This project is co-funded by the European Union

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nexus

The Water-Energy-Food Nexus in the Arab Region

Nexus Technology and Innovation Case Studies

Summary

Technology and innovation play a critical role to address the water, energy and food challenges. Introducing innovation, renewable energy and the concept of "circular economy" contribute to improving efficiency, productivity, and sustainability. In general, the introduction of new and appropriate technologies can improve resources efficiency in water, energy and food sectors, and contribute to their collective security and sustainability. However, when introducing a single sector efficiency measure, an economic efficiency evaluation should be made within the WEF nexus framework, otherwise it may backfire and may lead to unintended consequences and spill over effects on the other sectors if not appropriately designed. On the other hand, technological and innovative solutions within the WEF nexus, where two of, or the three components of the nexus are integrated as inputs to each other not only enhance resource efficiency, but also expand the available natural resource base and thus have even more contribution to the sustainability and security of the three sectors.

Technological and innovative solutions for the nexus are at their early stages of development in the Arab region. These pioneering initiatives need to be funded, scaled up and replicated to reach tipping points. Yet, there are some good examples on the adoption of innovative solutions within the nexus in many Arab countries. These include: integrated seawater energy and agricultural system in UAE, Qatar, and Oman; Sahara Wind Power Project in Morocco; renewable energy for wastewater treatment and reclaimed water use in agriculture in Jordan; solar desalination in Saudi Arabia;
agriculture waste-to-energy in Sudan; landfill-gas-to-energy project and aquaponics-energy production in Lebanon. These case studies demonstrate the potential and benefits to be unlocked if technology and innovation are fully harnessed within the WEF nexus.

Recommendations

To enhance the role of technological innovation in the sustainability and security of the water, energy, and food sectors, it is recommended to undertake the following measures and actions:

- Encourage collaborative and focused applied R&D on the nexus by forming regional research teams and alliances to promote innovation and technology transfer;
- Scale up, replicate and fund on-going projects related to the nexus including integrated seawater energy and agricultural system, renewable energy for wastewater treatment and reuse, and solar desalination;
- Support and provide incentives for strategic partnerships and cooperation between research centres and the private sector; and
- Build capacity for policy makers and institutionalize regional knowledge management systems to share best practices on the WEF nexus.

The WEF Nexus in the Arab Region Series is published by the League of Arab States (LAS), with technical and financial support from the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ). Opinions expressed in the briefs do not necessary reflect the views of either LAS or GIZ.

Policy Brief Authors:
Maha Halalsheh, University of Jordan, Jordan; Taha Ouarda, MASDAR Institute, UAE; Odeh Al-Jayousi, Arabian Gulf University

Policy Brief Reviewers:
Hammou Laamarani, GIZ/LAS; Gerhard Rappold, GIZ; Abdelhadi Abdelwahab, Arabian Gulf University

Policy Brief Series Editor:
Waleed K Al-Zubari, Arabian Gulf University

Introduction

Water, energy and food scarcities and competitions have resulted in technological solutions contributing to some WEF nexus challenges. These technological and innovative solutions are expected to be increasing in the future. It is insightful to be mindful of the implications of the Paris Climate Summit during the COP21 in 2015, as it was agreed to allocate US$ 100 billion per year in 2020 and beyond to support developing countries in clean technologies to lower their ecological footprints.

In general, the introduction of new and appropriate technologies can improve resource efficiency in the water, energy, food sectors, and contribute to their security and sustainability. Introducing renewable energy and improving energy efficiency, precision agriculture, water recycling, and wastewater reuse are just few examples of such driving force between the nexus three components and technology. Such technological options and solutions are being implemented in many Arab countries, though at varying degrees, and are contributing to the efficiency of the utilization of these resources but need to be expanded to meet the attainment of mandates of both the nexus relevant SDGs and Paris Climate Summit of 2015. However, sound selection of technology and proper policies across

