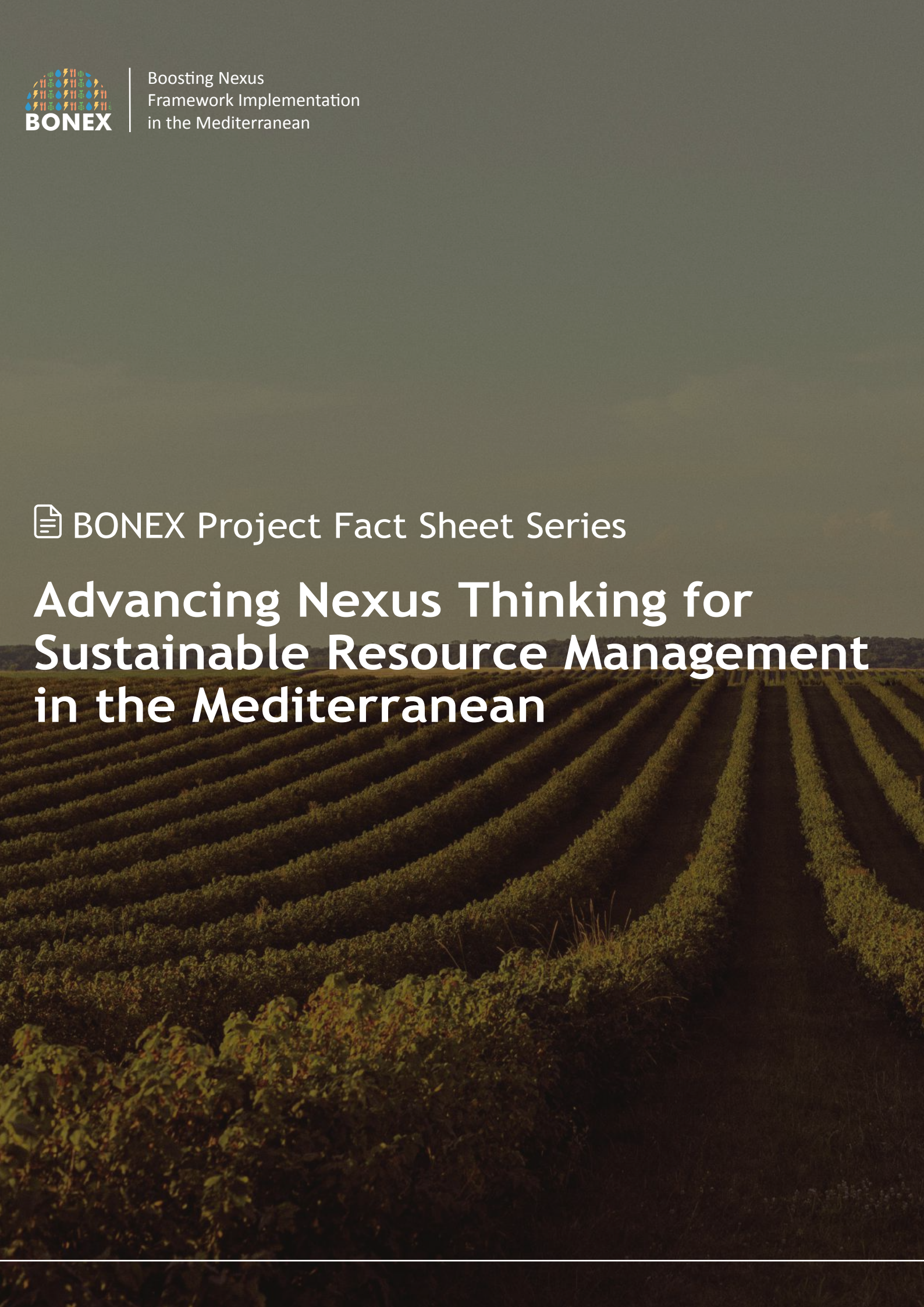
BONEX

Boosting Nexus
Framework Implementation
in the Mediterranean

BONEX Project Fact Sheet Series

Advancing Nexus Thinking for Sustainable Resource Management in the Mediterranean



BONEX
Boosting Nexus Framework Implementation in the Mediterranean

About BONEX

BONEX (Bridging the Water-Energy-Food-Ecosystem Nexus through Nature-Based Solutions) is a PRIMA-funded project working to operationalize the WEFE Nexus in the Mediterranean through real-world demonstration, stakeholder engagement, and policy integration. The project focuses on co-developing and testing sustainable, inclusive, and scalable solutions to manage natural resources in an integrated way.

BONEX works across seven demonstration sites—each representing different socio-environmental challenges and institutional settings—to identify how the Nexus approach can strengthen local planning, build resilience, and foster innovation in water, energy, food, and ecosystem management.

About the Fact Sheet Series

This series of fact sheets presents key tools, outcomes, and lessons from the BONEX project in a practical, accessible format for decision-makers, planners, researchers, and stakeholders. Each sheet highlights a different element of the BONEX approach—ranging from site-specific Demonstration Pilots to cross-cutting methodologies and tools—to support replication and scaling of the WEFE Nexus approach in other Mediterranean regions and beyond.

Fact Sheets Index

PRIMA
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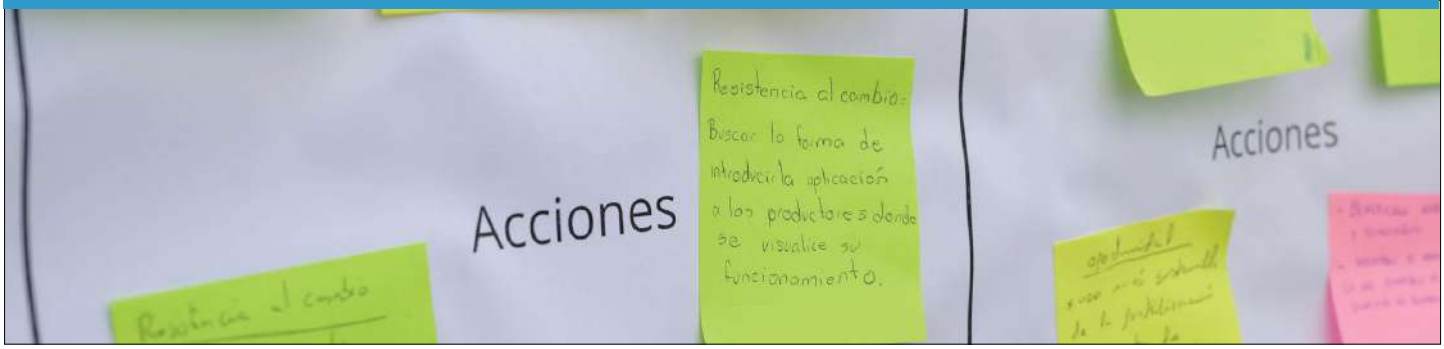
FACTSHEET | WEFe Bridging Framework



Purpose

The WEFE Nexus Bridging Framework (WEFEF) is a comprehensive set of methods and tools designed to overcome fragmentation in policy and practice across the Water-Energy-Food-Ecosystems (WEFE) sectors. It addresses the limitations of siloed decision-making, which often leads to inefficient resource use and missed opportunities for synergies. By promoting cross-sectoral integration, the framework supports the co-development of Nexus Bridging Plans (NBPs) that align systemic interdependencies with local priorities and needs.

