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# Scenarios Framing the Water-Energy-Food Nexus Challenges in the Mediterranean Area

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**To cite this article:**

Rafael Rodriguez-Clemente. Scenarios Framing the Water-Energy-Food Nexus Challenges in the Mediterranean Area. *Journal of Water Resources and Ocean Science*. Vol. 6, No. 6, 2017, pp. 90-97. doi: 10.11648/j.wros.20170606.13

**Received:** October 5, 2017; **Accepted:** October 19, 2017; **Published:** November 29, 2017

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**Abstract:** The Euro-Mediterranean Conference on Research and Innovation held in Barcelona in April 2012 recognizes that there are no alternatives to a deep collaboration between the European Union and its Southern and East Neighbors to cope with their common problems and set a new frame for the cooperation in science and innovation based in the co-design, co-finance and co-ownership of the results of the joint actions. The water-food-energy nexus is a challenge in the Mediterranean area where the effect of climate change and unintended consequences of policies seeking to solve one part of the nexus end up worsening another. A nexus oriented approach meaning integration, inclusion, trans-sectoral vision as well as innovation, which are the basic key to sustainability, is needed to understand the interlinkages and inter-dependencies across water, energy and food sectors through a holistic framework that explicitly defines interactions between systems and the effect one has on another. However, such interactions in the actual frame could be synergistic or antagonistic, and care must be taken to analyze the local circumstances in the handling of the three nexus components before defining possible actions with a nexus vision.

**Keywords:** Water-Food-Energy Nexus, Synergies and Antagonisms, NEXUS Components Scenarios, Climate Change, Euro-Mediterranean Policy

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## 1. Introduction

The interaction between the policies addressing the Water-Food-Energy, the NEXUS [1], is at the heart of the Euro-Mediterranean Cooperation frame, as they represent some of the biggest challenges faced by the societies in the North, East and Southern shores of the Mediterranean Sea. However, the silos character of the decision making political structures in most of the riparian countries makes it difficult to define a common policy addressing the various angles and perspectives of the NEXUS, not to mention the intrinsic conflicts created by the competing demands of each field on the other's. In this paper we review these conflicts together with the possible synergies between the three components of the NEXUS based in the analysis of number of articles. Moreover, we propose some scenarios resulting from the challenges addressed by the NEXUS. In conclusion, we propose the creation of an harmonized 'nexus database' and a modeling tools that could be used for monitoring or trade-off analyses, promoting a higher degree of coordination between policies and regulations and presenting the challenges of the

NEXUS as a driver for innovation and a business opportunity.

## 2. The Euro-Mediterranean Political Context of the Nexus

The Euro-Mediterranean Conference on Research and Innovation held in Barcelona in April 2012 [4] set a new frame for the cooperation in science and innovation based in the co-design, co-finance and co-ownership of the results of the joint actions.

About 1 billion people live in the EU and in the neighboring countries. Of this total roughly half live in the EU-27; slightly less than 30% live in the countries of the South and East Mediterranean Countries (SEMCs), including Turkey. The population of the SEMCs will increase by some 25% to 370 million in the next 20 years; in the EU-27, the population will increase only very slowly, by less than 2% over the entire period. In the EU-27, the population in the age group from 15 to 64 will fall by 6.5%, from about 330

million in 2010 to 310 in 2030. This decline contrasts with an increase in the comparable age group in the SEMCs by more than 31%; the total in this cohort will increase from 195 million to 250 million over the period. A consequence is that about 55 million more people will be looking for work [6].

Agriculture is at the heart of Mediterranean culture, but it depends upon water; traditional practices are hard to maintain as demand for water grows and resources shrink. At present in the SEMCs, 70-80% of all available water is used in agriculture, much of the produce from which is exported. Many typical Mediterranean products, like oranges and tomatoes, require large volumes of water for their production. Paradoxically the SEMCs are exporting water in the form of water intensive products, even though they are perhaps the most arid inhabited region of the world.

The Mediterranean basin will be among the worst affected regions in the world as a consequence of climate change, but SEMCs contribute little to the cause of the problem.