Implemented by:
giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

With contributions from:
Arabian Gulf University
AUB American University of Beirut
Issam Fares Institute for Public Policy and International Affairs
معهد عصام فارس للسياسات العامة والشؤون الدولية
BIOLOGICAL & AGRICULTURAL ENGINEERING TEXAS A&M UNIVERSITY
Masdar INSTITUTE معهد مصدر

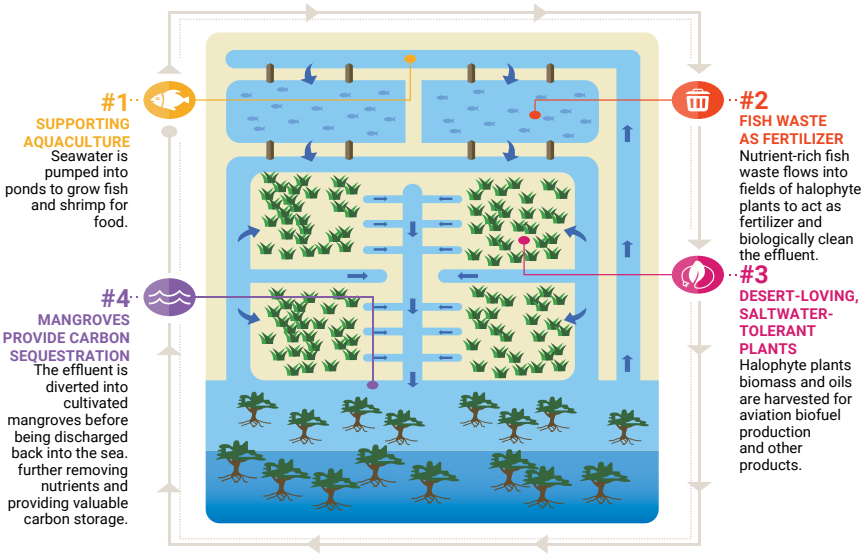
the nexus must be made to ensure a holistic water, energy and food security. Policy makers should be mindful of the fact that single sector efficiency may sometimes lead to negative impact in the other two sectors, as in the case of water subsides in irrigation and the promotion of the use of solar pumps which both led to over-abstraction of groundwater.

On the other hand, technological and innovative solutions within the WEF nexus, where two of, or the three components of the nexus are integrated as inputs to each other not only enhance resource efficiency, but also expand the available natural resource base and thus have even more contribution to the sustainability and security of the three sectors. Under the current constraining conditions in the Arab region, such technological and innovative solutions may lend themselves as one of the most important drivers for the WEF nexus approach adoption by various stakeholders. However, such WEF nexus technological and innovative solutions are at their early stages in the Arab region. This is understandably due to the need for large capital investments, extensive dedicated collaborative R&D, immature private sector, lack of the enabling environment for innovation, and many other factors that are required. However, there are some good examples of the adoption of these in many Arab countries, which are summerized in the following sections.

Case Study 1: Integrated Seawater Energy and Agricultural System, UAE and Qatar.

Technological innovation is an enabler for realizing the value of the nexus approach in natural resource management. One evidence is presented by Masdar Institute, UAE, through the Integrated Seawater Energy and Agriculture System (ISEAS) project. The project uses coastal seawater to raise fish and shrimp then utilizes the nutrient- rich wastewater of the aquaculture to fertilize the oil-rich halophyte plants. This plant in turn is used to produce biofuel for aviation industry. This innovation was enabled by partnerships between R&D entities and private sector. This initiative was conducted through the Sustainable Bio-energy Research Consortium (SBRC) which was founded by Masdar, Etihad Airways, Boeing and Honeywell UOP, and later joined by aerospace companies Safran and GE. The pilot project demonstrates a real application for the nexus where technological innovation is harnessed to develop a model of sustainability. This model is envisioned to be scaled up to a large scale in 2018. Besides, Seawater greenhouses can be integrated with a number of other technologies (aquaculture, halophyte and algae cultivation to produce food and biomass, anaerobic digestion and pyrolysis of the organic waste to produce methane, fertilizer and biochar, etc.) to contribute to food security and reduce CO2 levels through sustainable water and energy production. The Sahara Forest Project (SFP) in Qatar represents a successful example of the integration of all these technologies in one single facility that provides water, energy, food and salt autonomously. SFP has yielded satisfactory results growing more than 75 kg/m2/-year of high quality products and increasing 100 to 1000 times the biomass in the desert.