How NBPs Support Natural Resources Management

Nexus Bridging Plans (NBPs) are practical, context-sensitive planning instruments that help territories manage natural resources more effectively. They enable:

- **Holistic diagnosis of WEFE challenges:** Identify interdependencies, trade-offs, synergies, and mismatches across water, energy, food, and ecosystems.
- **Inclusive stakeholder engagement:** Facilitate multi-actor dialogue to reflect diverse perspectives and co-create legitimate, locally grounded solutions.
- **Identification and assessment of interventions:** Explore technical, organizational, and governance options while evaluating their potential impacts from a WEFE Nexus perspective.
- **Evidence-based decision-making:** Provide structured, comparative insights to prioritize actions, understand risks, and determine enabling conditions.
- **Design of implementation pathways:** Translate analysis into actionable roadmaps—defining concrete steps, roles, resources, and alliances for effective execution.
- **Bridging strategy and action:** Connect high-level sustainability goals with real-world interventions, fostering operational coherence across sectors.

Overview of the Methodology

Developed under the BONEX project, the WEFE Bridging Framework 2.0 is rooted in co-creation, participatory processes, and systems thinking. It guides stakeholders through a step-by-step, iterative process to develop integrated solutions adapted to each territorial context.

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The framework is organized into five key phases:

Initiation
Define the system boundaries and focal area, identify relevant stakeholders, and (optionally) assess ecosystem-related non-monetary values.

Diagnosis
Map the socio-economic, ecological, and governance context. Use participatory system mapping to uncover feedback loops, trade-offs, and mismatches in the WEFE system.

Intervention Identification
Co-develop potential solutions with stakeholders—technical, organizational, or governance-related—using local knowledge and expert input.

Intervention Assessment
Evaluate the expected impacts, risks, and enabling conditions of proposed interventions, including effects on ecosystem services and cross-sector synergies.

Implementation Pathway
Design a Nexus Bridging Plan (NBP): a clear roadmap detailing actions, responsibilities, resources, and alliances, aligned with existing strategies where possible.

Application in BONEX

In the BONEX project, the WEFE Bridging Framework 2.0 was applied to co-develop seven Nexus Bridging Plans across diverse Mediterranean territories. Its implementation enabled:

- **Comprehensive analysis of all WEFE dimensions:** Structured methods guided stakeholders to consider synergies and trade-offs, ensuring ecosystems—often neglected—were fully integrated into planning.
- **Engagement of over 250 stakeholders:** A multi-actor approach brought together farmers, public authorities, NGOs, civil society, citizens, and researchers to co-create context-relevant solutions.
- **Participatory diagnosis and systems mapping:** Localised analyses provided a shared understanding of Nexus challenges and informed the identification of suitable interventions.
- **Assessment of BONEX technologies:** Solutions such as water reuse, agrivoltaics, solar irrigation, Nature Based Solutions and digital tools were evaluated through the framework to determine feasibility, risks, and implementation strategies.
- **Capacity building for integrated governance:** The process enhanced skills in systems thinking, transdisciplinary planning, and collaborative decision-making, reinforcing local capacities for long-term resource management.

Added Value and Transferability

Nexus Bridging Plans (NBPs) offer a practical means to implement integrated resource management, turning the often abstract Nexus concept into actionable strategies. They help shift from fragmented planning toward coordinated, cross-sector governance by:

- **Revealing interdependencies and trade-offs** across water, energy, food, and ecosystems—making visible the synergies and conflicts often overlooked in siloed policies.
- **Supporting structured, inclusive decision-making** through a clear set of tools that guide stakeholders from system diagnosis to implementation planning.
- **Ensuring broad stakeholder representation**, including farmers, utilities, regulators, civil society, and others whose perspectives are essential yet often disconnected in conventional planning.
- **Informing the selection and deployment of technologies** (e.g. water reuse, agrivoltaics, solar irrigation) by assessing their relevance and impact in a systemic, cross-sector context.

The **transferability** of the WEFE Bridging Framework lies in its adaptability. Rather than imposing a fixed model, it provides a flexible methodology that can be tailored to diverse institutional settings, socio-environmental conditions, and governance capacities.

With appropriate **capacity-building efforts**, the framework can be applied to other regions facing Nexus-related pressures—serving as a tool for **policy design, investment planning**, and the development of **cross-sector partnerships** to support integrated, sustainable resource management.

