The Water, Energy & Food Security Nexus

Opportunities for sustainable development and effective environmental governance

THE REGIONAL KNOWLEDGE NETWORK ON WATER - RKNOW

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R-KNOW partnership

- International Union Conservation of Nature (IUCN), Global Water Programme – Switzerland and the Regional Office for West Asia (ROWA) – Jordan
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Introduction to the Water, Energy, Food Security Nexus

Water, energy, and food security are complex sectors on their own but they become even more complicated when their interactions begin to be studied. Rather than view the interrelatedness of the water, energy and food security sectors as a hindrance, their relationships should be used as an opportunity to tackle development issues with a multi-sectoral approach. The Water, Energy and Food Security (WEF) Nexus approach aims to understand how of each of these three sectors relates to the other two and how this understanding can be used to make policy decisions that promote sustainable development and poverty reduction (Bizikova, Roy, Swanson, Venema, & McCandless, 2013).

The connection between water, energy and food security may seem apparent in some cases. For example, agriculture is a main user of water and energy and water can be used as an energy source to power food production processes. In other cases, the link between the sectors may more discrete. For example, does an increase in the production of biofuels affect a country's food security (Bizikova et al., 2013)? Similarly, advances in one sector may lead to degradation of the others. The inefficient use of water for agriculture can lead to the over withdrawal of groundwater, which may lead to food insecurity in the future. The Nexus approach is more than technological advances; it requires collaboration across ministries, different levels of government and international cooperation. Reliable and effective governance is critical to the nexus approach. A crucial aspect of effective governance is the engagement of participatory approaches. Participatory approaches, including stakeholder involvement, and monitoring and evaluation of community responses, are critical to ensuring that the priorities of those affected by policies are being met.

In 2011, the German Federal Government organized an international conference titled "The Water, Energy and Food Security Nexus – Solutions for the Green Economy." The conference aimed to position the nexus approach as a critical element of the post-2015 agenda and featured case studies and policy recommendations. One set of recommendations put forth by the conference is:

- Increase policy coherence
- Accelerate access
- Create more with less
- End waste and minimize losses
- Value natural infrastructure
- Mobilize consumer influence

Using these tactics and engagement from governments, civic organizations and the community, the nexus approach aims to ease sectoral tension and encourage policies that benefit water, energy and food security sectors equally (The Federal Government of Germany, n.d.).

As we enter a post Millennium Development Goals world we are faced with tackling contemporary issues as well as continuing the fight for poverty elimination. Outside pressures, such as urbanization and climate change, are playing a significant role in the water, energy and food security sectors and will continue to do so in the future [Figure 1]. Not only does the nexus approach focus on the link between water, energy and food security but it also aims to address external pressures and how they ultimately affect quality of life and development.

