

On the quest of solutions to achieve a ‘virtuous’ WEF nexus in the Mediterranean region

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Introduction

Providing water, energy, and food to all, while staying within the limits of ‘planetary boundaries’ is considered a prerequisite to survive in the new geological epoch: the Anthropocene. This awareness has led a significant body of literature to consider water, energy, and food systems as intricately linked and, as such, to be understood and managed in conjunction, through the so-called water-energy and food (WEF) nexus approach, especially in a context of scarcity of fundamental resources for human well-being and in a scenario in which the impacts of climate change become increasingly intense and frequent.

The Mediterranean region could be considered both a water, energy and food (WEF) nexus and a climate change ‘hotspot’ (Mohtar and Daher, 2014; Id., 2016; Dubreuil et al., 2013; Saif et al., 2014; Magazzino and Cerulli, 2019). WEF resources as well as WEF nexus and climate change are strongly interlinked through multiple bidirectional interactions. So far, Mediterranean countries’ approach to WEF policy and decision-making has been largely supply-oriented, in silos, and completely disconnected with climate change issues, triggering an inefficient circle that has favored trade-offs rather than synergies across resources, sectors, and societal and environmental goals. These challenges call for a paradigm shift to turn the conventional WEF nexus into a virtuous circle.

Starting from the concept of WEF nexus and the status of the main characteristics of the nexus in the Mediterranean region, this paper aims to detect the barriers and the opportunities to turn the WEF nexus from a vicious circle of trade-offs into a virtuous circle of synergies that feed each other. To face this challenge, several actions are identified and specific recommendations are drawn for the way forward.

The nexus approach and its evolution

The WEF nexus is often presented as an evolution and improvement of the existing integrated water resources management (IWRM) as it promotes a multi-centric approach connecting water, energy, and food policy objectives. Being a relatively new concept and being complex due to the interlinkages between water, food and energy, the nexus has no clear definition and no agreed conceptual framework for implementation.

Unesco has outlined some key principles of the WEF nexus that can be summarized as follows (Carmona-Moreno et al., 2021):

- understand the interdependence of resources within a system across space and time and focus on the whole system’s efficiency rather than the productivity of individual components;
- provide integrated solutions that contribute to the sustainability of water, energy, and food security objectives;
- recognize the interdependence between water, energy, and food and promote rational and inclusive dialogue and decision-making processes;
- identify integrated policy solutions to encourage mutually beneficial responses optimizing trade-offs and maximizing synergies across sectors;
- ensure coordination across sectors and stakeholders to enhance the potential for cooperation between all components.

The term ‘nexus’, therefore, is three-dimensional and contemporarily describes a discourse, a conceptual governance framework, and a mix of analytical tools (Harwood, 2018; Nhamo et al., 2019). First, as a discourse, it provides a systemic understanding of the interconnections of the WEF

resources. The logic behind the nexus comes from the awareness that WEF resources are closely intertwined and interdependent since there is no energy production without water, no water supply without energy, and no food production without water and energy. It then follows as a corollary that impacts on one resource, whether from the demand or supply side, affect all others and thereby, the entire production or consumption chain. Second, as a governance framework, it draws attention to the interdependencies between the management of different WEF resources and raises questions on the limits of single-resource integrated governance models like IWRM (Pahl-Wostl, 2019). Since sectoral policies cannot address trade-offs nor leverage synergies among the wicked nature of water, energy, and food interdependencies, the WEF nexus considers water, energy, and food as subsystems of a same framework rather than as independent ones, offering an integrated and systemic approach to address interactions (Harwood, 2018). As an analytical concept, the nexus calls for interdisciplinary communication between complex system methods capable of quantifying relations between resources (Zhang et al., 2018) and for policy instruments able to effectively address complex problems (Vennghaus and Hake, 2018). Accordingly, as stated by Lazaro et al. (2021, p. 9) “The nexus approach is seen as a transformative and shifting paradigm from the traditional ‘silo’ thinking approach, to a new model of doing business and decision-making wherein policy integration for resource management processes can increase the efficiency of natural resource use.”

