



# Can the Implementation of the Water-Energy-Food Nexus Support Economic Growth in the Mediterranean Region? The Current Status and the Way Forward

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Water resources is a crucial environmental good for the function of the human societies and the ecosystems. Moreover, water is an important input for the economy and an indispensable factor for economic growth. Especially in regions that are facing water scarcity, the adoption of water management policies and approaches fostering the sustainable use of resources while promoting economic growth becomes an emerging issue. The Mediterranean region is one of the most vulnerable regions regarding the availability of water resources due to climate change and human activities. The Water-Energy-Food (WEF) Nexus offers an integrated approach analyzing the synergies and trade-offs between the different sectors in order to maximize the efficiency of using the resources, whereas adapting optimum policies and institutional arrangements. The Mediterranean is a region where we observe a large spectrum of issues emanating from water pollution and natural resource degradation to water scarcity, large amounts of food loss and waste and increasing demand for energy and food. Agricultural practices, urban development, demand management for water, and protection of ecosystems, particularly aquatic ecosystems, are areas of particular intervention available to the decision-makers in enhancing availability of water for the various water using sectors. In this context, the current policy note paper aims to address a major issue: how can the implementation of the WEF

Nexus support the economic growth in the Mediterranean? Based on the outcome of an experts and stakeholders regional workshop, this paper presents the current status, including the opportunities and the practices of applying the WEF Nexus in the Mediterranean and draws specific recommendations for the way forward. Regarding the later, the strengthening of WEF Nexus in the Mediterranean requires a set of interventions to strengthen the institutional capacities, to enhance the finance mechanisms, to support the intra-regional dialogue as well, to enhance data collection and management, as well as to implement economic instruments and integrated economic approaches to measure the impact of Nexus into economy and employment.

**Keywords:** economic growth, Water-Energy-Food Nexus, Mediterranean, water policy, economic instruments, recommendations, opportunities, integrated approach

## INTRODUCTION

Water is inextricably linked to energy and food production. Energy depends on water for power generation, the extraction, transport and processing of fossil fuels, and the irrigation of biofuel crops [International Energy Agency (IEA), 2012]. At the same time, water provision depends on energy for its abstraction, purification and distribution (Copeland, 2014). Food production needs water, productive land and energy to grow crops, maintain livestock, and process food. Food waste can also be used to generate energy via anaerobic digestion. Such bi-directional links are further complicated by the sector-specific externalities that modify the physical or chemical characteristics of water and alter water flows. The structural modification of water courses resulting from their use for energy can impair their integrity, alter water flows and negatively affect the health of rivers. Farming byproducts that are released into surface and groundwater bodies lead to the contamination of water resources and the degradation of ecosystems.

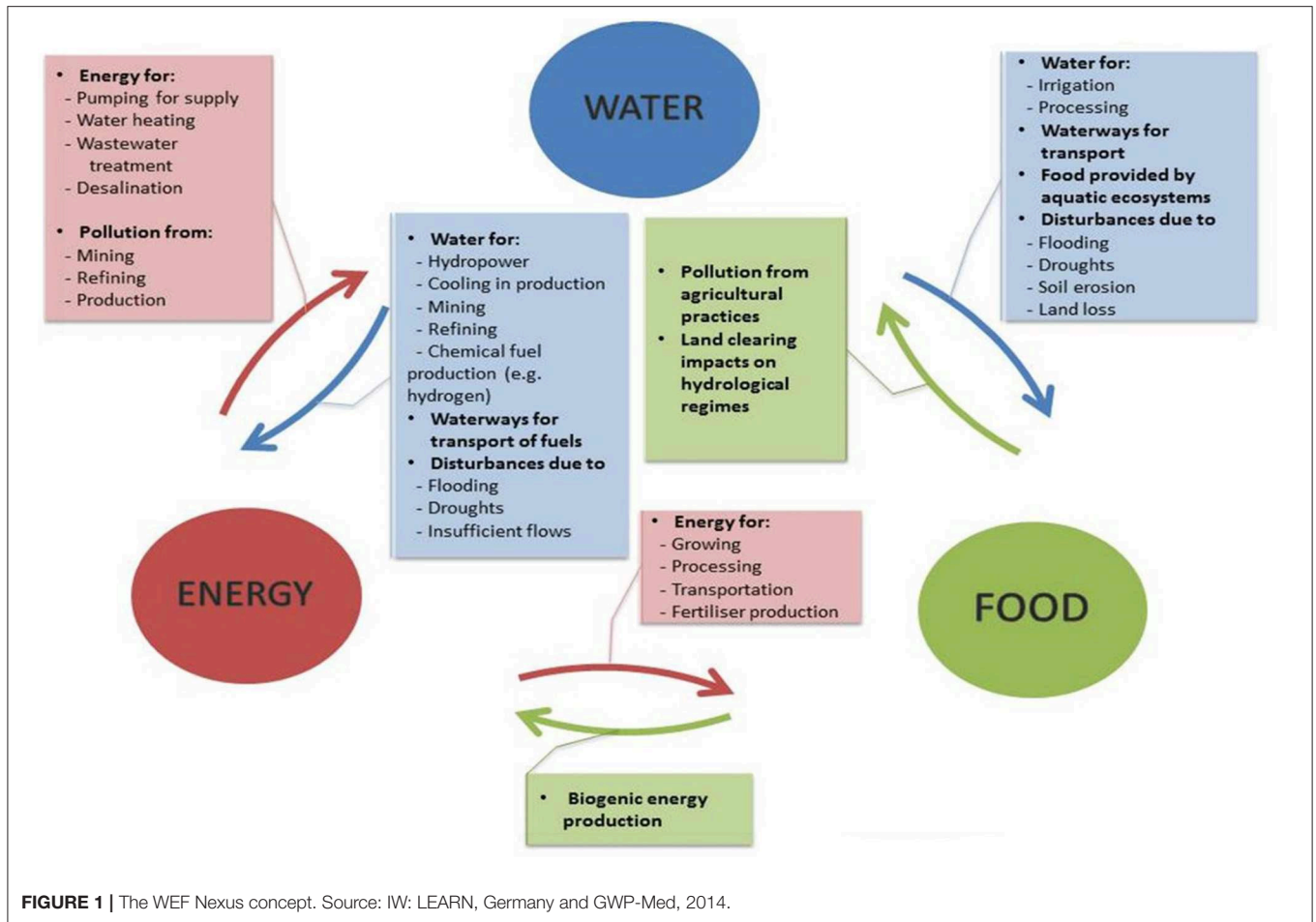
This web of mutual interlinkages defines the Water-Energy-Food (WEF) Nexus. Given that societal changes drive the growth WEF demand, and that ongoing environmental changes are likely to alter the availability or accessibility of water, the WEF Nexus is central to natural resource management and climate change policies. Coping with the WEF Nexus requires that the multi-sectoral use of water be reconciled and brought into line with the restoration and/or preservation of river (basin) integrity. Compared to integrated water resources management (IWRM), the WEF-Nexus puts emphasis on non-linear system analysis and dynamic feedbacks across water-intensive sectors (**Figure 1**). Over the past decade, the body of knowledge positioning water in the WEF Nexus has increased substantially.

