystem health) should empower stakeholders across sectors to understand the full impacts of resource use in their decision-making efforts.

   An example of an initiative to harness data is the WEFE Nexus Index, developed by Simpson et al. in 2022 [9]. Adapted for use in 181 countries, the index utilizes open-source data to map 21 indicators against water, energy, and food pillars. While this index has limitations – for instance, it fails to capture political and social considerations – it represents an initial step toward collating data and facilitating dialogue around the WEFE nexus.

   Beyond data collection, key applications of nexus data infrastructure could include tradeoff analyses and foresight methodologies. Tradeoff analyses help identify unintended consequences of actions in one sector against their impacts on others and prioritize policies or investments that maximize joint benefits, which involves foresight methodologies such as scenario planning or predictive modeling to forecast resource demands and test policies or infrastructure plans under future uncertainty. Governments should also strengthen data collection at all levels and ensure interoperability with international frameworks, while simultaneously accounting for local and Indigenous knowledge.

c. **Effective Governance and Partnerships:** Strong governance and inclusive partnerships are vital for a sustainable WEFE nexus. Collaborative governance across local, national, and transboundary scales ensures resource use, policy, and planning are synergistic and just. At regional and global levels, governance frameworks should promote policy alignment, facilitate transboundary collaboration, and enable mutual accountability across regions and nations.

   Inclusive approaches must prioritize the voices and agency of traditionally marginalized groups, such as youth, women, indigenous peoples, and smallholder farmers, who are principal stewards of water, energy, and food systems.

   Just Water Partnerships (JWPs) exemplify inclusive governance in addressing financial barriers. They consist of multistakeholder coalitions that promote equitable and sustainable water management, which accounts for water, energy, food, and ecosystem interdependencies. These partnerships go beyond technical activities to tackle system-level challenges such as economic development, social justice, and climate resilience. Developing inclusive engagement models, such as JWPs, will be crucial to mitigate silos and ensure the WEFE nexus produces its intended outcomes.

d. **Agile Methods and Adaptive Management:** Perhaps most importantly, shifting toward a practical WEFE nexus approach requires agility and adaptive management. Resilience is rooted in the ability to adapt; what works at one moment in time or geography may not remain effective as landscape dynamics, political contexts, and economic conditions evolve. For this reason, programs, policies, and investment frameworks related to the WEFE nexus must be designed to be iterative, enabling continuous learning and adjustment to remain effective over time.

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Photo: Kafue George Dam (credit: Marie-Charlotte Buisson)

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Front cover photograph: Women farmers draw groundwater using a portable micro Solar Irrigation Pump (SIP) installed by the Rural Development Academy in Kayumer Char, Fulchhari Upazila, Gaibandha District, Bangladesh (photo: Tanmoy Bhaduri).

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