An additional rationale for adopting the WEF nexus is that it is a mechanism for achieving the relevant sector-related Sustainable Development Goals (SDGs), i.e. SDGs 2 (zero hunger), 6 (clean water and safe sanitation), 7 (affordable and clean energy) and 13 (climate action). Brouwer et al. (2018) claim that "the Nexus concept is a sound tool to support the sustainable management of resources across sectors, suitable for addressing the challenge of the next few years, namely achieving the SDGs."

While the WEF nexus has tremendous potential for increasing efficiency, reducing trade-offs, building synergies and improving governance across sectors, the application and diffusion of such a framework face several challenges, particularly with respect to migrating from its theory and modeling to real-life applications. Cairns and Krzywoszynska (2016) argue the term ‘nexus’ can be currently seen as a ‘buzzword’ and various recent studies claim that the approach has not lived up to its potential (Albrecht et al., 2018; Galaitsi et al., 2018). These critiques emphasize the need for an effective transition from ‘nexus thinking’ to ‘nexus doing’, highlighting the relevance of the WEF nexus as a conceptual framework and as a discourse, but lacking in analytical tools that can be used to provide real-world solutions (Liu et al., 2021; Nhamo et al., 2018).

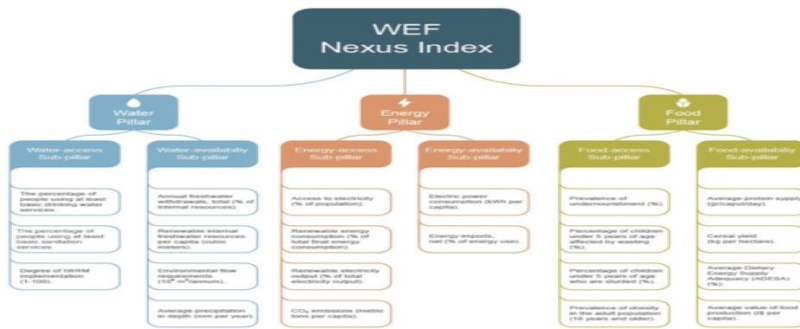
A first step in transitioning an integrated WEF nexus program from concept to action in the Mediterranean region is to fill the gap in integrated data, holistic information and knowledge related to the most critical inter-linkages and their dynamics. To this end, the WEF Nexus Index represents an effective tool to assess and quantify constraints and opportunities at the regional and country levels and a first step to achieve a ‘virtuous’ WEF nexus in the Mediterranean.

The Water-Energy-Food Nexus assessment in the Mediterranean region

Holistic acquisition and accessibility of data is recognized as a limiting factor to a successful implementation of the WEF assessment and the achievement of efficient and sustainable WEF nexus design. The main difficulties are related to the fact that a system that includes water, energy, and food-related parameters is complex not only because these resources are quantified utilising different units, but also because they vary significantly over time and space. One means of integrating sectoral resources which are measured in different units and time scales is through the development of a composite indicator. To this end, the WEF Nexus Index provides an entry point for the evaluation of the status of a nation in terms of integrated resource management and offers a first step for evaluating trade-offs and synergies, supporting policy and decision-making processes.

This composite index comprises the three resources sectors by means of individual indicators addressing the ‘access’ and ‘availability’ sub-pillars (Fig. 1).

Fig. 1. Schematic layout of the WEF Nexus Index, with its constituent pillars, subpillars, and indicators



Source: Simpson, 2020.

By exploring the underlying pillars, sub-pillars and indicators, the Mediterranean countries’ status in terms of access to and availability of water, energy and food becomes evident, also emphasizing the remaining work required for this region to attain the SDGs. As it emerges from table 1, which presents WEF Nexus Index, ranks, pillar and sub-pillar values for some Mediterranean countries, the highest-ranking, in terms of the WEF Nexus Index, in SEMCs, are Turkey and Israel with global ranks of 82th and 83th, respectively and the two lowest-ranking SEMCs are Syria and Libya, 159th and 165th, respectively. In NMCs, the two highest-ranking are France (17th) and Albania (22th) while the two lowest-ranking are Spain (54th) and Portugal (63.4th).