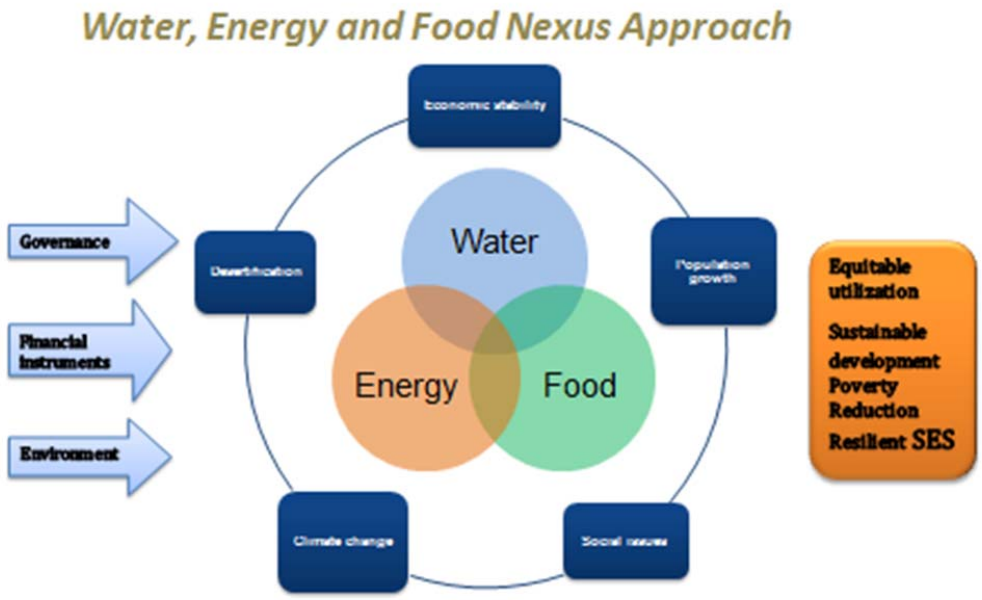


Figure1. Nexus perspective, external pressures and approach

Figure 1 proposes a Framework for a Nexus approach. The three components; water, energy and food are resources and are dealt with as sectors in the meantime. As resources there are excessive pressures on, due to population growth, increasing social welfare, climate change, desertification due to water scarcity, and fluctuations in economic stability, in addition to many other factors.

When we look at them as sectors of management, there is a need to work within three domains; i) governance, ii) financial instruments, iii) environmental assessment. The governance domain entails sector coordination, stakeholders dialogue for concerted actions, community participation, strong institutional setup, rules and practices governing the relations between the relevant sectors. The financial instruments involve incentives for private sector encouragement to invest in the renewable energy production, subsidy policies to maintain subsidized services to the needy, prices of agriculture entry elements such as fertilizers, export and import strategies, etc. The environmental assessment is component mandatory to assess the impacts of policies on natural resources, impacts of climate change, valuation of ecosystems, vulnerabilities and resilience assessment, and hence support the decision making and planning processes regarding the nexus and the tradeoffs incurred. Working in the above mentioned fields requires capacity building as a prerequisite at the institutional and the human levels.

Having worked on these, the objectives of sustainable development, equitable utilization, poverty reduction, and resilience of social and ecological systems could be attained.

WEF Nexus in the Arab Region

Egypt is only one example of a country that can benefit from utilizing the nexus approach. The interactions between water, energy and food security sectors can be seen across the Arab region. The region's population is currently over 358 million and expected to increase by 50% by 2050 ("Food security and nutrition in the Arab region: key challenges and policy options," 2012). Poverty, resource depletion and degradation are present throughout the region. Despite containing 43% of the world's oil reserves and immense potential for renewable energy, 35 million people in the region remain without access to modern energy services, mainly electricity (Gelil, El-Ashry, & Saab, 2013). Additionally, the region only contains 1.4% of the world's freshwater sources, making it the world's most water scarce region in absolute and relative terms, (Siddiqi & Anadon, 2011; Sadik, 2013). Over 50% of Arab countries are already below the water stress level of $500m^3$ per capita per year and water availability is expected to decrease by 50% by 2050, while demand will only continue to grow (Sadik, 2013;Immerzeel et al., 2011). The Arab Region is the world's largest importer of wheat and recent economic stability has left its population even more vulnerable to food insecurity (World Bank, 2009). Utilizing the nexus approach in the Arab Region has the potential to benefit all three sectors and reduce poverty through the improvement of livelihoods and job creation (Gelil, El-Ashry, & Saab, 2013).

Water

Average water availability in the Arab Region is $840m^3$ per person per year, only 12% of the world's average of $7000m^3$ per person per year (Sadik, 2013). The Arab region is currently using 75% of exploitable water sources in the region and it is estimated that 58% of the region's renewable water resources will be depleted by 2030 (Sadik, 2013; Immerzeel et al., 2011). Arab countries obtain their water from several different sources, including groundwater, desalination and wastewater treatment. Groundwater provides 84% of total water supply in the Arabian Peninsula and is the largest water source in Bahrain, Jordan, Lebanon, Libya, Oman, Saudi Arabia, Tunisia, the United Arab Emirates and Yemen. Multi-stage flash distillation is the most common desalination technology used in the region and is primarily found on the Arabian Peninsula, where it supplies 8% of total water supply (Siddiqi & Anadon, 2011). Over 85% of the region's water use is dedicated to agriculture. Domestic and industrial water demands are 7.8% and 7% of total demand, respectively (Sadik, 2013).