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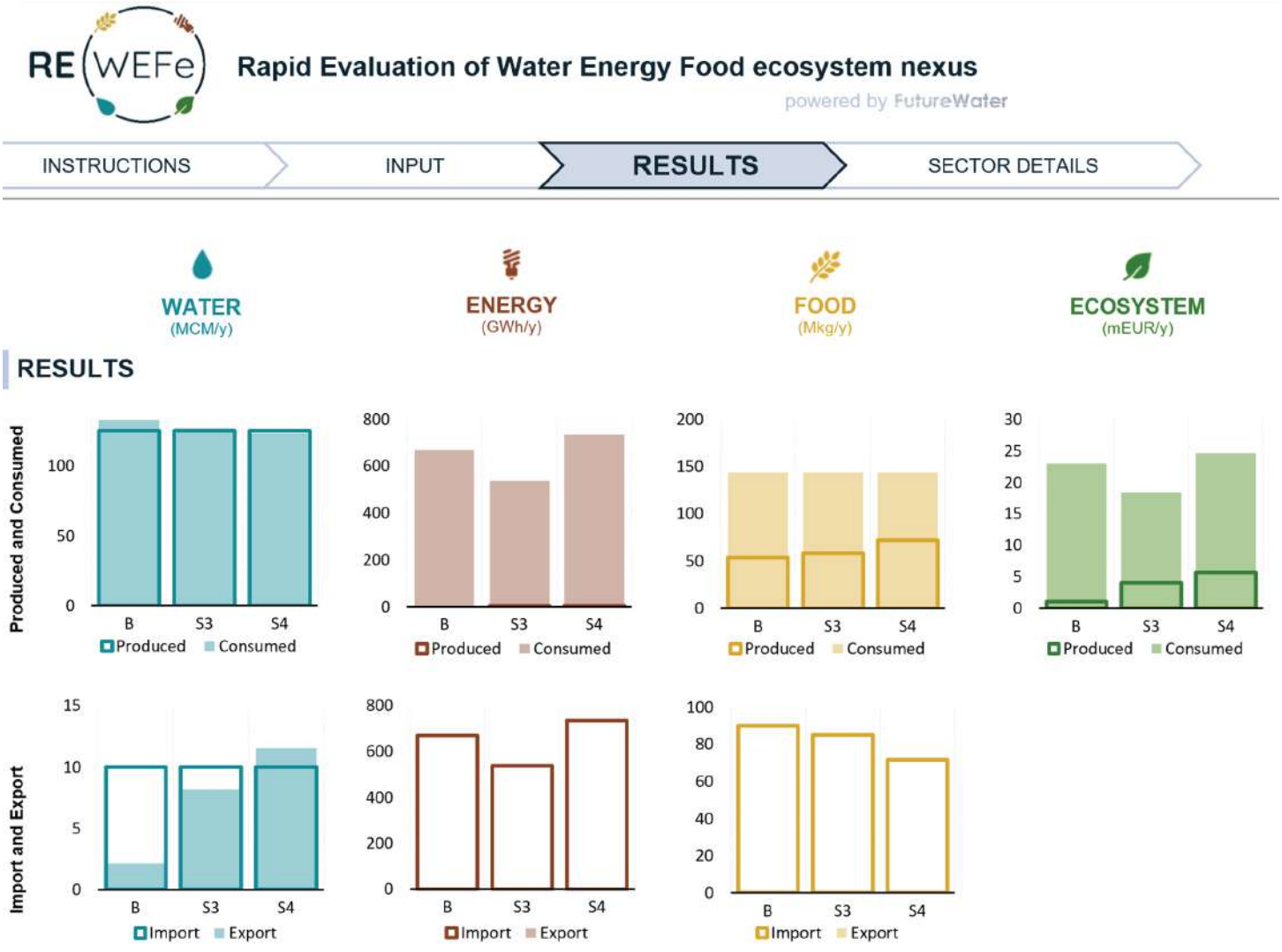
FACTSHEET | REWEf Tool

Context

What challenge or need does the REWEf tool address within the WEFE Nexus?

Strategic decision making on resources across the WEFE Nexus needs to be supported with quantitative information on potential impacts of changes and decisions. Existing tools for assessing the WEFE Nexus are often too complex and detailed, requiring extensive data and technical capacity, while a few other user-friendlier tools are limited to qualitative outputs only.

Other available tools do not fully account for the interconnections between all WEFE sectors, nor are they accessible to policymakers or practitioners without specialized expertise. There is a clear need for a simple, adaptable, and universally applicable tool that enables quick and informed strategic decision-making within the WEFE Nexus.



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Description of the tool

Its main features, methodology, target users, and added value.

The REWEFe tool is an application that provides a user-friendly interface through Excel, to assess and visualize the current state and future scenarios of the WEFE Nexus for a particular region of interest. Users input data in categories such as land use, population, industry, climate/water, food production, energy, and ecosystems.

The tool processes these inputs to generate statistical and graphical summaries of production, consumption, imports, and exports across the WEFE sectors. It allows users to build and compare multiple scenarios under different technological, climatic, and socio-economic conditions. Its target users include policy makers, government officials, researchers, development organizations, and private sector consultants.

The tool is freely available, easily adaptable to various languages and regions, and does not require internet connectivity or advanced technical expertise.

It offers a balance between simplicity and comprehensiveness, enabling high-level assessments of nexus interlinkages.

Application

How and where has the tool been used/tested in BONEX?

The REWEFe tool has been tested extensively within the BONEX project across multiple Demonstration Projects (DPs) in Spain, Jordan, Italy, Portugal, Morocco, Lebanon and Tunesia; covering a wide range of conditions, from interventions related to wastewater reuse, Nature-based Solutions, greenhouse technology, and renewable energy. This iterative testing process allowed for continuous improvements and fine-tuning of the tool.

Main results or findings so far

Through testing in BONEX, the REWEFe tool has demonstrated its capacity to provide a holistic overview of the WEFE Nexus, supporting strategic decision-making and scenario analysis.

The tool effectively enables users to explore the impacts of various development interventions on water, energy, food, and ecosystems, making it valuable for policy design and investment planning.

Future potential

Possible applications beyond BONEX or options for scaling up.

Beyond BONEX, the REWEFe tool is poised for applications across diverse geographic contexts where WEFE decisions need to be supported with quantitative information. Currently already, the REWEFe tool is being used for (1) capacity building on water accounting with FAO in the NENA region, for (2) investment planning and training across 5 countries of East Asia with a regional partnership organization (PEMSEA), and for (3) institutional capacity building in the Global South (The Hague Academy).

It is expected that the partnerships and outreach will expand even further over the next years, given the challenges and need for informed decision-making on WEFE nexus interventions in many regions of the world.

RE WEFe

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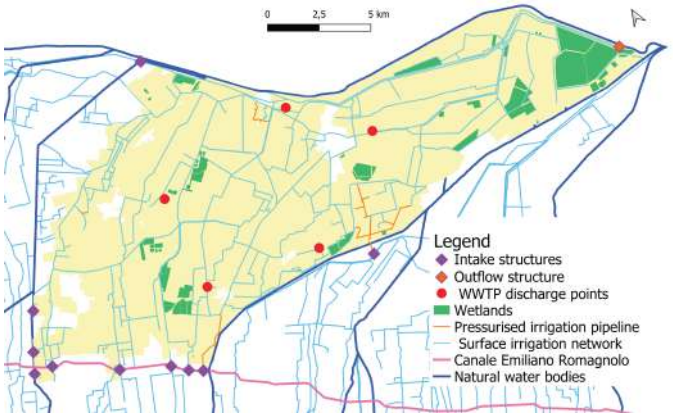
FACTSHEET | DEMOSTRATION PILOT ITALY

Lorgana-Botte irrigation (Italy)

Context of the demonstration project

The Lorgana-Botte irrigation district in Emilia-Romagna (Figure 1) covers the area of around 22,500 ha, and represents an important agricultural production zone. It is characterised by a developed irrigation network and a total of 12 wastewater treatment plants (WWTP) discharging their effluent into irrigation canals, representing a case of indirect water reuse. Moreover, due to water scarcity and increasing energy costs, it is needed to reduce water consumption. Therefore, the Italian DP focused on analysing water and energy conservation strategies based on the district's water balance, also considering irrigation water quality and the impact of Nature-based Solutions (NbS) within this intricate nexus.