Table 1. WEF Nexus Index, ranks and pillar values for several Mediterranean countries, 2021

Country	WEF Nexus Index	WEF World Rank	Water pillar	Water pillar world Rank	Energy pillar	Energy pillar world Rank	Food pillar	Food pillar world Rank
SEMCs								
Israel	59.6	83	58.9	100	50.2	139	69.6	22
Turkey	59.6	82	67.9	58	45.6	153	65.3	39
Algeria	57.1	102	51.5	132	59.0	84	60.7	65
Tunisia	56.0	109	54.1	119	51.7	128	62.3	56
Egypt	53.1	125	40.3	164	61.1	64	57.8	78
Morocco	52.1	131	57.9	105	38.1	172	60.4	68
Lebanon	45.2	156	51.0	137	36.7	173	48.0	128
Jordan	45.1	157	52.2	127	36.5	174	46.5	136
Syria	44.8	159	52.6	125	44.5	156	37.2	164
Libya	42.6	165	50.9	138	53.9	113	23.1	176
Average	51.5		54.5		47.7		53.1	
NMCs								
France	69.7	17	76.3	21	59.1	80	73.7	7
Albania	68.5	22	67	65	69.4	24	69.2	24
Slovenia	66.7	33	74.5	25	58.8	91	67.3	67.3
Greece	63.9	53	70.5	39	51.8	126	69.5	23
Italy	63.9	52	71.2	38	49.6	142	71.0	14
Spain	63.9	54	70.5	40	51.1	132	70.0	20
Portugal	63.4	60	68.6	53	50.8	133	70.7	17
Average	65.7		71.2		55.8		70.2	

Source: Elaboration from the WEF Nexus Index, <https://www.wefnexusindex.org>

The average water, energy, and food pillar scores for SEMCs are 54.5, 47.7, and 53.1, respectively. The water pillar is, therefore, the highest-ranking pillar of the three, on average, while the energy pillar scores the lowest, on average, for SEMCs. The nation with the highest pillar value is Turkey (water pillar = 67.9), with Egypt having the highest value for the energy pillar (61.1), and Israel having the highest value for the food pillar (69.6), showing the relatively good access and supply of these resources to those countries’ populations. Two nations, Syria and Libya, have food pillar values

below 40, highlighting that in the lower ranking countries, food is generally the lowest ranking pillar. Conversely, NMCs perform better in all pillars, especially in water and food.

Access to basic drinking water and sanitation services has improved in SEMCs since 1990. However, as data show (table 2), several countries still have a significant share of population that does not have access to water and sanitation. There is, therefore, much work remaining within SEMCs to achieve SDG 6 by 2030. Regarding the degree of IWRM implementation, i.e., SDG indicator 6.5.1, Lebanon, Egypt and Algeria have values below 60, illustrating the relatively weak adoption of water integrated principles within national policies, institutions, management tools and financing. In a specular way, the same trends are also reflected in terms of water availability, highlighting how often, in these countries, a natural scarcity of water resources is associated with strong human pressure. In contrast, NMCs, except for Albania, show higher percentages in terms of access to drinking water and basic sanitation services as well as higher values regarding the degree of IWRM implementation.