Several concepts, frameworks and methodologies have looked at the interlinkages between water, energy and food (Mohtar and Daher, 2012; Bizikova et al., 2013; Benson et al., 2015) using a Nexus approach. Scott et al. (2015) provide a comprehensive definition of the WEF Nexus, including the basic interactions as well as institutional and policy implementation issues. The Food and Agriculture Organization of the United Nations (Food Agriculture Organization of the United Nations, 2014) developed a conceptual approach to the WEF Nexus, balancing

different user goals and interests in support of food security, sustainable agriculture and human development. In addition to the importance of welfare in the Nexus approach, Ringler et al. (2013) include the environmental impact when analyzing the interactions and balance between water, energy, land and food. In an effort to explore the green economic growth potential of a Nexus approach, the paper of Hoff (2011) presents initial evidence on how a nexus approach can enhance water, energy and food security by increasing efficiency, reducing trade-offs, building synergies and improving governance across sectors.

While integrated, holistic approaches to resource management and sectoral planning have been largely embraced by stakeholders and decision makers, and although the benefits of the WEF approach may appear obvious to its advocates, the Nexus concept still needs to be appropriated beyond the academic domain. At the EU policy level, the WEF Nexus is considered in the Renewable Energy Directive, the Green Infrastructure Communication, and (arguably) the Common Agricultural Policy (CAP). Indeed, most studies and papers have focused on assessments and analyses of the WEF Nexus, reaffirming the importance of the concept, but there is still a lack of concrete examples of the actual implementation of such an approach. In that context, a number of organizations, including the JRC, the FAO, the United Nations Economic Commission for Europe (UNECE), the Centre International de Hautes Études Agronomiques Méditerranéennes (CIHEAM), Plan Bleu, Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), Global Water Partnership (GWP) have recently been piloting Nexus approaches through modeling, assessment, dialogue, assistance to policy making, and technical applications, testing new methodologies; most of these are work-in-progress, with actual results and lessons learned pending. Importantly, key regional and sub-regional multilateral institutions have been addressing or have expressed an interest in exploring the Nexus approach, including the European Union (EU), the Regional Cooperation Council (RCC), the League of Arab States (LAS), Union for the Mediterranean (UfM), and the Barcelona Convention (MAP UNEP). Some highlights from these initiatives and programs are presented in **Table 1**.

In order to move from concepts to implementation, it is necessary to identify the economic sectors of the Nexus that



**FIGURE 1** | The WEF Nexus concept. Source: IW: LEARN, Germany and GWP-Med, 2014.

can benefit from a change in the planning process. This is the main topic of the present policy note, which aims to analyze the potential of a WEF Nexus approach to create economic growth. The focus is on the Mediterranean region, an area under threat of water scarcity due to climate variability and change, population growth, developmental pressures and consequent imbalanced water allocations by different sectoral water users, and where demand for food and energy is expected to increase in the coming decades. We analyze specific economic options, policy setting and institutional arrangements that, if incorporated into a WEF Nexus approach, could contribute to sustainable economic growth in this region. The content of this paper is based on the outcomes of the Workshop “Can implementation of the Water Nexus support economic growth in the Mediterranean region?” held in Ankara, Turkey, on 12–13 February 2015.