The district faces significant challenges stemming from uneven water resource distribution and intensifying climate change, evidenced by recurring droughts (2012, 2015, 2016, 2017, 2022) and recent floods (May 2023, October 2024). This water scarcity impacts the region's substantial agricultural production, also increasing its costs.

Moreover, and the energy use and cost is another problem since it is needed to transport and distribute water. There are also different environmental issues such as water quality, wetland loss and riparian vegetation removal, although conservation efforts are underway. While water quality has been improving, water losses persist, highlighting the need for efficient water management in this vital agricultural area vulnerable to climate extremes.

Description of the technology demonstrated in the DP

The DP primarily aimed to optimise the irrigation network's water balance to minimise losses and reduce water abstraction, thus also lowering energy consumption and costs. This can result in improving agricultural sustainability, by analysing all water fluxes and also implementing NbS for water quality improvement.

The BONEX project interventions also included evaluation of the impact that WWTPs effluents can have on irrigation water quality by considering different sections of the distribution network and variable hydrological conditions.

The application and analysis of the interventions applied showed promising results and possible extent of water savings was estimated.

Moreover, the NbS tested (i.e. wetland, riparian buffer) had a valuable effect on water quality improvement, and WWTP effluent was found to increase nutrient content in irrigation water therefore potentially allowing lower use of artificial fertilisers, while not significantly affecting microbiological parameters.

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WEFE Nexus dimensions

The BONEX DP addressed the WEFe Nexus dimensions through three main interventions.

To close the irrigation network's **water** balance, the project quantified different components (e.g., crop needs, infiltration, evaporation) and related energy consumption, using four years of data and empirical estimations for previously unmeasured variables like infiltration (through canal trials) and evaporation (Figure 2). This quantification aimed to optimise water inlet, reduce pumping, lower energy use, and promote sustainable water practices, also involving stakeholders like farmers' associations and authorities.

Moreover, the water quality was also considered, both through testing the effects on indirect water reuse and application of Nature-based Solutions (NbS). The project implemented wetlands, both existing and restored (Figure 3) and a novel mowing technique for riparian vegetation, that could both improve water quality, therefore contributing to a more sustainable food production. Finally, these NbS and other interventions enhance water quality with minimal energy use, boost biodiversity, and improve overall **ecosystem** state.

These promising results were also positively evaluated by the DP stakeholder that were involved, with dedicated activities, in the intervention design and testing throughout the project lifetime.

Main policy recommendations

In order to apply on a large scale the new approach developed by the Italian DP within the BONEX project, specific actions must be taken.

First of all, it must be ensured that the implementation is properly planned and designed, taking into account all key players and potential regional variables. It is also crucial to assess the possibility of extending the technology to a larger scale. To this end, it is necessary that the quantitative and qualitative criteria are uniform throughout the area and applicable to different territories. The policy makers should therefore implement specific actions that would favour water saving and quality improvement interventions, requiring specific planning for agricultural areas, also taking into consideration the overall ecosystem status.

Gender dimension

The work carried out in the Italian DP took into account the gender dimension mainly in terms of identifying stakeholders to involve and obtain information. The main activities with stakeholders were the project workshops and, in the first instance, invitations to participate in these events were usually sent to organisations or institutions, which decided autonomously who would represent them.

However, it was noted that this approach led to a low participation of female stakeholders and therefore a specific strategy to identify also these stakeholders and invite them individually was implemented.

Moreover, during the project lifetime CBR started an internal process that led to the inclusion of a Gender Equality Plan among the corporate objectives, aligning with the requirements of Horizon Europe. UNIBO already has this kind of policy document and therefore it was applied also on the project activities.

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FACTSHEET | DEMOSTRATION PILOT JORDAN

Wadi Mujib (Jordan)

Context of the demonstration project

According to the National Water Strategy 2023-2040, Jordan has only 61 m³ of renewable water per capita annually, making it one of the world's most water-stressed countries.

Climate change worsens this crisis, as rainfall declines by 1.2mm yearly and temperatures rise by 0.03°C annually, leading to prolonged droughts that threaten agriculture and intensify environmental challenges.

At the same time, Jordan's heavy energy dependence and soaring prices strain households, industries, and businesses, reducing competitiveness and investment.

Reliance on costly imports deepens fiscal deficits, making sustainable energy solutions urgent for economic growth. Meanwhile, a rapidly growing young population heightens pressure on food security and job creation, with unemployment remaining a critical concern (21.4% in 2024).

Against this backdrop, the BONEX pilot in Jordan is located in Dhiban—a rural poverty hotspot marked by activism and social discontent (Colfax, 2019)—highlighting the need for a holistic approach to the WEFE nexus towards resilient solutions.

Description of the technology demonstrated in the DP

The BONEX Demonstration Project in Jordan implements a pilot with two hydroponic greenhouses (418.5 m² each) powered by solar PV compared to traditional greenhouses. The hydroponic system uses drip irrigation with locally sourced volcanic tuff as a soilless substrate, operating in a closed-loop water system sourced from Al Wala Valley. A smart fertigation system optimizes water and nutrient use, saving 25-38% water while increasing crop yields by 25-106%. Four crop cycles with three different crop types (cucumbers, peas, red cabbage) demonstrated superior performance, especially under extreme heat (40-49.9°C), where hydroponics suffered only 24% crop damage vs. near-total loss in traditional systems. The solar PV system has a capacity to produce 4 kW and generates over 1 KW/day surplus, ensuring energy neutrality. Managed by a youth cooperative (13 men, 10 women), the project enhances socio-economic sustainability by integrating gender-inclusive technology and capacity building. It serves as a scalable model for water-efficient, climate-resilient agriculture in Jordan, aligning with WEFE Nexus principles by addressing water scarcity, energy needs, and food security in degraded, resource-scarce regions. The initiative also engages with the WEFE4MED Knowledge Hub for policy integration and stakeholder collaboration.