Table 2. Water sub-pillar values for several Mediterranean countries, 2021

Country	Water access sub-pillar			Water availability sub-pillar			
	People using at least basic drinking water services (%)	People using at least basic sanitation services (%)	Degree of IWRM implementation (1-100)	Annual freshwater withdrawals, total (% of internal resources)	Renewable internal freshwater resources per capita (m ³).	Environmental flow requirements (10 ⁶ m ³ /yr)	Average precipitation in depth (mm/yr)
SEMCs							
Israel	100	99.9	85	159.7	86.1	0.6	435
Turkey	97	99.2	72	26.4	2,798.4	77	593
Algeria	94.4	86	54	87.1	271.8	4.6	89
Tunisia	97.5	97.4	60	113.7	366.9	0.7	207
Egypt	99.4	97.3	42	6,420	10.4	2.6	18.1
Morocco	90.4	87.3	71	36.5	815	8.2	346
Lebanon	92.6	99.2	25	37.8	703.9	1.4	661
Jordan	98.9	97.1	64	132.5	69.7	0	111
Syria	93.9	89.7	56	195.8	417.2	5.6	252
Libya	99.9	92.1	60	817.1	106.4	-	56
NMCs							
France	100	98.6	100	13.2	2,988.7	97.8	867
Albania	95.1	99	47	4.4	9,361.5	13.6	1,485
Slovenia	99.5	98.1	87	5	9,035.1	17.1	1,162
Greece	100	99	86	19.4	5,393	19	652
Italy	99.9	99.9	77	18.7	3,014.7	77.8	832
Spain	99.9	99.9	87	28.1	2,386.6	38.2	636
Portugal	99.9	99.6	72	24.1	3,689.2	27.6	854

Source: Elaboration from the WEF Nexus Index, <https://www.wefnexusindex.org>

Regarding the level of access to electricity (SDG indicator 7.1.1), in SEMCs, Israel, Turkey, Tunisia, Egypt and Jordan provide access to electricity for their entire population, while only 68.5% of Libya's population has access to electricity. In terms of renewable energy consumption (SDG indicator 7.2.1), an average of 3.3% of the total final energy consumed is classified as being renewable for SEMCs. Similarly, on average, only 7.2% of the total electricity output is renewable, highlighting their dependence on fossil fuels. Higher percentages, but still far from achieving the goals set by the Paris Agreement, are registered in NMCs.

The indicator "Energy imports, net as percentage of energy use" measures the degree of independence in terms of energy supply at country level, which provides a perspective of energy security. Except for Algeria, Libya and Egypt, all countries are net importers of energy, a phenomenon that highlights the extreme vulnerability of Mediterranean countries, especially NMCs, to volatility in energy markets.

Table 3. Energy sub-pillar values for the Mediterranean countries, 2021

Country	Energy access sub-pillar	Energy availability sub-pillar
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	Access to energy (% of population)	Renewable energy consumption (% of total final energy consumption)	Renewable electricity output (% of total electricity output)	CO ₂ emissions (metric tons per capita)	Electric power consumption (kWh/capita)	Energy imports, net (% of energy use)
SEMCs						
Israel	100	3.7	1.9	7	6,600.9	64
Turkey	100	1.9	32	5	2,847.2	75.2
Algeria	99.5	0.2	0.3	3.6	1,362.9	0
Tunisia	100	11.9	2.8	2.6	1,454.6	36.2
Egypt	100	4.7	8.3	2.5	1,6832.2	0
Morocco	99.6	10.8	14.3	1.9	904.4	90.7
Lebanon	100	4.7	2.6	4	2,588.9	97.9
Jordan	100	7.2	1	2.5	1,864.9	96.8
Syria	89.3	0.9	2.3	1.6	974.6	47.8
Libya	68.5	2.6	-	8.8	1,811.1	0
NMCs						
France	100	15.3	15.9	4.6	6,939.9	44.1
Albania	100	38.3	100	1.9	2,309.4	13.8
Slovenia	100	21	29.4	6.8	6,728	48.5
Greece	100	17.7	28.7	6.1	5,062.6	64.2
Italy	100	17.1	38.7	5.4	5,002.4	76.4
Spain	100	17.4	34.9	5.5	5,356	71.4
Portugal	100	27.6	47.5	4.8	4,662.6	76.9

Source: Elaboration from the WEF Nexus Index, <https://www.wefnexusindex.org>

As noted above, the food pillar is generally the lowest scoring in SEMCs. In terms of the availability of food, two critical indicators are the cereal yield (kg/ha) and the average value of food production (I\$/capita). In SEMCs, while three countries, Israel, Lebanon and Turkey, have cereal yields that exceed the global median of 3,032 kg/ha, many of the remaining SEMCs have very low crop yields. Unlike what is found in the NMCs, low agricultural productivity affects all pillars of food security (availability, access, utilisation, and stability) as shown by the still high percentages of undernourishment and children under 5 years of age who are stunted.