Recent studies [10] have shown that more than half of the food calories consumed in the region is imported and would increase to 64% over the next two decades. An older study in

the mid-1990s showed that the food imports of the region were equivalent to 83 billion m<sup>3</sup> of virtual water, or about 12% of the region’s annual renewable water resources.

### 3. The Social and Economic Challenges in the SEMC Related to the Nexus

“A new nexus oriented approach is needed to address current levels of insecurity in access to basic services; one that better understands the interlinkages and interdependencies across water, energy and food sectors as well as the influence of trade, investment and climate policies” [3]. The water-food-energy nexus is a global risk [2] where unintended consequences are common as policy makers seek to solve one part of the nexus and end up worsening another. Therefore, there is a need for creating a holistic framework that explicitly defines the links between systems and understands the effect one has on another. Table 1 offers a scenario integrating the actual Trends, Tensions and possible Transitions affected by the NEXUS components.

Table 1. Factual scenario framing the water-energy-food nexus challenges.

Trends	Tensions	Transitions
Demographic increase	Now 50% of human population is city dwellers, they will be 70% by 2050. Megacities will increase their number	Political and social changes toward more participative approaches
Energy demands increase by 35% by 2035 becoming an important security issue.		
Photo-voltaic (PV) and wind technologies remain the least water-intensive electricity generation options.	Demographic pressure	More stringent climate policy is necessary. Carbon Capture Storage (CCS) and biomass energy production will develop.
Critical water resilience threshold. Water demands increase at least by 20% by 2050 is becoming an important environmental and security issue.	Progressive resources scarcity and growing demand	Energy, water and food use and consumptions efficiency
Food demands increase of about 70% by 2050	Need of economic development	New models of agriculture for food security, water saving and waste uses
	Changing lifestyle	Solar energy as a driver to cope with energy demand
	Civil conflicts on resources and difficulties in law enforcement	The NEXUS approach
	Security issues on the nexus components	

However, these scenarios can be strongly affected by disruptive elements, such as the impact of climate change, dietary changes or the actual Syrian refugees crisis, as negative factors that could create new tensions and obstacles for the expected Transitions, but some other possible elements, such as saline and algae agriculture or development of nanotechnologies in water treatments can be positive disruptive factors [22].

Water security, energy security, and food security are intimately linked. In simple terms, food production demands water; water extraction, treatment, and redistribution demand energy; and energy production requires water. Energy inputs

via fertilizers, tillage, harvest, transport, and irrigation and processing have their influence on food prices. Environmental pressures and climatic changes, as well as growing economies and populations, both intensify the existent relations between the three systems [11]. However, even if the synergies are associated to the holistic approach of the Water-Energy-Food NEXUS, some contradictory arguments appear when we consider the issues related to one of the components in its relation to the two other. Table 2 summarizes some of the synergetic and antagonism arguments in the relation between the three branches of the NEXUS found in a review of literature.

Table 2. Synergies and antagonisms between the three branches of the Water-Energy-Food NEXUS detected in the literature.

Leading topic	Energy			Food				
	Synergies	Ref.	Antagonisms	Ref.	Synergies	Ref.	Antagonisms	Ref.
Water	Reduce water-intensity of power sector is a source of water in water-stressed regions. RE, notably PV, CSP and wind, are	14	Delivery of 1m <sup>3</sup> of water needs form 0.37 kWh/m <sup>3</sup> from lakes or rivers to up to 2.58 - 8.5 kWh/m <sup>3</sup> from seawater	11	Virtual water offers a metric to calculate water impacts in food production	14	The use of fertilizers and pesticides residues affect the surface and groundwater. These non-points sources must be studied and controlled	12