Energy

The Arab Region has become almost synonymous with oil production. Oil and gas are major sources of income in the region, contributing to 36% of total Arab GDP. The shares from export earnings range from 33% to 97% in the region. However, as recent events have shown, oil revenues are vulnerable and subject to shocks and instability (Gelil, El-Ashry, & Saab, 2013). Oil and gas are not only important for earnings from exports but they provide 97% of domestic demand in the region. The region's overwhelming dependence on traditional energy sources has had a tremendous impact on greenhouse gas emissions. Carbon dioxide emissions in the Arab Region increased by 247% from 1990 and 2010; 95% of this increase has been attributed to the production and use of oil and gas sources (Gelil, El-Ashry, & Saab, 2013). Progress in renewable energy sources is being made. As of 2013, there were 106 renewable energy projects in the works. These projects equaled a more than 4%

increase in current non-hydropower renewable capacity. Additionally, between 2008 and 2011, non-hydropower renewable capacity doubled (Bryden, Riahi, & Zissler, 2013). Despite these advancements, regional policies that have kept energy prices artificially low have helped traditional energy sources remain popular and more attractive than renewable sources (Gelil, El-Ashry, & Saab, 2013).

Food Security

The Arab Region is the number one importer of wheat in the world (World Bank, 2009). Despite being almost self-sufficient in red meats, vegetables and fruits, the region severely lags behind the world in cereal productivity and requires twice as much land to grow the same amount of cereal as other parts of the world. Many countries have suffered from stagnant productivity for years (Sadik, 2013). Seven countries account for 85% of total agriculture GDP in the region. Population is expected to reach 633 million by the year 2050 and reaching self-sufficiency in cereal production will require an additional 105 million hectares of land. Land quality is limited in the region so increases in yields will have to come from improvements in irrigation, agriculture inputs and research and development (Sadik, 2013). Malnutrition is also present across the region. About 25% of children under five years old suffer from stunting and there are vast differences between countries. Yemen has the highest rate of childhood stunting at 57.9% (Breisinger, Ecker, Al-Riffai, & Yu, 2012). The poor are especially vulnerable to food insecurity in the Arab region. The poorest families in the region are estimated to spend 35 to 65% of their income on food ("Food security and nutrition in the Arab region: key challenges and policy options," 2012).

Nexus Opportunities in the Arab Region

The connections between the water, energy and food security sectors are overwhelming. Agriculture is the single largest user of water in the region, yet it suffers from one of the lowest efficiency rate at only 40% (Gelil, El-Ashry, & Saab, 2013). Irrigation has been linked to higher cereal yields yet only 27% of cultivated land in the Arab Region is irrigated (Sadik, 2013). Irrigation should be expanded but it must done correctly and efficiently in order to save water and energy (Siddiqi & Anadon, 2011). Raising irrigation efficiency to 70% could save enough water to produce an additional 35 million tons of cereal by 2030 (Sadik, 2013).

The opportunities for utilizing a nexus approach are particularly apparent when observing the interactions between the water and energy sectors. It is estimated that the water cycle, from abstraction to treatment post-use, may use up to 15% of national electricity consumption in most Arab countries (Gelil, El-Ashry, & Saab, 2013; Siddiqi & Anadon, 2011). Saudi Arabia relies almost entirely on groundwater and desalination for oil extraction and 10% of total fuel consumption in the country is attributed to water pumping. In Libya, 14% of total fuel consumption is used for groundwater pumping (Siddiqi & Anadon, 2011). Saudi Arabia and Libya are only two examples but the links between water and energy can be seen throughout the region. The Arab Region is currently home to 50% of the world's desalination capacity. Desalination is a highly energy-intensive process, using an average 3.5 kwh of energy per cubic meter of water (Mofor, 2013; Moawad, 2011). By 2050, desalination and wastewater are predicted to provide 28% and 15% of the region's water, respectively (Sadik, 2013). Energy demand for desalination will increase with the increased capacity and the Arab region must consider how it will power these plants in the future. These links become

even more critical when you consider the impact these changes in water and energy use will have on agriculture and food systems.