Table 3. Food sub-pillar values for the Mediterranean countries, 2021

Country	Food access sub-pillar				Food availability sub-pillar			
	Prevalence of undernourishment (%)	Children under 5 years of age affected by wasting (%)	Children under 5 years of age who are stunted (%)	Prevalence of obesity in the adult population (18 years and older)	Average protein supply (grams/capita/day)	Cereal yield (kg/ha)	Average Dietary Energy Supply Adequacy (ADESA) (%)	Average value of food production (I\$/capita)
SEMCs								
Israel	2.5	0.8	2.6	26.1	125	3,035.4	154	112
Turkey	2.5	1.7	-	32.1	109.3	3,163.9	156	159
Algeria	2.5	2.7	9.3	27.4	92.3	1,758.8	151	72
Tunisia	3	2.1	8.6	26.9	99.7	1,428.9	147	112
Egypt	5.4	9.5	22.3	32	97	7,148.5	141	79
Morocco	4.2	2.6	12.9	26.1	99.7	2,263.6	144	74
Lebanon	9.3	6.6	10.4	32	69.3	3,155.6	119	52
Jordan	9.5	2.4	7.3	35.5	70	1,506.4	116	48
Syria	-	11.5	29.6	27.8	-	1,204.7	117	103
Libya	-	10.2	43.5	32.5	-	660	-	58
NMCs								
France	2.5	0.8	2.6	21.6	108.7	6,884.6	141	187
Albania	3.9	1.6	9.6	21.7	116.7	4,840.5	137	161
Slovenia	2.5	0.8	2.6	20.2	97	6,052.4	129	103
Greece	2.5	0.6	2.2	24.9	106	3,798.6	135	218
Italy	2.5	0.8	2.6	19.9	104.3	5,264.6	140	156
Spain	2.5	0.8	2.6	23.8	107	4,067.8	134	218
Portugal	2.5	0.6	3.3	20.8	114.3	4,756.1	140	140

Source: Elaboration from the WEF Nexus Index, <https://www.wefnexusindex.org>

Whilst the high-level comparative analyses above are illustrative of the progress achieved in the different components of the WEF nexus, they tell us nothing about the interconnections between the different nexus sub-systems and, consequently, about the possible trade-offs and synergies that characterize the WEF nexus at different spatial and temporal scales. From this point of view, the WEF Nexus Index should be considered a first step towards a more in-depth analysis. In particular, WEF Nexus Index assessments should be combined with other quantitative and qualitative research to broaden the analysis beyond the scope of the constituent indicators to highlight barriers and opportunities in turning the WEF nexus into a virtuous circle.

Barriers and opportunities to implementing a WEF Nexus approach in the Mediterranean

In the Mediterranean region, water, energy and food are perhaps more closely connected than in any other region of the world. As WEF resources become increasingly scarce due to climate change, demographic pressure and economic growth, political instability, and forced migration, not only the nexus interlinkages intensify, but also direct competitions or trade-offs between sectors increase, limiting countries' ability to meet the growing demand in a sustainable manner (Markantonis et al., 2019).

Strong governance and institutional innovations are critical for navigating trade-offs and identifying appropriate policy interventions that achieve equitable nexus solutions. So far, in the Mediterranean countries, water, energy and food challenges are mainly addressed within the sectors concerned. 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. This 'silos' approach leads to policies and strategies that focus primarily on individual sectors, rather than considering the broader cross-sectoral impact. The lack of coordination, dialogue and collaboration among sectors significantly affect the efficiency and effectiveness of policies and also prevent appropriate measures from being taken (Giordano and Quagliarotti, 2020).