Leading topic	Energy		Food					
	sources of water.							
	RE can boost water utilities and security by improving accessibility, affordability, safety (solar pumping...) and desalination, and decoupling it from fossils fuels	14, 10	Increasing energy demand for water production, treatment and distribution. Fluctuating costs of water due to variability in energy prices. Unreliable access to affordable energy necessary to extract water	14	Improve access to and sustainability of water supply for agriculture use	14	Increased variability in water availability for food production, particularly due to climate change	14
	Replace traditional water heating	14	Energy production accounts for 15% of total fresh water withdrawal. Risk of re-allocation of water resources from other end-uses to energy	14	Create more with less. New and less water consuming agriculture	9	Impact of water quality on food production and consumption	14
	Decrease energy requirements for desalination processes	8	Contamination of water resources due to energy extraction and transformation processes. Energy end use and waste disposal contaminate water resources	14, 11			Water resource over-utilization impacts of food security ambitions	14
	The water cycle (extraction, purification, delivery and treatment) could represent at least 15% of national electricity consumption in the arab countries			10				
	Affected by							
	Water				Food			
	Synergies	Ref.	Antagonisms	Ref.	Synergies	Ref.	Antagonisms	Ref.
	The atmosphere can hold increases of 7% of water by °C Celsius increases, leading to extreme weather events. Predicted rises in temp. of 2-6°C will results in amplification of the hydrological cycle by 15 to 40%.	15	Shifts in water availability and quality due to natural or human-made reasons. Biofuels consume much water and fertilizers.	14, 11	RE integration in the food production chain provides locally available and secure energy	14	Potential trade-offs between bioenergy production and food crops	14
	Increasing share of RE reduces water consumption	14	Shifts in water availability for energy production (changing precipitation patterns)	14			Variations in crop-based bioenergy feedstock prices	14
Energy			Management of dams for hydropower without considering needs of flood risk management	14			Rising demand for energy needs for agriculture strain the energy system, particularly in regions with a potential to expand irrigated agriculture with pumped water	14
			Water is a substantial risk to energy business operations. The largest withdrawal of water in USA and other industrialized countries is for power plan cooling, particularly nuclear energy	14, 11				

Leading topic	Energy		Food					
Food	Affected by Water				Energy			
	Synergies	Ref.	Antagonisms	Ref.	Synergies	Ref.	Antagonisms	Ref.
	Trade helps food security. Jordan import 90% of food needed, equivalent to 5-7 billion m <sup>3</sup> of water. Water withdraw in Jordan is 1 billion m <sup>3</sup>	11	Food selection and its production must rely mainly on green water (rain fed) in arid regions, and save blue water (surface and underground water). Water productivity is the key factor	11	Enable integrated food and energy production to enhance security	14	Biofuels consume grain needed for food. Arable land is limited	11
	Waste water from cities and industry is a source of nutrients (N and P among others) to be used in agriculture	16	Heavy rainfalls could induce eutrophication and mobilization of contaminants in fertilized agriculture systems	15	Decouple agro-food chain from fossil fuels	14	Lack of energy availability hinders food processing and irrigation	14
			Disruptions in global food supply due to regional water variability, given geographic concentration of food production and consumption	14			Price volatility and supply shortages of energy inputs introducing economic and physical risks in the food supply chain	14
			Water resource over-utilization due to food security ambitions	14				
	Water dams can provide water for irrigation and hydro energy production	21	Priorization of energy production can withdraw water for irrigation		Water dams for hydro energy production can provide water for irrigation	21	Priorization of food production can withdraw water for energy production	

In the Middle East, the roles of the branches of government in setting national priorities and addressing them are not clearly drawn. Soft security, such as security of water, energy, and food, is probably more important to a country's development than hard security, which emphasizes and gets the lion's part in the military and defense. Science-based policies will be needed to meet the challenges of developing water, energy, and food security, simply because they are likely to promote development that is both effective and efficient. But it is important to ensure that initially, policy development makes full use of existing science [12].

The type of technology used for electricity generation is highly influential for the water needs of power production, but this does not apply to renewable technologies such as PV and wind, which do not require water for cooling purposes. In the SEMC water availability is becoming as important as security of energy supply. In view of the linkages between water and energy supply, integrated optimization analyses and policies regarding energy and water resource systems are necessary. Rather than first finding least-cost energy systems and subsequently finding the least cost water supply that these systems require, instead one should attempt to minimize the costs of energy-water systems jointly. Due to water constraints it is likely that further efforts will need to be made to reduce the water usage of power plants in regions such as the Middle East. This is an example of the kind of trade-offs that policy makers need to consider when

designing and implementing policies related to the energy-water nexus sectors, as well as climate policies. More research is needed to determine the water intensity of a large variety of energy production options. Conversely, much more is needed understand and improved the energy consumption of fresh water production, including desalination [7].