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WEFE Nexus dimensions

Reflecting on the impact of BONEX intervention in Jordan, the following WEFE dimensions can be highlighted:

- **Water:** Implemented closed-loop hydroponics using filtered spring water, achieving 25-38% savings vs traditional irrigation.
- **Energy:** Solar-powered system generated >1KW/day surplus, making operations energy-neutral.
- **Food:** Increased productivity (25-106%) with climate-resilient cash crops (cucumbers, peas, cabbage).
- **Ecosystems:** Used local volcanic tuff substrate and smart fertigation to minimize environmental impact.

The system reduced the CO2 emissions by 66.7 kg CO_2 eq. and 13.2 kg CO_2 eq. compared to fuel-powered and grid-powered hydroponics.

- **Socioeconomic:** Empowered a youth cooperative (23 members, 43% women) through training and employment.

Main policy recommendations

Jordan needs effective governance and policies that foster integrated planning and action. A critical step is empowering the existing National WEFE Nexus Council to harmonize strategies across water, energy, agriculture, and environmental sectors.This council should lead the development of long term holistic strategies to address the nexus. Such strategy should capitalize on successful existing projects, like the BONEX Wadi Al Wala demonstration site, and reflect on upscaling pathways.

Policy reforms should incentivize efficiency through adjusted subsidies, while financial tools (green grants, low-interest loans) support small farmers and cooperatives.To boost small-scale farming profitability, simplify land permits, improve market access, and promote innovations like shared logistics, cooperative models, and vertical supply chain integration.

In parallel, investing in data platforms, like the REWEF tool, will enable evidence-based planning. Strengthen multi-stakeholder partnerships (government, NGOs, private sector, donors) for inclusive, scalable solutions and launching capacity-building and public awareness campaigns should drive adoption of sustainable practices.

Gender dimension

The BONEX DP incorporated gender equality through its design and implementation. The project engaged a youth cooperative of 23 members (10 women, 13 men), achieving 43% female participation—significant in Jordan's male-dominated agriculture sector.

Women agricultural engineers received training and employment, improving technical and financial empowerment. Hydroponic technology was chosen as a gender-sensitive solution, reducing physical labor demands while creating skilled roles accessible to women.

The cooperative ensured equal participation in decision-making and profit-sharing. Monitoring confirmed women's active involvement in crop production and solar PV maintenance. Targeted capacity-building strengthened women's expertise in modern farming and entrepreneurship.

By challenging traditional gender roles, the project demonstrated how WEFE Nexus interventions can promote equity in rural Mediterranean areas.

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FACTSHEET | DEMOSTRATION PILOT LEBANON

Beqaa Valley (Lebanon)

Context of the demonstration project

The solar-powered hydroponics Demonstration Project (DP) at AUB was developed under the BONEX project to address pressing environmental and agricultural challenges in Lebanon, particularly the Beqaa Valley. This region is considered as Lebanon's agricultural heartland, is facing extreme water scarcity, groundwater depletion, energy shortages, and land degradation. Agricultural practices have become unsustainable due to chemical overuse, water pollution, and outdated infrastructure. Environmental corruption rooted in poor regulation and fragmented governance has worsened these challenges. Originally planned for the Beqaa, the unit was relocated to AUB's Beirut campus due to conflict-related mobility issues, without affecting its core goals.

The AUB unit serves as a controlled environment innovation hub that demonstrates how solar powered hydroponics can optimize water and energy use, improve food security, and reduce pollution. It engages multiple stakeholders from ministries to local producers to build a replicable, sustainable model aligned with Lebanon's National Agriculture Strategy.

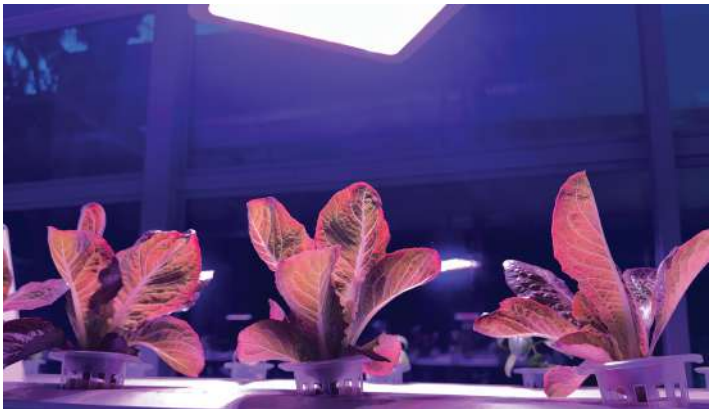
Description of the technology demonstrated in the DP

The intervention is a solar-powered greenhouse at AUB equipped with three hydroponic systems: vertical rotating towers, Nutrient Film Technique (NFT), and gutter systems.

The system supports year-round soilless cultivation of leafy greens and fruiting vegetables like tomatoes and strawberries. Solar panels on the rooftop generate 3,627 kWh per cycle, powering automated water and nutrient delivery systems.

It operates on a closed-loop water system, reducing water use to just 40.6 mm/year down from 150–200 mm in traditional systems. Romaine lettuce yields reached 28 units/m², surpassing traditional greenhouse productivity.

The unit also functions as a training and demonstration site for researchers, students, and farmers, integrating academic research with market-driven innovation.



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WEFE Nexus dimensions

WEFE dimension is addressed in many ways:

- **Water:** The closed-loop system recycles water, achieving 70–80% savings.
- **Energy:** Powered by rooftop solar panels, reducing reliance on diesel or grid electricity.
- **Food:** Soilless cultivation boosts yields, quality, and year-round production.
- **Ecosystems:** Eliminates agrochemical runoff and minimizes land use, protecting local ecosystems.

Main policy recommendations

- **Incentivize** solar-powered agri-tech via tax relief, grants, and local manufacturing support.
- **Include hydroponics** in national strategy, formally recognizing it as a sustainable farming method.
- **Facilitate public-private-academic** partnerships to bridge research and field application.
- **Train municipal and rural actors** through vocational curricula and community outreach on solar hydroponics.
- **Reduce import duties** on solar and hydroponic components and promote locally made alternatives.
- **Encourage inclusive financing models** (low-interest loans, microfinance) to overcome adoption barriers.

Gender dimension

Gender inclusion was actively integrated in all phases of the AUB hydroponic DP. Women made up over 60% of workshop and training participants, many with no prior agri-tech experience. Through hands-on activities in system assembly, nutrient management, and data monitoring, participants gained confidence and skills.