In addition, climate change both affects and is affected by the WEF nexus through multiple bidirectional interactions that intertwine within the web of WEF interconnections (Rasul and Sharma, 2016). In particular, climate change drives a series of phenomena that have negative effects on water, energy and food security, exacerbating nexus conflicts within the region: rising temperatures, changes in precipitation patterns, extreme weather events, and sea-level rise may gradually alter the balance between the nexus resources, and even the nature of their interactions (Cramer et al., 2018). Moreover, current sectoral approaches to climate change mitigation and adaptation may amplify rather than reduce negative externalities and trade-offs within the nexus. While some sector-oriented mitigation and adaptation measures may have the potential to trigger synergistic 'win-win' opportunities across one or more of the other sectors in the nexus, other measures, such as hydropower, first generation biofuels, the shift to non-conventional water resources, and agricultural intensification, are not always nexus-smart. At the same time, water, energy and food production may increase GHG emissions contributing to climate change.

As several nexus studies point out, the need to meet the rapidly growing demand for water, energy and food in an increasingly resource-constrained scenario, associated with WEF conventional policy and decision making in 'silos', have fueled a vicious circle that has ended up favouring trade-offs rather than amplifying synergies between sectors (Shannak, Mabrey & Vittorio, 2018).

In the Mediterranean region, turning the WEF nexus from an inefficient cycle of scarcity, competition, conflict and instability into a virtuous cycle of resilience, sustainable resources management, cooperation and security is a prerequisite to allow countries to implement their commitments under the Paris Agreement and Agenda 2030 and to strengthen countries' ability to deal with the impacts of climate change. To face these challenges several actions have been identified.

Mainstreaming climate change into the WEF nexus and decouple water, energy and food from fossil fuel

At the outset, it is necessary to add into the WEF nexus the climatic dimension. Mainstreaming climate change into the nexus involves the identification and quantification of the bidirectional interactions between WEF resources and climate change as well as the adoption of nexus-based mitigation and adaptation approaches, which integrate a nexus perspective into climate change policy and strategies. In this regard, a critical role can be played by technology and innovation. Since the WEF nexus includes the main drivers of climate change and the main sectors affected by the impact of global warming, and energy represents both a critical input along different stages of the water and food supply chain as well as the largest source of GHG, renewable energy technologies should be considered the first step towards sustainable integrated solutions able to enhance security and sustainability across sectors, while supporting global climate ambitions. The development of non-conventional water and energy sources, i.e., desalinated water and renewable energy, could address water and energy security challenges by combining economic efficiency and social equity under the constraint of environmental protection (Giordano and Quagliarotti, 2020). Especially in SEMCs, renewable energy technologies may provide access to a cost-effective, secure and environmentally sustainable supply of energy, simultaneously triggering spill-over effects in the water and food sectors. SEMCs have a high potential in renewable energy development, especially solar, for the presence of vast desert lands with a solar radiation density ranging between 1,300 and 2,500 kWh/m² per year (IRENA, 2015). Generally, renewable energy technologies are less water intensive than conventional options. Water needs for solar photovoltaics (PV) negligible compared to conventional thermoelectric generation, withdrawing up to 200 times less water to produce the same amount of electricity (IRENA, 2016). In addition to contributing to significant water savings, clean energy can be used to increase non-conventional water supply, such as desalinated water, whose production is still affected by high economic and environmental costs because of the considerable amount of fossil energy necessary to feed the reverse osmosis. Great opportunities emerge from those projects aimed at increasing renewable energy to optimize the link between clean energy, food, and unconventional water. The use of renewables would not only satisfy the energy demand of those countries that do not have sufficient oil reserves, but also improve the resilience and adaptive capacity of those countries that due to environmental constraints and the scarcity of two strategic resources for human well-being – water and food – are more vulnerable to the impact of climate change. In the Mediterranean countries, projects based on a nexus approach still are at their early stages of development. This is understandably due to the need for large capital investment, lack of know-how and of enabling environment for innovation, and many other relevant factors.

To enhance the transition towards a mix of renewable energy and non-conventional water, several measures and actions should be undertaken, such as reforming the subsidy and tax system to ‘internalise’ environmental and social costs (Burnett and Wada, 2018); encourage the development of renewable energy technologies with the help of international financing, the development innovative means of financing, and the removal of institutional, technical, regulatory and economic barriers (Halalsheh et al., 2018); strengthen the nexus between non-conventional energy (renewable) and water sources (treated wastewater and desalinated water) to address both climate change mitigation and adaptation; promote cross-sectoral projects; and incorporate the key principles of green and circular economy into the WEF nexus through multi-functional production systems and cross-resources and cross-sector recycling.