Taking the full life-cycle into consideration, PV and wind technologies remain the least water-intensive electricity generation options relative to other energy technologies considered. The type of cooling system used for electricity generation is at least as influential for the water needs of power production as the type of energy technology used. In certain world regions water availability is becoming as important as security of energy supply; in view of the linkages between water and energy supply, integrated optimization analyses and policies regarding energy and water resource systems are necessary. Due to water constraints it is likely that further efforts will need to be made to reduce the water usage of power plants in regions such as the Middle East. In a future that involves more stringent climate policy a large role may be reserved for CCS and biomass based power production. These two technologies withdraw large quantities of water. The water withdrawal savings that otherwise would perhaps be achieved in a business-as-usual scenario, would perhaps be over-shadowed. In the long run both water withdrawal and consumption can be reduced significantly if decisions are

made, particularly (but not only) in the field of energy production and consumption, that take water issues into account. We thus find that water-stress issues, also in those regions where at present they are not yet apparent but may emerge in the farther future, can often be addressed either by using different (energy and water) technologies or by moving certain (e.g. industrial) activities to different regions [7].

#### 4. The Win-Win Scenario

A realistic approach to a successful Euro-Mediterranean cooperation in research and innovation should start with the recognition of the major obstacles: absence of a shared vision; weakness of political will; cultural difficulties in trust building; lack of resources; lack of suitable institutions. Concrete, 'win-win' projects of common interest, co-design and co-financing are at the heart of the new Euro-Mediterranean policy in RTD cooperation. A common agenda of the EU and the Southern and Eastern Mediterranean Neighbors to develop scientific and economic partnership based in common interest can promote convergence in development and help solve common problems. It is in the common interest to increase the innovative capacity of the SEMCs. It has been documented that the innovative capacity at present is disturbingly low, but this stands in sharp contradiction to the outstanding performance of many individuals from the SEMCs working abroad. There are several topics of very substantial common interest that could act as foci for innovation. Solar energy is an excellent example. A Euro-Mediterranean innovation partnership for solar energy would help mobilize and strengthen the industrial and technological capacities of SEMCs around a common and significant effort towards large scale deployment of solar energy for local and European markets. This would stand in continuity with the ongoing Mediterranean Solar Plan (MSP).

An essential incentive for SEMCs to participate convincingly in these activities is that they should benefit from the industrial spin-off. There is a great opportunity to create focused clusters of high-level research and innovation based in the SEMCs. The water sector offers another great opportunity for 'win-win' policies. There has been considerable effort in this area already, but political and governance difficulties have impeded progress. Among priorities are: technological and sustainable development of desalination of brackish water (mapping of resources, development of strategy, improvement of technologies); establishment of clear targets for embedded component and system performance where cost of desalination could again be an area suitable for an innovation partnership; coordination of activities and policies for decontamination of discharges into the Mediterranean sea; design and implementation of effective policies to deal with water poverty; precision agriculture, particularly water use efficiency including the promotion of the reuse of waste water; socio-economic research on welfare implications of water allocation; creation of targets for water efficiency–

benchmarking and the coordination of policies for sustainable allocation and distribution of water.

Climate is also another important issue, which is common to both north and south rims of the Mediterranean, and could also be key in enhancing innovative solutions. The southern countries have been grappling with desertification and the challenges of arid lands for centuries and have much relevant experience. The northern rim has considerable competence through agricultural policies of research and extension programmes designed to support farmers, also from the south, in adapting to new technologies and changing circumstances.