The project collaborated with AUB's Gender Studies Program to ensure intersectional representation and collected gender-disaggregated data to track engagement and outcomes. Some women trainees have since launched rooftop hydroponic units or community outreach initiatives. These efforts underscore the project's success in portraying women not just as beneficiaries, but as decision-makers and innovators in climate-resilient agriculture.

The greenhouse continues to serve as an inclusive space for cross-disciplinary learning and leadership, especially for women students in engineering, agriculture, and environmental studies.

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FACTSHEET | DEMOSTRATION PILOT MOROCCO

Souss-Massa basin (Morocco)

Context of the demonstration project

The region of Chtouka, located in the heart of the Souss-Massa plain in southwestern Morocco, is a major agricultural production region that faces a major water crisis compromising the sustainability of agricultural production. This critical situation results from a combination of structural and climatic factors. On the one hand, climate change is causing a significant decrease in rainfall, rising temperatures, and greater seasonal variability, all of which are intensifying pressure on already scarce water resources. On the other hand, human activities particularly the intensive exploitation of groundwater are contributing to the depletion of underground reserves. Added to this is the growing salinization of soils, a direct consequence of excessive groundwater use and seawater intrusion into coastal aquifers, which is degrading the quality of agricultural land and undermining its productivity.

These multiple pressures threaten not only the viability of the agricultural sector but also food security and the livelihoods of rural communities. In light of this situation, several measures have been considered to preserve natural resources. Among the key responses implemented is the construction of a seawater desalination plant as an ambitious and strategic project based on reverse osmosis technology. This innovative solution makes it possible to significantly reduce pressure on aquifers while ensuring a stable and reliable water supply for crops. Furthermore, desalinated water contains low levels of dissolved salts, which contributes to improved long-term soil management.

In this context, in the framework of BONEX project, DP Souss Massa focuses, under the Water-Energy-Food-Ecosystems (WEFE) Nexus approach, on the environmental and economic sustainability of the use of desalinated water for irrigation, especially since it is, at the country level, the first use of desalinated water for irrigation.

Description of the technology demonstrated in the DP

Three experimental studies were conducted as part of this initiative. The first focused on evaluating different proportions of desalinated water and well water applied to two zucchini varieties (Radia and Kayssar). The results showed that a mixture containing 25% desalinated water provided a good balance between plant growth, water consumption, and CO_2 emissions. Then, in order to better valorise the use of desalinated water and promote the nexus approach, the second and third studies conducted on green beans and zucchini, and carried out under controlled conditions, implemented an integrated and sustainable approach combining desalinated water, magnetic water treatment, the use of biofertilizers, and solar-powered irrigation. This strategy led to improvements in crop yields, nutrient availability in the soil, and plant resilience to environmental stress.

In addition, a practical irrigation guide was developed for farmers in the region, on the basis of the experimental work and through several surveys targeting key export crops such as tomatoes, peppers, raspberries, cucumbers, and zucchinis. This guide offers concrete recommendations for adjusting both the quality and quantity of desalinated irrigation water according to the specific needs and development stages of each crop. The aim is to promote agricultural practices that are sustainable, efficient, and well adapted to the increasing scarcity of water resources.

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WEFE Nexus dimensions

The intervention carried out in the Chtouka region integrated the Water–Energy–Soil–Food (WEFE) dimensions.

On the water front, the installation of a reverse osmosis desalination plant helped secure the water supply for irrigation while reducing pressure on groundwater resources, with optimized blends of desalinated water and well water ensuring efficient use.

The energy dimension was addressed through the integration of solar energy to power irrigation systems, thus reducing both costs and CO_2 emissions. To preserve soil health, the project introduced the use of biofertilizers and magnetic water treatment to enhance nutrient absorption, prevent salinization, and maintain soil fertility.

Finally, the food dimension was tackled by improving agricultural practices for key crops in the region, with the development of a practical guide offering recommendations that contribute to sustainable and climate-resilient agricultural production.

Main policy recommendations

To support the implementation and scaling up of desalination technology and sustainable agricultural practices, it is recommended at the local level to train and support farmers in the use of desalinated water and associated technologies, while fostering the creation of cooperatives to pool costs and facilitate collective adoption. It is also essential to establish agronomic monitoring units to assist farming operations.

- **At the regional level**, desalinated water should be integrated into integrated water resources management plans, coordination among local institutions should be strengthened, and financial incentives should be provided to encourage the adoption of optimized irrigation systems.

- **At the national level**, it is necessary to incorporate desalination into food security policies, support agricultural innovation, strengthen applied research on the impacts of desalinated water, and promote a national strategy for the use and valorization of non-conventional water resources.

These measures, combined with appropriate taxation policies and targeted subsidies, will help ensure the sustainability of water resources and the effectiveness of agricultural practices in a context of water stress and climate change.

Gender dimension

The gender dimension was integrated throughout all project activities to ensure an equitable distribution of benefits and opportunities between women and men. Acknowledging that women play a fundamental yet often underestimated role in agricultural systems and water resource management, the project adopted an approach aimed at recognizing, valuing, and strengthening their active participation at all stages of the initiative.

From the beginning of the project, special attention was given to the effective involvement of women. Specific efforts were made to promote women's participation in participatory workshops, field demonstration sessions, and community consultations.

The objective was not only to ensure their presence but also to guarantee their active inclusion in reflection processes, co-creation of solutions, and decision-making.

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FACTSHEET | DEMOSTRATION PILOT PORTUGAL

Alentejo (Portugal)

Context of the demonstration project

Located in southern Portugal, the Alentejo region is the country's largest by land area but one of the least populated. Known for its traditional cork oak forests (montado) and extensive farming systems, the region has long suffered from water scarcity, limiting agricultural modernization and rural development. The BONEX Demonstration Project focuses on the Alqueva irrigation zone, where the construction of the Alqueva dam has increased water availability and transformed the landscape. Vast cereal steppes have been replaced by irrigated permanent crops like olive trees, vineyards, and almond orchards. While this shift has boosted productivity and economic growth, it has also intensified pressure on natural resources, exacerbated by climate change. Key challenges include water scarcity, soil degradation, biodiversity loss, ecological imbalances, and the decline of traditional ecosystems. The region also faces rural depopulation and socio-economic inequality. Expanding irrigation raises energy demands and environmental stress, while the degradation of ecosystems such as the montado threatens long-term sustainability. These issues call for integrated, nature-based solutions that protect resources, restore biodiversity, and promote a more resilient agricultural model.