In the first section, we gather evidence on the opportunities for adopting the WEF Nexus in the Mediterranean region. Water resources are particularly limited and vulnerable to pollution and weather extremes in the Mediterranean countries. Despite water scarcity and land degradation, agricultural practices do not represent sound, sustainable practices, and a significant proportion of food remains lost or wasted in the food value chain. Moreover, environmental protection is occasionally in conflict

with economic growth. The integrated perspective provided by the WEF Nexus may help to meet the needs of different water uses and ecosystem protection, by stimulating appropriate investments in the Mediterranean region, based on consistent and effective cross-cutting water, energy and food policies. Nexus interdependencies should also be taken into account for improved designs of water tariffs for domestic, agricultural, and industrial water uses in the region. In the second section, we discuss the barriers hampering the adoption of a cross-sectoral perspective for integrated water management. The discussion focuses on administrative, legislative and market-related barriers (transaction costs, interest groups, constraints due to limited water property rights, tariffs, subsidies etc.). “Good” and “bad” practices linking water-energy-food security and ecosystem protection to investments, jobs creation, innovation, and competitiveness in the Mediterranean region are identified, taking account of feasibility in terms of the presence or absence of an enabling environment, potential for growth, implementation and transaction costs, actors involved, and financial risks. The final section of this paper provides specific recommendations and suggests a way forward for implementing the WEF Nexus in the Mediterranean area. This section explicitly covers institutional, economic and policy aspects that would facilitate a better

**TABLE 1** | International WEF nexus initiatives and programs.

Organization	Initiative/Program	Source
European Union	Partnership for Research and Innovation in the Mediterranean Area (PRIMA)	<a href="http://ec.europa.eu/research/environment/index.cfm?pg=prima">http://ec.europa.eu/research/environment/index.cfm?pg=prima</a>
JRC—European Commission	Monitoring tool linking the Water-Energy-Food Nexus and Sustainable Development Indicators for the Mediterranean Region	<a href="https://ec.europa.eu/jrc/en/science-update/new-monitoring-tool-developed">https://ec.europa.eu/jrc/en/science-update/new-monitoring-tool-developed</a>
FAO	The Nexus Assessment WEF Nexus rapid Appraisal tool	<a href="http://www.fao.org/3/a-i3959e.pdf">http://www.fao.org/3/a-i3959e.pdf</a> <a href="http://www.fao.org/energy/water-food-energy-nexus/water-energy-food-nexus-ra/en/">http://www.fao.org/energy/water-food-energy-nexus/water-energy-food-nexus-ra/en/</a>
CIHEAM	Various research and education programs and tools	<a href="http://www.iamb.it/about/bari_institute/l&amp;w">http://www.iamb.it/about/bari_institute/l&amp;w</a>
Plan Bleu	Various activities	<a href="http://planbleu.org/en/1st-edition-avitem-workshops-resources-and-urban-development-mediterranean-nexus-water-energy-food">http://planbleu.org/en/1st-edition-avitem-workshops-resources-and-urban-development-mediterranean-nexus-water-energy-food</a>
GWP	Country-level pilots	<a href="https://www.gwp.org/en/we-act/themesprogrammes/Nexus-Water-Food-Energy-Ecosystems/">https://www.gwp.org/en/we-act/themesprogrammes/Nexus-Water-Food-Energy-Ecosystems/</a>
GIZ	Nexus Dialogue Programme	<a href="https://www.nexus-dialogue-programme.eu/">https://www.nexus-dialogue-programme.eu/</a>

implementation of the WEF Nexus. We discuss in particular how to improve governance and collaboration among stakeholders and between stakeholders and governments, in order to optimally tap the potential added value that the Nexus can bring to the economic growth of the Mediterranean region.

## WEF NEXUS OPPORTUNITIES IN THE MEDITERRANEAN REGION

The Mediterranean is a diverse geographical area of different economic, social, political and environmental conditions. In recent decades, several policies and programs have striven for the more efficient use of natural resources and enhanced sustainability in agricultural production and food systems at country, sub-regional and regional levels. In general, however, as in most other regions in the world, water, energy and food production have historically been managed separately, with little consideration of cross-sectoral interactions. During the past decade, there has been an effort to introduce IWRM in regional, sub-regional and national policies, with a certain level of success. Overall, although the terms and provisions of the IWRM were introduced into laws and policies, practices have not advanced accordingly. At the same time, integrated approaches in the food sector have advanced, including toward more “crop per drop” and more “crop per Kwh.” Much of the new investment in the region was put into the energy sector, as an engine for development. Although such cross-sectoral approaches are currently not systemically incorporated in decision making, strong opportunities in this direction are being made available at the level of economic, public policy and institutional arrangements.

For instance, Daccache et al. (2014) modeled, mapped and quantified the links between irrigation demand, crop production and energy consumption in Mediterranean irrigated agriculture. Garrido et al. (2010) explored opportunities to alleviate water scarcity and increase water productivity of Spanish agriculture by reallocating agricultural water toward more productive crops.

Siddiqi and Anadon (2011) developed a Water-Energy Nexus approach to estimate the energy demands for freshwater supply in the Middle East and North Africa. In their review paper addressing water desalination in a Nexus perspective, Bazilian et al. (2011) concluded that the benefits of a holistic WEF Nexus would include better economic development conditions and overall welfare optimization of society in the Middle East and North Africa.

A WEF Nexus at the Mediterranean could be developed within multiple frameworks, such as the Post-2015 development agenda, the United Nations Framework Convention on Climate Change (UNFCCC), Union for the Mediterranean (UfM), Barcelona Convention (MAP UNEP), Regional Cooperation Council (RCC) contexts. In such cases, the Nexus can provide an analytical and innovative framework (complementing a new policy perspective) and a design principle for water, energy and food security policy. Research and development (R&D) could be an initial step in applying a WEF Nexus agenda, building on future planned actions, such as Horizon 2020 and the COST Action, and including the active involvement of the private sector.