The main obstacles for EU-SMEC cooperation is the mutual ignorance of the cultural frames and worse, the misunderstanding of the root of behaviors and social values of their societies. Perhaps the main problem for a win-win approach in EU-SMEC cooperation is the lack of a conscious perception from all sides that there is no alternative to collaboration in solving many of the problems that are piling up in this geographical and social space, such as the impact of migrations, pollution of the common sea, impact of the climate change, transition in the energetic models used up to now and so on. At the end, the win-win approach is a cultural and educational one in the sense that all populations must be conscious of the challenges at stake, and the long term benefits that will derive of a closer cooperation between the two sides of the Mediterranean. Finally, and almost useless to repeat, social, economic and environmental sustainability are an integral part of any possible Win-Win scenario.

#### 5. Discussion

It is well known that there are no alternatives to a deep collaboration between the European Union and its Southern and East Neighbors to cope with their common problems. We learned that NEXUS approach means integration, inclusion, trans-sectoral vision as well as innovation, which are the basic key to sustainability.

"However, the risk of crisis or set back is real in a context of polarization of political forces and in the absence of an agreement among political actors on a joint vision for the political transformation process. In recent months, the unstable political situation and growing social unrest have strongly affected the performance of the Southern and Eastern Mediterranean governments in implementing reforms. The continuing change revealed even greater differences between the transition trajectories of individual countries in the region [18]". The NEXUS is one of the areas on which a strong scientific Euro-Mediterranean cooperation can be built and become a pilot for the north-south cooperation at large, in spite of the actual fragmented approaches of its three components.

As stated in different occasion, event recently in Barcelona<sup>1</sup>, There is need today to "deconstruct" Water, Food

1 The FP7 INCO.Net Project MEDSPRING, organized in January 2015 a Meeting gathering some tens of coordinators of EU-funded projects dealing with the three subjects, water, energy and food issues in the Mediterranean area, together with some projects dealing with horizontal issues, such as social and

and Energy projects or initiatives and framed them into a broader and integrated context, which is the NEXUS context [13]. Constant attention must be paid to the NEXUS vision and priorities in the Mediterranean, considering the stand of the social demands, market needs and opportunity and possible future scenarios.

A regional approach should be considered through NEXUS, giving emphasis on “South to South” diversifications, introducing socially driven Innovation that does not come in conflict with technology innovation and respond to market and societal development. Regulations set a balance between the two sides. Although there is a huge accumulation of data in all sectors, they are not utilized due to bad management. A correlation function is sought in order to produce a system that connects the different fields through NEXUS. It was suggested to propose merging of competences from different disciplines to create new technologies under the demand of the NEXUS logic, focusing on well identified challenges in view of contributing to sustainability and facilitating development (both industrial and societal). The three fields of NEXUS should be clustered to identify and stress the added value gained by the process, which needs mutual adaptation of the sectors involved, and identification of cases where the NEXUS approach can be applied.

Genuine objectives of sustainable development should be used, also ensuring an ethical and eco-centric approach especially when promoting the idea of producing more with less, and giving a balanced and ethical definition of the “more” and the “less”. The paradigm of coping sustainable quantity of biomass production with less water needs to be further explored and become a key “motto” for the NEXUS approach. Another issue that could be considered in operating the NEXUS interlinkages is the Mediterranean Diet, as a key and solution for dietary problems in future generations while enhancing economic, environmental and social sustainability, developing local varieties adapted to less water demands. When looking countries’ experience and best practices, Jordan seems a land which could offer today a rich number of examples, where NEXUS is dealt on an everyday base, Jordan being affected by very limited water, food and energy resources.

There seems to be today an agreement and a serious positive concern even, to highlight the importance of the NEXUS concept. However, the energy side of the NEXUS still looks far from being plugged to water and food and to sustainability. Reasons can be found in different places: it is primarily a private concern, the subsidy policies turn out to be economical catastrophes, shortage in fossil fuels which favors urgent fragmented solutions. On the side of Wind energy the situation is stable with the break-even point successfully overcome. For photovoltaic however, and solar in general, the situation is still uncertain. NEXUS should incorporate readily the waste management issue, a corner stone in sustainable development.

More generally, it looks of primary importance to identify full cycles of the different renewable resources, water and energies. A global impact assessment considering both market and environment is not really addressed at this moment. Too many fluctuating factors and irrational elements still structure the markets, which are dominated by big business and rapid benefit expectation. In this respect, cost of inaction-vs. “Business as Usual’s” is deteriorating the present social and environmental conditions and their assessment is of particular importance.