Schematic presentation of the Integrated Seawater Agriculture system (Farm).



Source: http://www.greenaironline.com/news.php?viewStory=2033

Case Study 2: Sahara Wind Power Project, Morocco

The case of the Sahara Wind project in Morocco provides insights of the key success components to transform economy. These include strategic vision, economic feasibility, partnerships, and an enabling policy and legal environment. The vision was to connect 5 GW of wind capacity to a High Voltage DC line to supply North African and European electricity. The cost of wind-generated electricity was about 3 US cents/kWh for the first phase with 800 MW target to be expanded to 2 GW of wind power by the year 2020. Partnerships with the government of Morocco, the World Bank and the African development Bank made the funding possible. The reform of the energy law (Renewable Energy Law 13-09) enabled wind-electricity to be used for industrial purposes used for industrial purposes and opened opportunities for some industries to match power generation with demand. Besides, this in turn enhanced access to wind technologies and contributed to job creation and sustainable development. Evidence on the added-value of the nexus was manifested in several projects in Morocco. These include: wind energy is used in pilot projects for fertilizers production and water treatment. The first project is applied by Morocco's state owned phosphate firm (OCP Group), which supplies 20% of the world's fertilizers. The second project is located in the main water treatment facility in Morocco, and run by ONEP the water utility of Morocco. In the latter case, electrolyzers are coupled to wind turbines to produce chlorine (used as water disinfectant). Electrolyzers also generate hydrogen which has multiple functions as a feedstock and energy carrier.

North Africa-Europe Interconnection at Fardioua, Morocco

(Source: Sahara Wind Project)

"In 2006, the Sahara Wind Project Began regional capacity-building to tackle energy scarcity and foster sustainable development. Working with NATO, wind energy became a joint research project led by academic institutions in Morocco and Mauritania. In 2012, Africa's first wind-hydrogen storage system was commissioned at Al-Akhawayn University of Ifrane in Morocco. With financing help from the World Bank, EIB, AfDB, the project has boosted Morocco's wind capacity to 380 MW, contributing to ONEE's plans for 2GW Moroccan wind energy by 2020."

Cited in: Journal of Energy Security, 2014. http://moro-coonthemove.com/2014/05/02/energy-transition-saha-ra-wind-per-project-journal-energy-security/#sthash.ES8Wmbg6.dpbs

Case Study 3: Renewable Energy for Food Security, Egypt

The imperative to adopt the nexus approach is illustrated in the case of Egypt. Achieving food, water, and energy efficiencies can be attained by harnessing hydropower and renewable energy for water pumping for agriculture. Realizing the fact that about 20% of Egypt's cultivated land is used to grow water-intensive crops such as rice and sugar and being mindful of the fact that the irrigation efficiency ranges from 40% to 73% implies that there are substantial potential savings in applying the WEF nexus.

Use of Solar Energy for Groundwater Pumping in Agriculture

Sources: http://karmsolar.com/wp-content/uploads/2013/10/KarmSolar-PV-magazine-article.pdf

Enhancing water efficiency in agriculture is a key to food security in Egypt. The food-water security strategy is based on an increase in wheat production, stabilizing rice cultivation at 1.2 million feddan, introducing new irrigation technologies, and rehabilitation of irrigation systems in reclaimed land. Water sector is likely to benefit from the adoption of the nexus approach through linkages with energy sector. Hydropower currently constitutes 83% of the installed renewable energy and the government is planning to increase the total installed renewable energy from 5% up to 20% in 2020. The government plans to diversify its renewable energy sources by increasing supply through wind and solar energy. Renewable energy applications are piloted in Egypt for water pumping for agricultural use. For instance, KarmSolar and WorldWater & Solar Technologies implemented a 50kW off grid solar water pumping facility on Al-Tayebat farm in the Bahariya Oasis. The farm powers 30 kW submersible pump that has an average flow rate of 120 m3/h. The well which is powered by solar energy serves a pivot irrigation area of around 120 acres. Prominence of the project lies in its direct social and economic impact on stakeholders within agricultural sector.