A number of regional partners of various backgrounds, constituencies, and areas of focus, have launched and/or advanced regional programmes and initiatives that contribute to building mechanisms that support the Nexus approach at various levels. For instance, UfM, International Center for Advanced Mediterranean Agronomic Studies (CIHEAM), Center for Mediterranean Integration (CMI), Global Water Partnership-Mediterranean (GWP-Med), Association of Agricultural Research Institutions in the Near East & North Africa (AARINENA), and Plan Blue are some of these partners with various strategies to support Nexus perspectives toward sustainable development in the Mediterranean region. Further opportunities emerge in building cooperative agreements and dialogue platforms (established already by Plan Blue and UfM). In this context, Plan Blue has initiated a dialogue with many partners, which is already meeting the multi-disciplinarily perspective of the Nexus framework. As a starting point, a

Nexus-oriented platform for dialogue requires a road map and action plan supported by governments and stakeholders, which can be applied at regional, sub-regional, national, basin, or transboundary level. In this dialogue platform, all relevant actors (the public and private sectors, knowledge institutes and NGOs) should be included through a participatory approach. The Nexus dialogue can be also a strategic starting point for capacity-building activities and agreements to share data and information systems, as already set up in the Blue plan-SIMEDD database (the Mediterranean Information System on Environment and Development). However, due to the specific conditions of the region/sub-regions, it may be difficult to involve all the countries and establish a dialogue network along the lines of WEF sectors.

Food waste and changing dietary habits have large effects on the Nexus, which as yet have not been accounted for (Vanham et al., 2015). Lundqvist and Unver (2018) argue that commitments, such as those through SDGs cannot be treated in isolation from one another and alternative pathways chosen to attain them, as in the water and food systems, can take us to different, unintended ends. Throughout the Mediterranean region, ongoing dietary shifts are mostly translating into a move from vegetables, fruits, and legumes toward increased consumption of animal protein and sugar products. Such a movement away from the healthy Mediterranean diet has significant implications for water and energy use. As López-Gunn et al. (2012) described, dietary shifts of Spanish consumers have led to an increase in water consumption by 8%, while a shift to a Mediterranean diet could potentially lead to a saving of 750 liters/person/day in Spain (Blas et al., 2019). Such an increase not only adds to the pressure on existing water and land resources, but also poses a challenge from a health perspective. It is estimated that around 30% of food is wasted along the production, processing and consumption chain. FAO ([http://www.fao.org/fileadmin/user\\_upload/newsroom/docs/water\\_facts.pdf](http://www.fao.org/fileadmin/user_upload/newsroom/docs/water_facts.pdf)) provides a rough, average figure of one liter of water to produce one Kcal of food energy. The following is an example of a simple computation of water consumption in the Apulia region (southern Italy), which has a population of around four million people: considering that every person needs around 2,000 Kcal/day, and 30% of food is wasted, we have:

$$\begin{aligned} 2,000\text{l/person/day} \times 0.30 &= 600\text{l/person/d} \\ 600 \times 4,000,000 : 1,000 &= 2,400,000\text{m}^3/\text{d} \\ 2,400,000 \times 365 &= 876,000,000\text{m}^3/\text{year} \end{aligned}$$

Hence, around 875 million m<sup>3</sup> of water are lost every year, which corresponds to the total annual irrigation requirements for all the crops in the region.

Footprint assessments of natural resources, including water (Garrido et al., 2010; Dumont et al., 2013), have proven to be an effective tool for exploring options for their reallocation among sectors and promoting economic development. Also, such accounting for water facilitates exploration of the impacts of policy measures on water resources and the environment. For instance, Salmoral et al. (2011) showed that agricultural subsidies that aim to promote the productivity of woody crops, such as

olive trees in southern Spain, have led to increased groundwater abstractions for olive irrigation (an historically rain-fed crop) and increased pressure on local groundwater resources. Wichelns (2003) studied the role of public policy in motivating virtual water trade, stating that “countries in water-short regions may gain from trade by importing water-intensive crops, while using their limited water supply for activities that generate greater incremental values.” In the case of Egypt, he tried to identify the best policy to fit Egypt’s water-scarce yet highly productive agriculture sector. When planning which crops to invest in, farmers will most likely favor crops that give a high return on land value rather than on water value, irrespective of a better national option to import virtual water. Consequently, an understanding of the impacts of agricultural/food security and macro policies at the farm level can help to better formulate virtual water policies.

Novo et al. (2015) explored existing barriers and the government’s reluctance to take action to halt illegal groundwater use and adopt a Nexus approach to conciliate agricultural and environmental water use in the Upper Guadiana Region of Portugal and Spain. Their study showed that the largest share of the agricultural water footprint in the area is due to illegal groundwater use, which is contributing to unbalance the aquifer dynamics and causing large environmental trade-offs in a nearby wetland. Actions to halt this illegal water use, however, have been scarce, to a large extent because this region generates the largest farm revenues and is a major source of local employment. This situation largely explains the complexities surrounding the illegal use of groundwater resources and the reluctance of regional managers to take action in promoting a Nexus approach. Considering the energy dimension in groundwater pumping and transfer for irrigation aiming at optimizing uses, is within the Nexus approach pursues.