The benefits of conservation are also tremendous for the Arab Region. Reducing energy losses to only 10%, from the current 19.4%, would save the region $5.5 billion. Furthermore, transitioning to compact fluorescent lighting could reduce carbon emissions by 2.56% (Gelil, El-Ashry, & Saab, 2013). Expanding the water cycle could also bring immense benefits to the region. Libya, Kuwait and Qatar could meet all of their industrial water needs by recycling 25% of their annual wastewater (Siddiqi & Anadon, 2011). Reusing this wastewater also prevents industrial and thermal pollution from harming local waterways. Agriculture policies that reduce the production of water-intensive crops and consider virtual water trade should also be considered as a conservation tool for the water and energy sectors (Gelil, El-Ashry, & Saab, 2013). The Arab Region must also consider the effects of climate change as it moves forward. Studies estimate a 3° to 7° C temperature increase by the end of the century. This temperature increase could reduce groundwater supplies by 40% ("Food security and nutrition in the Arab region: key challenges and policy options," 2012). Climate change may also reduce crop productivity and agriculture yields. In Egypt, rice productivity may decrease by 11%, barley by 18%, corn by 19% and wheat by 18% by 2030. Rain-fed yield may decrease 20% across the region (Sadik, 2013).

The interdependencies of the water, energy and food security sectors are vital to the development of the Arab region. Approaching these sectors with a nexus lens in Egypt can provide a strong example of how a nexus approach can be used in the greater Arab region to address national and regional issues.

WEF Nexus in Egypt

The potential for a nexus approach in Egypt is apparent. Agriculture uses more than 85% of all water consumed in Egypt and this is expected to increase as population grows (Nour El-Din, 2013). Currently, 29% of children under 5 are stunted signifying a major food security problem in the country (UNICEF, 2012). Additionally, the potential of hydropower as an energy source has increased in recent years. This section aims to provide landscape analyses of the water, energy and food security sectors in Egypt and the potential for using a nexus approach to promote sustainable development.

Water

Egypt is reliant on the Nile River for more than 60% of its water supply (Nour El-Din, 2013). As a result of the 1959 Nile Treaty with Sudan, Egypt receives 55.5 billion cubic meters (bcm) of the river's flow each year (Attia, 2009). Other sources of water include deep and shallow groundwater, desalination and minimal rainfall and flash floods [Figure 2]. More than 80% of this water is used for agriculture with current agriculture water demand at 57.8 bcm and expected to increase as population grows [Figure 3].