Case Study 4: Renewable Energy for Wastewater Treatment and Reuse in Agriculture, Jordan

The integrated approach for managing the WEF nexus is well-illustrated in the utilizing of renewable energy for waste-water treatment at Khirbit As-samra wastewater treatment plant in Jordan. The business model is based on a Public Private Partnership (PPP) to finance the construction and operation of public infrastructures based on Build Operate Transfer (BOT) contract for 22 years. The annual average energy consumption of the activated sludge system at Khirbit As-samra plant was around 61.58 GWh in 2014. The plant has achieved a self-energy sufficiency of 78-90% between 2009 and 2014. This energy saving is achieved by utilizing renewable energy resources including hydraulic energy and biogas produced through anaerobic digestion. Biogas production generates thermal and electrical power of 5.4 MW and hydraulic energy accounts for 3.45 MW.

The As-Samra Wastewater Treatment Project

Source: http://www.thesourcemagazine.org/sweco-contributes-to-improving-the-water-situation-in-jordan/

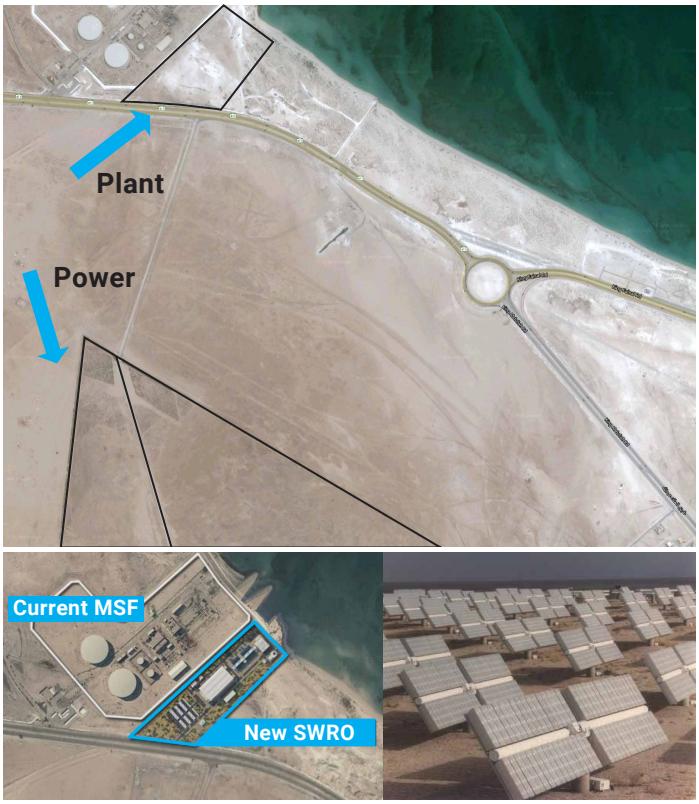
The plant is a good example of cost-effective performance since it operates at 18% of the operating budgets, compared to global figures which range between 25-40%. Besides, the system had reduced CO2 emission by around 300,000 tons per year and the effluent of the treatment plant (100 Million cubic meters annually) is used for agricultural production. As-Samra plant is currently expanding the existing capacity by 37%. The expansion includes a new sludge dewatering processes which will eventually result in 10% increase in energy consumption.