## GLOBAL NEXUS PROGRAMS AND EXAMPLES FROM OTHER REGIONS

A glimpse of the developments both globally and in regions provide the interest by the stakeholders and the potential for implementation. A recent review commissioned by Nexus Regional Dialogue Programme (Aboelnga et al., 2018) identifies a number of frameworks into which Nexus approaches can be incorporated as well as case implementations from various regions. The opportunities include Sustainable Energy for All (SEforALL, 2018) initiative launched by the former UN Secretary General Ban Ki-Moon to facilitate the achievement of SDG 7 (Ensure access to affordable, reliable, sustainable and modern energy for all), which uses a Nexus approach in its High Impact Opportunities platform to engage multiple stakeholders. The World Bank Group’s Thirsty Energy Initiative (World Bank Group, 2018), United Nations Economic Commission for Europe’s (UNECE, 2018) transboundary basin assessments, and United States Agency for International Development’s Grand Challenges for Development initiative (USAID, 2018) each uses a Nexus approach in assessing co-benefits and trade-offs and engaging stakeholders in selected implementation projects in different regions. The current portfolios include

South Africa, China and Morocco in the World Bank initiative; Alazani/Ganykh, Sava, Syr Darya, Isonzo/Soča, and Drina river basins in UNECE transboundary assessments; and two of the ten grand challenges of the USAID programme. The United Nations Economic and Social Commission for West Africa [United Nations Economic Social Commission for Western Asia (UN-ESCWA), 2017] lists a number of initiatives and arrangements in the Middle East and North Africa (MENA) region that use a Nexus approach, under the frameworks of the League of Arab States, the Arab Ministerial Water Council, and Arab Ministerial Council for Electricity.

Providing more evidence on global practices a recent JRC report (Barchiesi et al., 2018) presents examples of implementing the Water-Energy-Food-Ecosystems (WEFE) in various geographical regions: Africa, MENA and the Arab region, Central Asia, Latin America and the Caribbean. The paper of Gulati et al. (2013) explores the impacts of energy and water costs on food security in South Africa. Flachsbarth et al. (2015) explore the interlinkages between food production, water use and ecosystem services trade-offs in Latin America. In a similar way, Rasul (2014) developed a WEF Nexus approach for sustaining water, energy and food resources in South Asia, while preserving upstream river basin ecosystem services. Providing a different spatial view, Lawford et al. (2013) analyze the potential for advancing water sustainability, increasing understanding and collaborative governance approaches. Recently, Karabulut et al. (2016) evaluated the water provisioning services in the Danube, giving a spatially explicit quantification of the amounts and economic values of water used by the food, environment and energy sectors, with the aim of better understanding the trade-offs between the water needs of the different sectors.

## PRACTICES IN AND BARRIERS TO IMPLEMENTING A WEF NEXUS APPROACH IN THE MEDITERRANEAN

In this section, we analyze the emerging practices and conditions that either enhance or hamper the adoption of a cross-sectoral perspective for natural resource management as a particular sector of the WEF Nexus. In this context, we study the Mediterranean region with a focus on the Water perspective, including water market functions, technical considerations on the available data, trade-offs within the product supply chain, institutional barriers and governance arrangements. We then present specific “good” and “bad” practices that can influence the adoption of the WEF Nexus.

In economic terms, water is characterized as a common good that has no substitutes. The fair distribution of this particular resource is governed by social equity and efficient allocation. In the Mediterranean region, where freshwater resources are scarce and need to be allocated efficiently to supply the domestic, agricultural, energy and industrial sectors, the Nexus can provide ways forward through trade-offs and an understanding of the different stakes involved. Addressing productive sectors and related natural resources separately leads to high opportunity costs across different uses as well as increased transaction

costs between the Nexus sectors. Hence, when implementing (or developing) a WEF Nexus approach, the minimization of high transaction costs should be at the core of the considered economic measures. Furthermore, water provision and energy distribution have the characteristics of monopolies, which are highly regulated and produce both positive and negative externalities. Positive externalities may exist for water provision in terms of benefits to public health, while negative externalities may exist in energy and food production (point and diffuse pollution). With regard to water management, the pricing of water should include social, environmental and cultural values that are difficult to estimate or to translate into monetary terms. Water services are strongly subsidized in most regions of the Mediterranean, and water prices mostly reflect investment and maintenance costs but do not include the opportunity cost or scarcity of the resource. Although water pricing is a necessary instrument, it is not sufficient due to the inelastic nature of water demand (increasing prices cannot substantially decrease consumption) and the need to provide sufficient subsidies to lower the costs to households and farmers.

In general, the WEF Nexus has the potential to create new employment opportunities in the Mediterranean. However, there is some skepticism that the new jobs that can be created in the medium term will only be for a limited number of skilled workers, while unemployment might be created in other competitive sectors (e.g., agriculture).

A significant barrier to the technical implementation of the WEF Nexus is the absence of precise and uniform data for the whole Mediterranean region. The Shared Environmental Information System (SEIS) and the Mediterranean Information System on Environment and Development (SIMEDD) that have been provided by the European Environment Agency (EEA) to set up a uniform database and provide links to water related initiatives, papers, events, etc., require greater contributions from Mediterranean countries. Several countries have only low levels of data availability and accuracy, while detailed socio-economic and climate data are necessary to conduct a sectoral and intersectoral WEF Nexus analysis. Furthermore, some countries may be unwilling to share certain types of required data, as they could be considered nationally strategic.

Regarding the potential WEF trade-offs, as product systems are closely interrelated, actions at the local scale that aim to improve a certain area of the WEF Nexus may cause a shifting of burdens to other areas, ultimately leading to negative consequences for water, energy or food security. To prevent this, a lifecycle perspective should be applied when assessing the different policy options. Lifecycle approaches and methods are, for instance, widely used by industry to manage water risks. Impacts on water security are not only limited to production sites, but extend over the entire supply chain, especially in the case of agricultural products that often require large amounts of water and energy for their management and harvesting. The virtual water content of traded products may be a suitable indicator for measuring the trade-offs related to the supply chain. The lack of available lifecycle-based data to complement local databases for the Mediterranean region is a challenging issue that would need to be extensively improved in national accounting

systems. Similar considerations apply to the other elements of the WEF Nexus. Regarding energy, for instance, activities along the product supply chain, such as manufacturing operations and product transportation, strongly contribute to the energy and carbon footprints of the whole system.