Description of the technology demonstrated in the DP

The BONEX Demonstration Pilot in Portugal implemented three Nature-based Solutions (NbS) tailored to Alentejo's landscape: waterline restoration with native hedgerows, restoration of a Mediterranean temporary pond, and use of biodiverse cover crops in olive groves. These solutions improved water retention, biodiversity, and soil health. Monitoring showed benefits like better soil infiltration, more stable crop yields under extreme weather, and increased wildlife presence. Farmers reported added value in landscape aesthetics, reduced labour after waterlogging, and improved farm branding.

The pilot also tested the KER Tool, which helps stakeholders evaluate the environmental, social, and economic trade-offs of NbS. Used at farms like Esporão and Marzalonas, it supported decision-making and natural capital assessments. The technologies demonstrated are scalable across Mediterranean areas, offering multifunctional, low-cost solutions to climate, biodiversity, and water management challenges in agriculture.

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WEFE Nexus dimensions

The BONEX pilot in Alentejo applied NbS to address all WEFE Nexus dimensions.

- **Water:** hedgerows, ponds, and cover crops improved retention, infiltration, and reduced runoff.
- **Energy:** healthier soils and moisture reduced irrigation and agrochemical use, lowering energy demand.
- **Food:** farmers reported more stable yields and enhanced soil fertility.
- **Ecosystems:** restored habitats increased biodiversity and ecosystem services.

The KER Tool supported evaluation of trade-offs across WEFE, linking ecological integrity to economic value and enabling integrated planning for sustainable, multifunctional landscapes.

Main policy recommendations

To scale Nature-based Solutions (NbS), an integrated policy approach is needed, combining training, incentives, and planning. Farmers and advisors must be trained in NbS benefits such as erosion control, water retention, and biodiversity.

Financial tools like Payments for Ecosystem Services (PES) and water pricing incentives should reward sustainable practices.

Cooperatives and advisory services can integrate decision-support tools for nutrient and water management aligned with NbS. Local platforms should foster dialogue and joint planning.

Demonstration farms promote peer learning and showcase results. Consumer awareness campaigns and product labelling can build demand for NbS-based farming.

Policies must reflect regional needs, mainstream NbS in eco-schemes and rural plans, and be supported by monitoring frameworks that measure both ecological and socio-economic outcomes.

Gender dimension

Although not addressed as a separate focus, gender considerations have been thoughtfully incorporated into the DP work. One example is the visibility of women in science, as the scientific team is predominantly female and played a key role in leading stakeholder engagement activities.

Particular attention was given to achieving gender balance in the three participatory workshops held in rural areas of Portugal, reaching near parity between male and female participants. Women were actively involved in co-design workshops, particularly from agricultural cooperatives and civil society organizations (1st workshop: 29 men and 14 women; 2nd workshop: 35 men and 25 women; and 3rd workshop: 19 men and 21 women). These numbers are especially significant given the rural context and the focus on agriculture, where women have historically been underrepresented in formal decision-making spaces. This reflects a commitment to inclusivity and recognition of the value of diverse perspectives within the WEFe nexus framework. The active involvement of women in both scientific and participatory processes provided strong role models and helped foster an equitable environment.

At the Esporão and Marzalonas site, women-led sustainability teams directly applied the KER Tool, highlighting its usability across gender lines. The project also emphasized the role of women in biodiversity conservation, both through leadership roles and decision-making contributions. Gender perspectives were considered in KPI development, ensuring the social impacts of NBS are comprehensively captured. Gender-disaggregated data was collected to monitor participation and support ongoing reflection on how to further strengthen gender sensitivity in future activities.

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FACTSHEET | DEMOSTRATION PILOT SPAIN

La Axarquía (Spain)

Context of the demonstration project

The Spanish Demonstration Project (DP) of BONEX was implemented in Axarquía, a region in Andalusia facing severe and long-standing water scarcity. The area's semi-arid climate, combined with the expansion of subtropical irrigated crops and population growth along the coast, has led to a structural water deficit. In response, regional authorities have prioritized supply-side solutions, including investments in reclaimed water and plans for desalination. Thanks to recent Drought Decrees and upgrades to treatment infrastructure, Axarquía is expected to have access to 19.14 hm^3 of reclaimed water for irrigation by 2025.

Nevertheless, the use of reclaimed water in agriculture is still relatively new in the region, and many farmers lack practical experience in its management. Reclaimed water presents both opportunities and challenges. Its high nutrient content can reduce the need for synthetic fertilizers, lowering costs and emissions. However, if not properly managed, excessive nutrient loads can lead to soil degradation and water pollution. A WEFE Nexus approach is essential to ensure that reclaimed water supports water security, environmental **sustainability, energy efficiency, and food system resilience.**

Description of the technology demonstrated in the DP

The RICHWATER tool, developed under the BONEX project, is a digital solution designed to support efficient fertigation strategies using reclaimed water. Its primary function is to optimise nutrient management by calculating nutrient concentrations in treated wastewater and adjusting fertilizer application according to crop-specific needs.

This approach aims to prevent nutrient overloading, reduce environmental risks such as soil degradation and water eutrophication, and align agronomic performance with environmental sustainability.

The tool contributes across all dimensions of the Water-Energy-Food-Ecosystems (WEFE) Nexus. By enhancing water use efficiency, lowering dependence on synthetic fertilizers, and promoting the circular use of nutrients, it supports more sustainable and cost-effective farming practices. Its implementation fosters collaboration between farmers and water authorities, enabling an integrated system for the treatment and reuse of urban wastewater in agriculture, with added benefits such as reduced production costs and carbon emissions.

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WEFE Nexus dimensions

The BONEX Demonstration Project integrates all four dimensions of the Water-Energy-Food-Ecosystems (WEFE) Nexus through the use of reclaimed water and optimized fertigation practices.

- **Water:** The reuse of reclaimed water in agriculture reduces dependence on freshwater resources and supports more resilient water management. Its nutrient content also decreases the need for synthetic fertilizers, improving both water efficiency and resource circularity.

- **Energy:** Water reclamation is significantly more energy-efficient than alternative supply-side solutions such as desalination or inter-basin transfers. Additionally, lower fertilizer demand reduces energy use associated with production, packaging, and transport.

- **Food:** The nutrient-rich quality of reclaimed water enhances crop growth while reducing input costs. These savings support farm profitability and contribute to the viability of rural economies, particularly in regions with high water stress.

- **Ecosystem:** By managing nutrient loads and avoiding over-fertilization, BONEX helps prevent soil degradation and water eutrophication, promoting ecosystem health and land productivity.