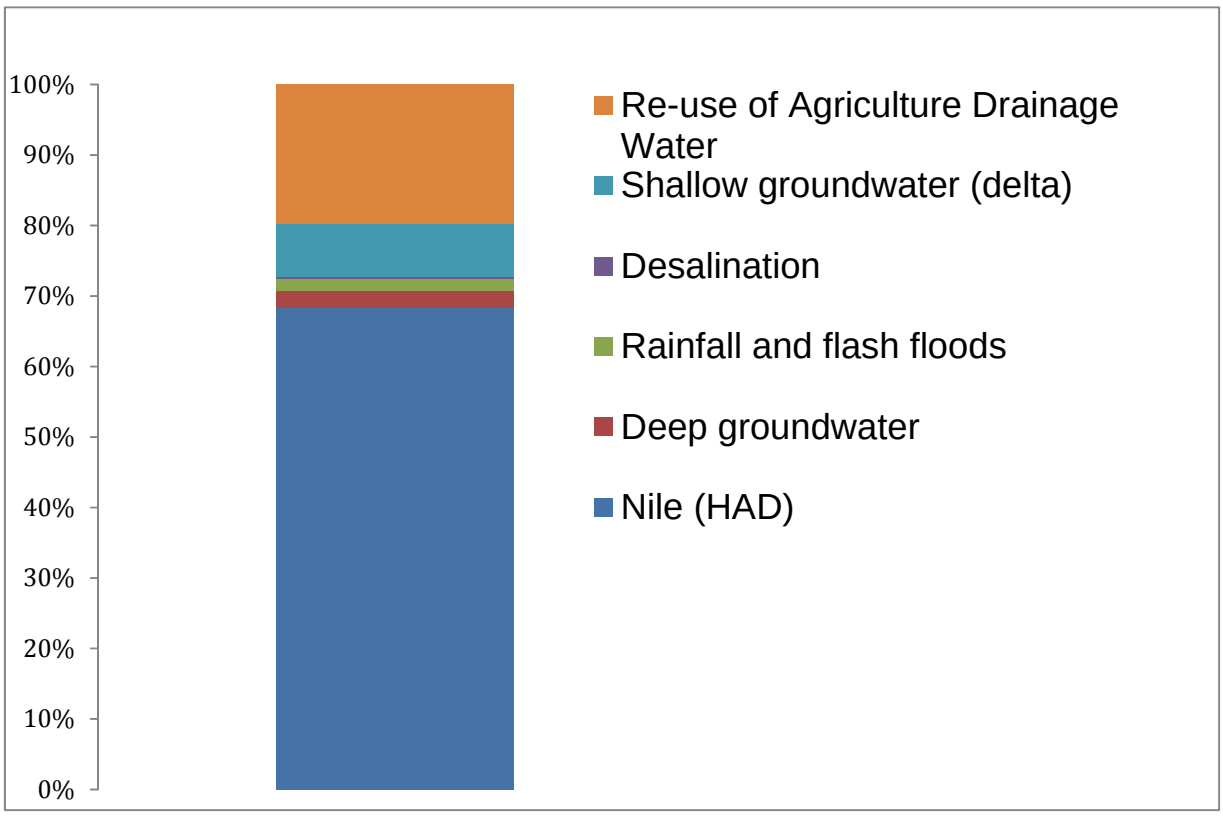


Figure 2. Total water supply in egypt

Although the Nile River still maintains its purification capacity, water quality remains an issue in Egypt. 20% of groundwater does not meet drinking water standards and several branches and canals of the Nile River suffer from domestic and industrial pollution. One source of water pollution is agriculture runoff. Egyptian farmers use over 1.8 million tons of fertilizer a year and a portion of that can end up in the Nile River and groundwater if proper buffers and practices are not in place (Nour El-Din, 2013). Water quality management is also lacking in Egypt with few preventative measures, such as financial incentives and monitoring and control regulations, in place to prevent the misuse of fertilizers and other water pollutants (Attia, 2009).

Future water management in Egypt is facing several challenges including population growth, climate change, continued degradation by human activities, upstream water projects, and sea level rise (Nour El Din, 2013). Water demand is expected to increase by 20% by 2050 and by 2025 water use per capita is expected to be 600 m^3, doubling from the current rate of 300m^3 (Ministry of Water Resources and Irrigation, 2014; Abdel Kader & Abdel Rassoul, 2010; "Water and Agriculture in Egypt," 2011). Domestic water use is 7% of total consumption but this is expected to increase as population grows (Abdel Kader & Abdel Rassoul, 2010). In anticipation of these challenges the Ministry of Water Resources and Irrigation has created a 2050 Water Strategy that includes plans to reduce water loss in the Upper Nile, address water pollution and promote stakeholder engagement (Nour El Din, 2013).