Considerable institutional barriers also exist. The varying levels of engagement of, and trust in, some stakeholders in the Mediterranean region, including civil society, hampers the development of a Nexus approach that demands a high level of cooperation and mutual trust. The responsibility for water, food and energy domains is often assigned to different ministries, which hampers the close communication and coordination that is needed to deal with the WEF Nexus. Innovative partnerships (such as in Plan Blue) need to be improved at the pan-Mediterranean level, although this may be a challenge due to geographical, political and social differences within the region. Science and policy should cooperate to initiate and support the sound planning of solutions for addressing challenges through the WEF Nexus. However, there is traditionally a low level of cooperation between science and policy, which often express different goals, agendas and priorities. There is also some skepticism on the role of governments, which do not seem to be ready and fit to build a WEF Nexus approach. In such cases, R&D may help advance the Nexus dialogue, with national governments following on their interest and readiness.

Furthermore, the WEF Nexus would require the close involvement of the private sector. The private sector has specific knowledge about production processes, their management and the markets they operate in. As people in the private sector make use of natural resources or are in the business of producing or processing them, it is imperative that they be included in the dialogue on the WEF Nexus. As business depends on the availability of resources, such as water, it is also in their economic interest to be involved. In addition, they can also provide equipment and personnel, and contribute to funding R&D on Nexus solutions. Although many enterprises understand the need to innovate in order to maintain sustainable growth, they are slow to make the required connections with other relevant parties, such as the public sector and knowledge institutes. Many barriers can be identified, such as the lack of communication, poor mutual understanding or differences in the dynamics between the different sectors. Special effort is required to overcome these barriers in order to start a constructive discussion on how the different interests can be aligned into a project or program that will simultaneously enhance the business model of the entrepreneur and help to significantly reduce the WEF Nexus challenge. The conditions, bottlenecks and opportunities for the effective engagement of the private sector in fostering the Nexus should be analyzed, and ways forward should be suggested.

An example is provided by wastewater reuse. Different approaches and legislation can be found in the Mediterranean countries. The Italian legislation imposes very strict limits to the use of waste water in irrigation. This makes very difficult such use as costs for treatments are too high to be afforded by farmers. As a result, two different phenomena occur: (i) waste water is released

to the sea without any use, (ii) waste water is used illegally by farmers without any control.

Research can play an important role in better understanding the most appropriate limits to be respected, the types of irrigation systems that can be used and the types of crops that can be irrigated by wastewater without creating any health problems to the population. Overall, research results should better orient policy makers.

Bringing the analysis a step further, we have identified current “good” and “bad” practices that link water/energy/food security and ecosystem protection to investments, job creation, innovation and competitiveness in the Mediterranean region. It is recognized that some of these practices may not be applicable to or preferred by some countries; however, this does not diminish their added value as “food for thought.” These practices are summarized in **Table 2**, for practices with positive and negative/adverse consequences.

Practices with unintended and/or negative consequences often emanate from common, underlying origins. These include the complexities of setting and implementing different prices for different sectors that use the same resources; lack of cooperation between science, policy and the business sectors; lack of coherence and cooperation between various levels of government; limited number of success stories and guidelines to help promote innovative partnerships; and the level of public awareness and support for innovation.

## RECOMMENDATIONS AND THE WAY FORWARD

Although there is evidence that the WEF Nexus approach brings added value in terms of sustainable development, and that it is generating emerging interest, or even demand, from a number of countries and institutions, the most crucial step to be taken currently is to analyze and debate the related conditions, bottlenecks, opportunities and ways forward through structured dialogues that lead to action plans, including the identification of investments and pilot demonstrations. In our analysis, we reviewed the economic, institutional and policy aspects of the implementation of the Nexus, particularly from a Water perspective, that could help promote the economic growth potential of the Mediterranean region.

### Water Pricing

Currently often underestimated, water pricing is an important economic issue that affects the implementation of the Nexus, especially with regard to the agricultural sector, which is the main water user. Pricing is a necessary economic instrument whose efficiency depends on how it is conceived, designed and implemented, and which should be adapted within the WEF Nexus framework. Different water valuation and pricing approaches are in use in the Mediterranean with varying levels of success, corresponding to policy choices based on socio-economic perceptions and realities. Among others, the Water Framework Directive provides a range of water-pricing tools that are applied by law in the EU Member States and have