Encourage WEF Nexus cooperation at the regional and sub-regional levels

Given the variability in the distribution of WEF resources in the region as well as the ever-increasing pressures on them, and since WEF solutions found at the local level can often transcend regional and

national borders, it is of great significance that the Mediterranean countries enhance their cooperation to face these challenges in a complementary manner. However, there is traditionally a low level of cooperation between countries, which often express different goals, agendas and priorities in addressing the complex nexus between WEF sectors.

Nevertheless, in the last decade, key regional and sub-regional institutions have addressed or expressed an interest in exploring the Nexus approach, including the European Union (EU), the Regional Cooperation Council (RCC), the League of Arab States (LAS), the Union for the Mediterranean (UfM), and the Barcelona Convention (MAP/UNEP). Even though their plans generally follow the same silo thinking within the different sectors, many of their objectives may present an opportunity for improving cooperation between Mediterranean states in a nexus approach. At the EU policy level, the WEF nexus is considered in the Renewable Energy Directive, the Green Infrastructure Communication, and is in line with the vision and the objectives of the EU Green Deal, which is a cross-sector reform project aiming at making the EU's economy sustainable by turning climate and environmental challenges into opportunities across all policy areas. Although the WEF nexus concept is not mentioned in the document, the Green Deal roadmap, proposing actions to boost efficient use of resources by moving to a clean and circular economy, achieve climate neutrality, revert biodiversity loss, cut pollution and provide a fair, healthy and environmental-friendly food system, is based on an explicit understanding of WEF interdependencies and leaves a clear call to rebalance resource use across sectors (Medinilla, 2021).

In the MENA region, several strategies on the WEF have been also developed. The *Arab Strategy for Water Security in the Arab Region 2010-2030* and the *Arab Sustainable Agricultural Development Strategy 2005 to 2025* and the *Pan-Arab Strategy for the Development of Renewable Energy Applications 2010- 2030*, suggest strengthening cooperation among Arab states through the development of integrated solutions able to enhance security and sustainability across all three sectors, while supporting global climate commitments. These strategies identify water as the key determinant for sustainable development in the region and calls for Arab cooperation in sharing experiences and know-how to increase efficiency in water uses, especially in agriculture, in exploiting countries' comparative advantages to increase the supply of both conventional and non-conventional water resources, and in using renewable energy sources in water desalination process.

Several ways could be envisaged to strengthen WEF nexus cooperation on different levels, being bilateral or multilateral. This is crucial not only to reduce resources scarcity and improve levels of access to affordable food, water and energy to the Mediterranean populations, but also to trigger positive spin-offs for reducing tensions in the region. Identify effective cooperation and collaboration mechanisms amongst institutions is key for mainstreaming the WEF nexus approach at local, national and regional levels. From this point of view, there is no need for a structural change leading to the creation of new institutions. Even though the regional institutional landscape remains mostly sectoral in structure, the WEF nexus approach may represent an opportunity for enhancing cooperation at the regional and sub-regional levels.

Consider comparative advantages as a nexus-smart opportunity at the sub-regional and regional levels

As the WEF nexus approach aims to support policy and decision-makers in managing resource trade-offs across different economic sectors and actors, adopting such an approach by taking into consideration comparative advantages within countries could help in securing water, energy and food at different levels. When complementarities and synergies among the three sectors cross national borders, the potential WEF nexus net benefits may increase. This approach should be adopted at both sub-regional and regional level. At the sub-regional level, particular emphasis should be given to the production and exchange of unconventional water and renewable energy considering the differences and variation in factor endowments at country level (IUCN ROWA, 2019). The MENA region may gain from the mutual dependencies triggered by this model of sub-regionally integrated water and