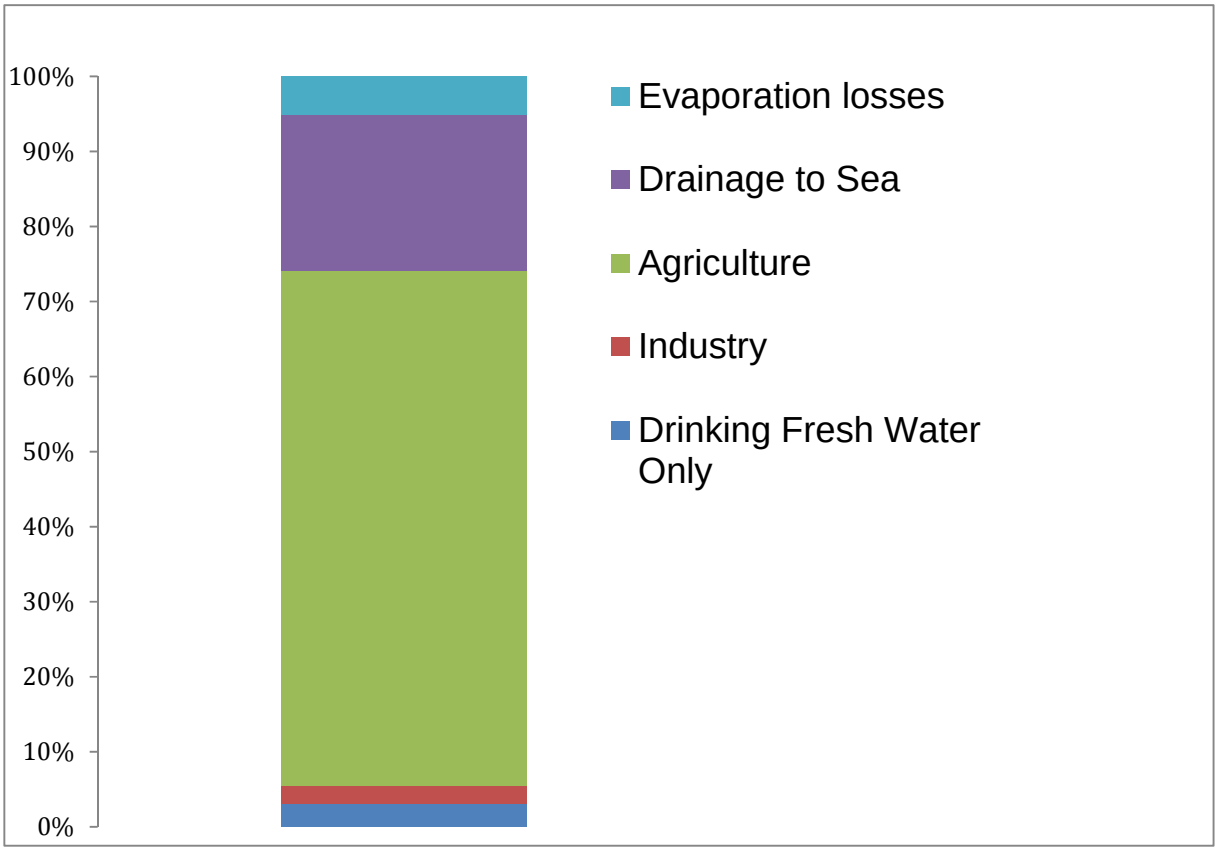


Figure 3. Water use in egypt

Energy

Natural gas makes up 54% of primary energy consumption in Egypt, followed by oil, hydroelectricity, coal and renewable energy at 41%, 4%, 1% and 0.3% respectively (BP, 2013) [Figure 4]. Industry, transportation services and residential use are the top three consumers of energy, making up over 70% of total final consumption [Figure 5] ("Egypt: Balances for 2011," n.d).