In that context, design of a common market is a strong driver to unify the different political agendas. Direct support to innovative solutions to specific Mediterranean Nexus issues should be incorporated in the general approach. Innovation is here conceived as the preparation of a new product or service for deployment on the market and is clearly distinct from research and demonstration activities. Consumer awareness should be fully incorporated in task definition. A strategic target will be regulatory stakes; we need to construct the case for the benefit of the NEXUS approach. Industry will not commit until the regulatory frame is profiled and established. Policy makers need consolidated solutions to change the regulatory frame. Support of industry for this change is required. An integrated approach for this endeavor includes:

An in-depth understanding of synergies and tradeoffs in the use of natural resources, while taking into consideration the role of ecosystem services, for the energy and agricultural sector

An enabling policy and institutional environment, with sound and flexible policies and effective instruments to implement these policies to enforce good practices

Proper impact monitoring, evaluation, reporting and policy response mechanisms [21]

The output of the research and innovation cooperation activities includes a vast critical mass of information that need to be properly processed in order to make it accessible and easy to understand by the civil society. Sharing useful and relevant information for the stakeholders will contribute to build fruitful collaborations inside and outside the projects. For this reason, developing relevant and tailored messages to be delivered to targeted actors and identifying the appropriate channels of communication, are a key issue to efficiently raise awareness and engagement of the stakeholders in international cooperation activities.

The NEXUS must be handled by incorporating externalities such as communication, measures to guarantee exploitation of possible results, provisions to perform short and long term technological impact assessment, as well as political and social impacts. The nexus approach supports more sustainable (green) growth through smarter use of resources and through integrated agricultural and ecosystem (i.e. landscape) management.

We should give impulse to aggregation of knowledge processes around the NEXUS challenges. Actions based in Projects dimensions are not enough to guarantee sustainability; a clear engagement of Institutions around the objectives of

addressing challenges is needed. Therefore, a common objective is to explore how the scientific community can reach the political level of decision on funding and continuity in actions and be present in the forums where the concerns are exposed, and be closer to the end users of the research effort, notably consumers and young generations. The Governance Gap in the Nexus triangle could be addressed by fulfilling some conditions [23]: 1) the conditions for cross-sector coordination and collaboration; 2) dynamics beyond cross-sector interactions; and 3) political and cognitive factors as determinants of change.

A “White Paper” of Mediterranean NEXUS is strongly needed and shared by the scientific community, stakeholders, policy makers and civil society. The paper should inevitably address: 1) Identification of running initiatives, key actors and interested parties. 2) Identification of the knowledge gaps existing among the participation countries and groups of experts. 3) Gathering of case studies dealing with NEXUS approaches and examples (Jordan could be focused as a first pilot). 4) References to three key issues: policy, regulations and young people sensibility on the subject. Moreover, as suggested by Bazilian et al [20], more work is needed 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.

## 6. Conclusions

The NEXUS complexity is framed by five major issues: the lack of proper and quantified understanding of the trends and impact of climate change on the global and regional variations of temperature, water stocks and atmospheric dynamics; the demographic evolution in the different world regions; the lack of a possible uniform international, national or regional strategy due to parceling of the political and administrative responsibilities in the governance of the territories due to their silo-like structures, lack of policy coherence [10]; the effects of water or energy shortages in food production and the consequent social instabilities which derive in political conflicts [8] and, finally, the slow pace of knowledge creation and transfer from the scientific and technical communities between themselves and to political, administrative and industrial and agricultural producers and users of water, energy and food. All these issues must be addressed by creating a harmonized ‘nexus database’ or analytical framework together with powerful modeling tools that could be used for monitoring or trade-off analyses, promoting a higher degree of coordination between policies and regulations and presenting the challenges of the NEXUS as a driver for innovation and a business opportunity.

## Funding

This work was supported by the European Union Framework Programme 7. INCO. Net Project MEDSPRING [Grant 311780].

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