energy sectors, enforcing interdependencies among countries and addressing water, energy and food security in an economically efficient and environmentally sound manner (Shannak et al., 2018). The *Pre-Feasibility Study for Mid-East Water-Renewable Energy Exchanges* carried out jointly by EcoPeace Middle East and the Konrad-Adenauer-Stiftung (2017) demonstrates the potential benefits when the nexus approach crosses national borders, allowing countries to cooperate to achieve greater economic efficiency in resources management. Particularly, the study involves three countries - Israel, Jordan, and Palestine – in a cooperation model for the concrete application of the international trade theory of comparative advantages, increasing interdependencies among states. Given the constraints in terms energy and water security and the disparities between countries in terms of factor endowments, the project takes as reference states' relative resources abundance to build a non-conventional water-renewable energy exchange model among the three countries. All countries will gain from this model of regionally integrated water and energy sectors, enhancing common social, economic, and environmental goals.

Focusing the analysis at the regional level, according to Rodriguez-Clemente (2017), "A 'White Paper' of Mediterranean nexus is strongly needed and shared by the scientific community, stakeholders, policy makers and civil society. The paper should address: 1) identification of running initiatives, key actors and interested parties; 2) identification of the knowledge gaps among countries and groups of experts. 3) sharing of case studies dealing with nexus approaches and examples; 4) references to three key issues: policy, regulations and young people sensibility on the subject".

Furthermore, great opportunities may arise from a Euro-Mediterranean partnership in the field of renewable, which goes beyond conventional trade relations in the energy sector to realize concrete 'win-win' projects of common interest. A Euro-Mediterranean partnership for solar energy would help strengthen the technological capacities of SEMCs around a common and significant effort towards large-scale production of solar energy for both national and European markets. Taking into consideration the geo-climatic advantages of the MENA countries in solar energy the idea is to create an integrate EU/MENA energy system as a kind of 'Energy District' from a 'Marshallian' point of view, able to maximise positive externalities through the creation of a sustainable circuit powered by a flow of technology, know-how, capital, and virtual water and a reverse flow of clean energy. As a co-product of solar power plant expansion in the MENA countries, large amount of seawater could be desalinated to overcome the projected water shortages in the region (Kennou et al., 2018).

In this way, innovative cooperation models between Europe and the MENA region in the field of renewables can address both the growing energy demand of the European countries hungry for non-fossil energy sources and the growing water demand of the Arab countries thirsty for non-conventional water resources.

Conclusions

In the Mediterranean region, the WEF nexus represents a growing challenge mainly driven by the changing demand of resource patterns, rapid urbanization, population growth, inefficient production systems, and climate change (Zhang et al., 2018). Applying a WEF nexus approach in the Mediterranean countries would provide an opportunity for innovation and learning to minimize security risks and maximize opportunities, enhancing resource efficiency and equity. More importantly, by reducing trade-offs, building synergies and improving governance across sectors, the WEF nexus can help the countries of the region in moving towards achieving the SDGs and meeting the mandates of a low carbon economy following from their committed Nationally Determined Contributions (NDCs) under the Paris 2015 Climate Change agreement.

Although the raising awareness of the WEF nexus challenges and the priority given to climate change in the political agenda, little attention has been given so far to the linkages between the WEF resources, WEF nexus and climate change as well as to the opportunity of developing nexus-based mitigation and adaptation responses. These challenges call for a paradigm shift to turn the conventional WEF nexus into a virtuous circle. To achieve this objective, several actions have been

identified: mainstreaming climate change into the WEF nexus; decouple water, energy and food production from fossil fuel; develop sustainable WEF sub-regional and regional cooperation; apply the principle of comparative advantages in cross-border nexus models.

Once recognized the need for a nexus approach to improve water, energy and food security, little is still known how to advance this approach, especially in a multi-stakeholder environment. The WEF nexus in the Mediterranean region requires a set of interventions to strengthen the institutional capacities and to support the intra-regional dialogue. As suggested by Bazilian et al. (2011), “Much work still needs to be done to frame the nexus issues around political motivators, building institutional capacity to understand and act on the complex interactions, and developing stronger modeling tools to support integrated decision-making”. Studies that identify how to design institutions and how to manage the complexity of decision-making processes to balance sectoral goals with political compromises between different interests are fundamental to energizing the WEF nexus and moving towards a sustainable development trajectory.

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