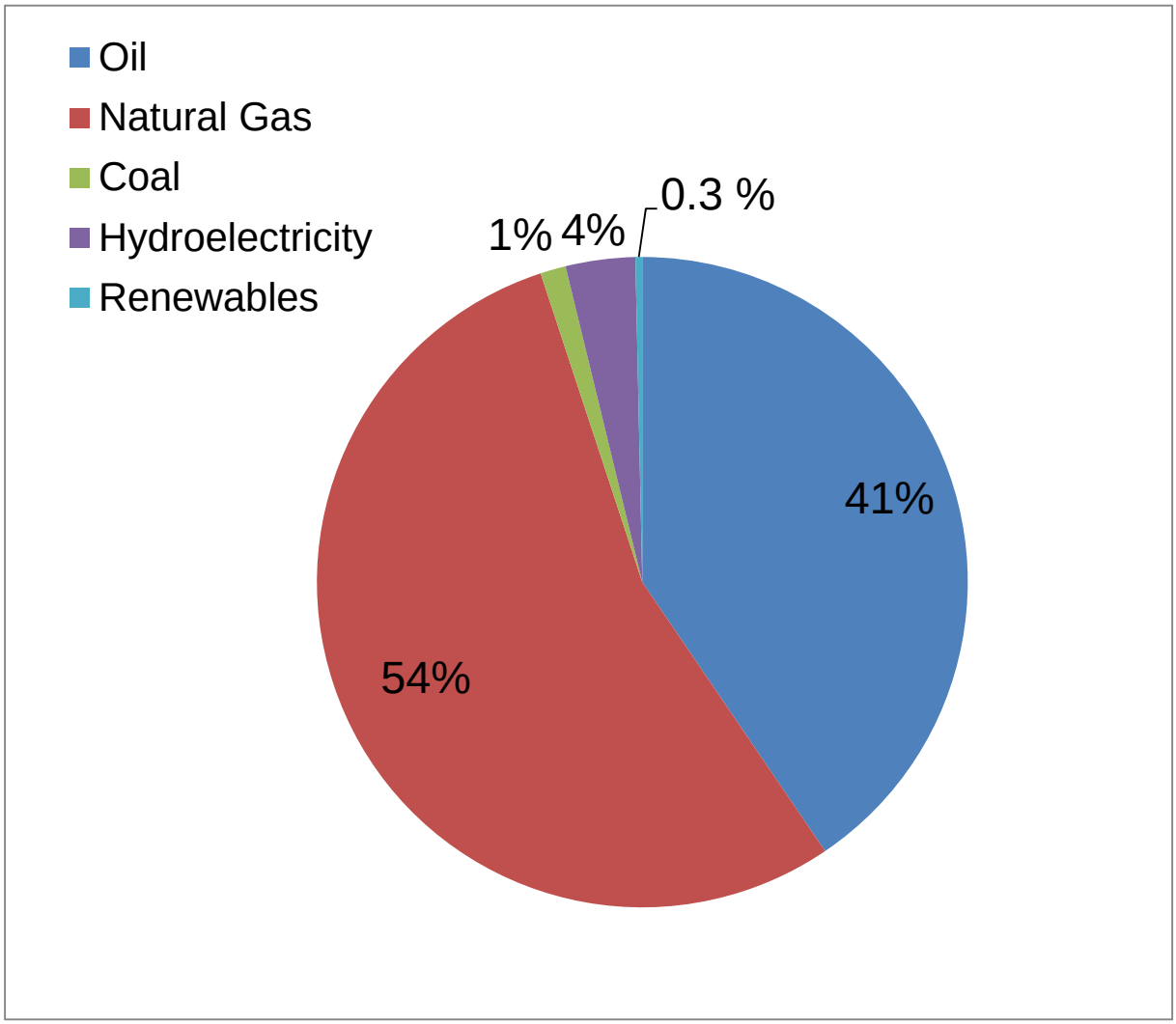
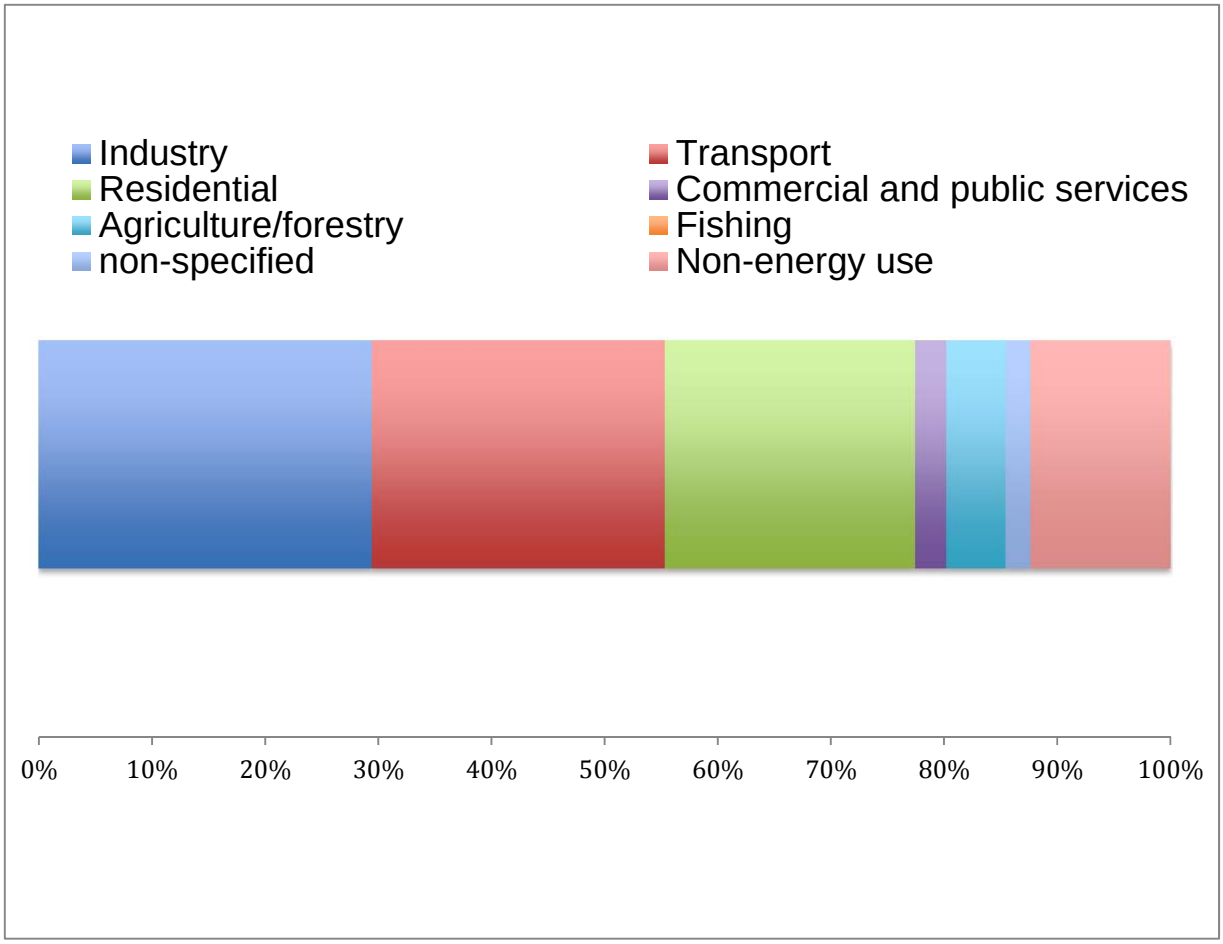