Case Study 5: King Abdullah Initiative for Solar Water Desalination, Saudi Arabia

There is an opportunity cost for using conventional energy resources for water desalination. Adopting the WEF nexus can save energy for other uses. The capacity of desalinated water in KSA represents 18% of the world's global desalinated water. KSA pumps the equivalent of 300,000 barrels of oil per day to operate desalination plants, providing 3.3 million cubic meters of water from stations operated by the state owned Saline Water Conversion Corporation (SWCC). This value neither includes oil consumption by non-state operated desalination plants nor groundwater extraction. The expected increase in oil consumption due to the high population growth rate would simply mean less oil export and associated reduced revenues which are an opportunity cost. As a result, KSA has a national objective to produce half of Saudi Arabia's power from renewable fuels by 2020. A transition to renewable energy is supported by economic incentives and subsidies to make it competitive in an open power market. It is worth mentioning that the first initiative in renewable energy was in 1977 followed by many initiatives. Recently, King Abdulla initiative for solar water

desalination was initiated. The national objective is to harness solar energy for all water desalination during the period 2010-2019. The initiative is expected to reduce production costs of desalinated water from 2.2-5.5 SR/m3 to 1-1.5 Saudi Riyals/m3 (one US dollar is equivalent to about four Saudi Riyals). A major part of this initiative is made by the King Abdulaziz City of Science and Technology (KASCT) by the development of the world's first large-scale desalination plant to be powered by solar energy in Saudi Arabia.

Al-Khafji sewater RO Desalination Using Solar Energy



Source: Water technology net: http://www.water-technology.net/projects/al-khafji-solar-saline-water-reverse-osmosis-solar-swro-desalination-plant/

The plant will produce 60,000 m3/day of drinking water to supply Al Khafji City in North Eastern Saudi Arabia, ensuring sustainable water supply throughout the year. This is a global pioneering project since it incorporates a plant that will have a 15 MW solar array using polycrystalline solar cells engineered by KASCT. The plant will be capable of supplying the power required by the RO desalination process, significantly reducing the operational costs, and GHGs emissions. The new project offers a golden opportunity to conserve fossil fuels and reduce carbon footprint, while ensuring sustainable supply of water.

Case Study 6: A Green Source of Energy and Food, Kenana Sugar Company, Sudan

The sugar industry may result in zero waste If its chain of production is carefully designed and managed, and therefore, can represent a good model for the implementation of the water-energy-food nexus approach. Since its inauguration as a successful model for joint Arab investment in 1975, the Kenana Sugar Company has adopted the motto of “Green Source for Food and Energy”, and has relentlessly pursued such goal in the development of the operation of its various sections. The most important of these is the joint power generation section which uses "Bagasse" (largest sugar industry waste in volume), for power generation during the production season that extends for 6 months without interruption. The section produces steam which represents the main source for electric power generation used for all the stages of sugar production. In addition, the self-generated electricity is used to supply the other associated industries, irrigation pumps, and the residential area of the company. Furthermore, in 2004 the company established a factory for animal feed concentrates using the remaining "Bagasse" waste after its use in power generation and part of the Molasses (second largest sugar industry waste). The company has a diversified commercial production of animal feed concentrates for ruminants, sheep, and poultry, and part of this feed concentrates is used for the company’s cattle fattening and milk production. Using Molasses also, the company has established the first factory of its kind in the Arab region for the production of Ethyl Alcohol with an annual capacity of 65 million liters. About 90% of the produced Ethyl Alcohol is exported to the European Union and some Gulf Arab States, while the rest is sold in the local market for the pharmaceutical and cosmetics sectors. In addition, part of the produce has been used as car fuel by mixing it with benzene by a 10% in experimental service stations, before its adoption as a mixture of fuel in Sudan.

The Kenana Sugar Company

Conclusion

The presented case studies provide evidence for the viability for scaling and replicating pilot projects on the WEF nexus in the Arab region. These examples should contribute to inform and reform public policy in terms of economic incentives, scale of investment in the nexus, and new knowledge for sustainability. Besides, these case studies provide evidence for the significance of science-policy interface.

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