**TABLE 2** | Practices with positive and negative/adverse consequences.

Intervention positive or negative	Country	Practice	Source
De green deals (positive)	Netherlands. Government program that has been in effect since 2011.	Contracts involving coalition of companies, civil society organizations and local and regional government to stimulate innovative investments	<a href="https://www.greendeals.nl/english">https://www.greendeals.nl/english</a>
PPP for Nexus (positive)	United Kingdom. Research in Innovative public-private cross-sector multi-stakeholder partnerships.	Innovative partnership models, and developing, testing, and applying an innovative framework for the appraisal and evaluation of partnerships in food-energy-water-environment Nexus domains, with a particular focus on infrastructure projects.	<a href="https://www.innovativeppp.org/">https://www.innovativeppp.org/</a> Study with project-level implementation, funded by UK Research and Innovation.
Mediterranean research centers			
Support for water efficiency (positive)	Government support program with grants and zero interest credits.	Turkish farmers receive support from the Government on the condition that they use innovative irrigation and farming systems that increase the efficiency of irrigation water use and reduce the agricultural pollution of water resources.	<a href="https://www.tarimorman.gov.tr/Belgeler/ButceSunumlari/ButceSunumu_2018.pdf">https://www.tarimorman.gov.tr/Belgeler/ButceSunumlari/ButceSunumu_2018.pdf</a> Support extended to 108,000 ha in grants and 670,000 ha in credits between 2006 and 2016.
Full cost pricing and extra service-based fees (positive)	Various	Environmental fees (e.g., in Israel, Greece, Portugal). Escalating irrigation fees (France)	
WEF in practice (positive)	Portugal	(1) Water-use-efficiency labeling on household appliances  (2) Association of textile and clothing firms  (3) IBET, a private non-profit research introduced the WEF nexus as an important research topic.	(1) Potential water savings of up to 45% with additional energy savings in water heating and water supply; (2) Promotes water and energy use optimization; (3) Links universities and firms for nexus research-implementation.
Willingness to pay, WTP (positive)	Academic study in West Bank of the Palestinian territories	Efficient allocation mechanisms based on WTP with key socio-economic variables suggested by economic theory are non-existent in Palestine.	<a href="https://www.sciencedirect.com/science/article/pii/S1053535712000546">https://www.sciencedirect.com/science/article/pii/S1053535712000546</a> Possible input for reforming allocation mechanisms.
Nexus in Government structure (positive)	Lebanon	Lebanon has the potential to lead nexus implementation given its integrated Ministry for Water and Energy.	
Support for water efficiency (adverse)	Turkey	Subsidies to farmers for reducing fertilizer and chemicals use and subsequently reducing water pollution in some cases decreased agricultural productivity and farm income.	Negative effects of internalizing the external costs. Input for policy revision.
Gradual quotas and prices (negative)	Israel	Scheme of gradual quotas and prices linking water consumption to price stipulates that if farmers do not use all of their quotas, their future quotas are reduced. This poor design is an obstacle for efficient water use.	The actual situation behind reduced quotas is more complicated as the country is severely water scarce.
Solar power for irrigation (positive)	Lebanon	A farm-level case study was carried out in Lebanon of a 120,000 m <sup>2</sup> organic farm in the western Bekaa valley, where the owner would spend \$200,000 annually on upkeep and maintenance. Nearly a quarter of that went toward electricity expenses, the bulk of which was for the irrigation system. He introduced 64 solar panels measuring 1.5 m <sup>2</sup> for solar-powered irrigation. By switching to solar power, the farm became self-sustaining and profitable.	Anderson (2009)

been voluntarily adopted in south-east Europe; other countries may be interested in exploring and adapting such tools to their national needs. Although the implementation of efficient water prices among sectors is a complicated affair, it also provides an opportunity for the WEF Nexus to incorporate externalities (environmental, social, cultural costs, opportunity costs) in a full-cost manner and apply a total economic value. In this context, we can go beyond abstraction costs, and include environmental

costs, wastewater treatment, and the preservation of resources and ecosystems. Moreover, prices have to be connected to specific uses and levels of use, introducing block tariffs and supplementary fixed tariffs. Additionally, water prices should reflect not only the cost of providing the service but also the opportunity costs, which will define the foregone benefits of those not using the water resources. In this context, water pricing based on economic principles can support political decisions and policy



making, and at the same time provide crucial information and incentives for businesses to invest in the water supply.

## Market Economic Instruments

Additional appropriate economic instruments (taxes, property rights, subsidies, etc.) can be selected as a toolbox that addresses various specific needs in the Mediterranean in order to promote allocation efficiency, the transfer of advanced technology and equity. Prior to applying any instrument, it is first necessary to identify the market structures, technological dimensions and the involved stakeholders. For example, although subsidies can lead to inefficient water management and use if applied to water consumption, they could prove useful in promoting WEF technology investments and could be combined with other mechanisms, such as lowering taxes on those investments. Economic efficiency or Pareto efficiency can be achieved when the marginal cost-pricing rule, which means the incremental cost of supplying an additional unit (marginal cost) equals the incremental amount that will be paid for a volume of water (marginal willingness to pay). In other words, Rogers et al. (2002) states that when water is priced at its real marginal cost, including environmental costs, it is put to its highest economically valued use. As an extra tool, awareness campaigns should be promoted since they can have very good results concerning water and energy savings by inducing advanced technologies.

## Integrated Evaluation Approaches

Regarding specific integrated methods for evaluating the economic effects of the WEF Nexus, in complement to the Cost Benefit Analysis, Cost Effectiveness with clearly defined objectives can be used as a tool to choose the optimal choices in the WEF Nexus. Alternatively, stated preference methods (Contingent Valuation and Choice Experiments) and “Benefit Transfer” methods can be further and more widely used to assess the specific welfare effects of the WEF Nexus application.