Main policy recommendations

To ensure that reclaimed water contributes meaningfully to sustainable agriculture, the following policy directions emerge from the experience of the Axarquía Demonstration Project:

- **Integrate Water Reuse into Nexus-Based Planning:** Reclaimed water strategies must be embedded in holistic planning frameworks that account for energy, food, and ecosystem interlinkages. Basin-level planning should be data-informed and promote long-term resource sustainability. Nexus integration ensures that reuse complements broader water, energy, and land management goals.

- **Enhance Water Reuse Infrastructure:** Safe and effective reuse requires sustained investment in the entire reuse chain—from advanced treatment technologies to storage, pumping, and delivery systems. Modernizing infrastructure improves reliability, reduces losses, and ensures that reclaimed water reaches farms at appropriate quality standards.

- **Strengthen Water Quality Monitoring and Data Access:** Real-time, site-specific monitoring of reclaimed water is essential to guarantee agronomic safety and environmental protection. Policies should promote the deployment of automated sensors for key parameters (e.g. salinity, nutrient content, microbial load) and ensure that monitoring data is transparent and accessible to farmers, water operators, and regulators.

- **Ensure Compliance with Nitrate Regulations:** Water reuse in agriculture must align with environmental protection frameworks, particularly the EU Nitrates Directive (91/676/EEC). In designated Nitrate Vulnerable Zones, nitrogen contributions from reclaimed water must be accurately accounted for in nutrient planning to avoid over-application, reduce the risk of eutrophication, and ensure regulatory compliance. Policies should support integrated nutrient management approaches that include reclaimed water within farm nutrient balances.

Gender dimension

The Spanish Demonstration Project adopted a structured gender mainstreaming approach, ensuring strong female participation in stakeholder engagement activities and visibility across all implementation phases. Special attention was given to involving women from farming cooperatives, public institutions, research centres, and the agri-food sector.

In parallel, the DP promoted gender equity by showcasing innovation initiatives with balanced representation in decision-making and technical teams, and by encouraging women's leadership in water reuse and agri-tech. These efforts contributed to rural employment, challenged gender stereotypes, and supported broader sustainability goals—aligning with both the UN SDGs and the Water Europe Vision on the Value of Water.

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FACTSHEET | DEMOSTRATION PILOT TUNISIA

Ouardanine (Tunisia)

Context of the demonstration project

The reuse of reclaimed water in Ouardanine, Monastir Governorate, Tunisia, began in 1997 to provide farmers with a reliable irrigation source, enhance community welfare, and reduce effluent discharge into the environment.

While the agricultural shift spurred economic growth through new investments, crop diversification, and increased land value, the area still faces challenges linked to poor water governance and mismanagement of water and energy resources.

Recent energy cost recovery measures have exacerbated the power cuts during peak consumption hours, disrupting reclaimed water distribution. This limits availability during critical periods, notably in summer, compromising crop yield and quality.

Moreover, aging infrastructure and limited pumping capacity allow farmers to receive only 30-50% of their water needs, with the rest discharged, disturbing the local community. Farmers often rely on outdated practices, overlooking nutrient loads in treated wastewater and actual crop water needs, resulting in overuse of water and fertilizers and contributing to environmental degradation.

Description of the technology demonstrated in the DP

The innovative technologies include the following tools

- An IoT-based agro-weather station for the real-time monitoring of weather parameters, with an integrated simulator to calculate accurately crops water requirements to improve water and nutrients management thus increasing yield, and reducing the release of pollutants into the water bodies. An irrigation schedule was established for fig trees.

- **Low-cost sensors** for real-time monitoring of soil moisture aiming at improving remote irrigation scheduling and water use efficiency. While requiring further testing, sensors showed reliable results at 30 cm depth.

- **Specific sensors** for a real-time monitoring of the TWW quality parameters (i.e. pH, electrical conductivity, temperature, salinity, total dissolved solids, turbidity, total suspended solids, chemical and biological oxygen demand (COD and BOD), total organic carbon (TOC), nitrates, ammonium, and potassium). The tool will enable decision-making, allow setting fertigation programs, and reduce analysis cost burden. Data will feed the Richwater nutrient-balance tool developed by BIOAZUL/Smart Logger to improve nutrients management.

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WEFE Nexus dimensions

WEFE dimension is addressed in many ways:

The intervention is meant to address all the components of the WEFE Nexus.

Taking into consideration the local context and concerns, Water dimension, with its quantitative and qualitative facets, was predominant being strongly linked to Energy; the other dimensions were indirectly tackled, through expected improvement in water and nutrients management.

In that, a better estimation of the water requirements implies a lower water consumption. Combined with the soil moisture sensors, an irrigation schedule is foreseen to be developed with enhanced water use efficiency leading to a reduced energy consumption.

On the qualitative front, water quality monitoring will improve nutrients' management, yield and crops quality; nutrient recovery will also benefit the ecosystem's health.

Main policy recommendations

Actionable recommendations at local, regional, or national level to support technology implementation and upscaling.

- **At local level**, enhancing water governance is highly recommended. The Water User's Association needs a robust economic framework and skilled staff to promote accountability and transparency and to guarantee a fair water distribution; the reliability of irrigation water supply and its compliance with the quality standards are a prerequisite. The rehabilitation of the irrigated area and the upgrading of the infrastructure would help upscaling and adopting the technologies for fertigation, especially by the small holders.

- **At the regional level**, building capacities of technicians on operation and maintenance of smart tools, data interpretation, and information sharing with the farmers 'community and the overarching authorities is suggested.

- **At the national level**, embedding the use of smart technologies in the water strategies and creating incentives for funding SMEs is important. Digital monitoring should be validated by the national authorities and a public-private partnership should be established.

Gender dimension

Gender was mainstreamed at all the stages and all levels. The project coordinator is a woman. She is member of the Gender Committee and a Work Package leader. The research team is composed of 50% of women and the technical non-permanent staff is made 100% of young women engineers and postdocs; this makes an overall rate of 70% of women involved in research and innovation. The Steering Committee is made of 50% of women including national and regional stakeholders.

At the regional level, the working group is made of around 50 members with 25 to 38% of women, some of them heading technical departments.

At the local level, women are underrepresented (about 12%) showing that the water reuse agricultural sector is still dominated by men.

Meanwhile, the DEMO site is managed by a young woman farmer who took part in all the activities, including those dedicated to women and WEFE Nexus, like the CAWTAR Conference on Rural Women. Promotional videos highlighted the experiences of young farmers in the irrigated area.

At the Policy workshop, a session on gender in the water reuse sector was organized with representatives of CAWTAR and the Office for Women Outreach at the national and regional levels.

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