## Financing the WEF Nexus

Financing the WEF Nexus is another considerable component of economic growth. The public sector is the appropriate institutional body for providing a holistic orientation and long term perspective of the WEF Nexus, as well as for appropriating funds to support the initiation and establishment of a WEF Nexus approach. In this case the use of public funds should be justified with a specific investment plan that incorporates reduced opportunity costs to other public investments. Generally, Nexus investments can potentially be justified when they are profitable and low risk in terms of economic and social welfare, regulated by the state. However, the participation of the private sector is indispensable, involved already at the planning phase and the R&D process. Overall, it is essential to encourage the involvement of the private sector from the beginning in the planning phase, because its knowledge is important for providing sustainable market solutions, innovations, and better operational arrangements. Public-Private Partnerships, although debatable, should be fostered in a consistent manner providing a factor for either further increasing welfare or achieving the same goal more efficiently and cost effectively. If there are no

obstacles and uncertainties and profitability emerges, then firms will invest without public involvement. However, when market conditions are not conducive to investments by private firms, government, universities and knowledge institutes should still invest for public welfare, and market-related shortcomings and share funding uncertainties should be corrected through the appropriate policies. An example of financing Nexuses are the investments in multiple-use water supply systems that support different user needs (water for Water, Sanitation and Hygiene (WASH), water for irrigation, water for small-scale hydropower, water storage for climate change mitigation, healthy wetlands, and aquatic ecosystems), improving people’s access to and effective use of water resources. However, this should also be accompanied by training sessions, capacity and trust building, and most importantly, in dialogue with the people eventually benefitting or losing from these investments.

## WEF Contributing to New Job Opportunities

Regarding the emergence of new employment opportunities, there is a need to accelerate the process of water management in that direction. Investment at R&D on Nexus approaches could also on its own induce a positive economic effect by creating more jobs while providing solutions. Investing in new efficient technologies (e.g., renewable energy for water-related activities and innovative farming practices for water and energy efficiency in agriculture) within a Nexus approach can create job opportunities, or at the least prevent job losses for several sectors in a region. In defining the right focus for R&D it is important to have good links between the knowledge parties and the technology users. To prevent purely academic exercises, research linked to viable business cases is needed and real life demonstrations, adopting a bottom-up approach before upscaling, can be considered. Further development of and innovation in the agricultural sector can play a central role in enhancing Nexuses, while in parallel mainstreaming and coordinating across sectorial policies. Other sectors could be further developed, attracting additional investments and producing new jobs within a Nexus framework, such as monitoring and auditing. Furthermore, desalination technologies and the smart use of ecosystems (wetlands) to collect and store water and carbon could also provide positive economic opportunities. The role of governments is of great importance for the Nexus implementation, since they can speed up the process by providing funding or subsidies for new technologies that contribute to the welfare of society which otherwise would not easily reach the markets.

The creation of jobs depends on the sector to which water is allocated (e.g., water for irrigation can provide more jobs than hydropower energy production). However, there should be a balance between efficiency and equity in the employment opportunities created. Promoting a better policy for water resource allocation through the use of the Nexus approach could also have a negative impact on employment. Given that at present in the Mediterranean countries, especially those in the south, the water sector receives substantial public subsidies in

order to maintain the well-being of users, any attempt toward rationalization, which requires a reduction in subsidies, will lead to a direct deterioration in the employment situation. The implementation of the Nexus should explicitly take account of this and do everything possible to alleviate it.

## Data Availability and Management

Concerning the data issue, which should be a priority for policy-makers, a WEF Nexus based on a holistic economic and environmental perspective should use consistent, reliable and comprehensive data as well as sound scientific references. It is also imperative that data across the nexus sectors are comparable in terms of accuracy and resolution. Accurate economic databases could further support the setting of efficient water prices. Moreover, precise data needs to be collected and maintained for agricultural and energy production and technology at various levels, including throughout the supply chains of goods and services concerned. Research and scientific institutions can initiate the collection of open data and other stakeholders can join the process, in order to build a sustainable database for analyzing the Nexus. It is imperative to invest in collecting highly disaggregated micro data, with the distinction for example between farmers benefiting from highly subsidized water in terms of price and farmers who mobilize their water supplies themselves, bearing all the costs related to water pumping. The collection of such data would substantially improve the estimation of the price elasticity of water demand, and thus serve as a solid basis on which to define tariff policy.

## Institutional Settings

Analyzing the institutional arrangements, partners could further support the establishment of a Nexus framework by sharing experiences, utilizing regional Institutions, promoting stakeholder involvement (including civil society), networking and strengthening trust and capacity building. Supporting the WEF Nexus is not a matter of defining new institutions, but more of how existing institutions are managed and interlinked. The human resources capacity sometimes limits the most representative and sustainable lines of action. Therefore, it is important to structure institutions around efficient management frameworks and allow integration of the concept “sustainable ownership.” It is necessary to promote innovation as one of

the key topics in establishing solutions to the WEF Nexus. The participation of regional institutions in global forums on innovation and Nexus dialogues is essential. Fostering linkages between science and policy is necessary for good governance and management, where institutions coordinate at a national level and participate in capacity building and cooperative activities at a regional level. To this end, institutions from all sectors involved should set a common WEF Nexus policy, which will be integrated into universities’ research agendas. Furthermore, civil society could support two strategic measures: awareness and monitoring for enforcement; governments should have the central role in evaluating and enforcing the agreed WEF Nexus provisions.

## Dialogue

Organized dialogue is another keystone of the WEF Nexus framework. Added value can be generated only through partnerships between the public sector, the private sector, knowledge institutes, NGOs and regional stakeholders. A Nexus dialogue process can start at the macro-regional level and then continue at higher levels. Dialogue at the macro-regional level can be organized by existing regional institutions, concentrating on success stories to promote greater use of these applications and/or to scale them up. The Mediterranean countries can then transfer this expertise through their reviewed internal national dialogue to their regional institutions to complete the dialogue chain. Initiating the dialogue between countries and introducing the Nexus at a macro-regional level first is more representative of the conditions and less clouded by conflicts. In this context, dialogue capacities can be built through regional and national activities and can be targeted to both national and regional partners/stakeholders.

## AUTHOR CONTRIBUTIONS

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