FIGURE 4. PRIMARY ENERGY CONSUMPTION IN EGYPT (2011)

Egypt has spent almost $100 billion over the last decade on energy subsidies that make up over a fifth of Egypt's annual budget (Associated Press [AP], 2014; Castel, 2012). These subsidies have led to excessive energy consumption, which along with population growth, has transformed Egypt from an oil exporting country to an oil importing country. The national government recently passed energy subsidies reforms in June 2014. The subsidy cuts raised the price of 80 octane by 78%, diesel fuel by 64% and gasoline by 40% (AP, 2014). It is hoped that the subsidy reforms will solve the country's frequent power cuts and enable more funds to be used for social reform programs. Egypt's National Energy Efficiency Action Plan calls for a target energy efficiency of 5% by 2015 but currently there are limited incentives for households and industries to demonstrate smart use of energy (Regional Center for Renewable Energy and Energy Efficiency [RCREEE], 2013a).

Figure 5. Total final energy consumption in egypt (2011)



Food Security

Egypt is suffering from the double burden of malnutrition. The nation faces the issues that emerge from changing diets, such as obesity and diabetes, yet more than a third of children under the age of five suffer from stunting. On the surface these issues appear to be at opposite ends of the spectrum, but both are a result of rising food insecurity that has led families to eat less or turn to less diverse diets made up of cheap and fat-dense food items (World Food Programme [WFP], 2013b). The state of Egypt's food security has been subject to several shocks over the past decade; the avian influenza epidemic of 2005, the fuel and financial crisis of 2007, and macroeconomic instability since the 2011 revolution have all made Egypt's population vulnerable to food insecurity (Breisinger, Al-Riffai, & Ecker, 2013).

In 2011, the World Food Programme estimated that 17.2% of Egypt's population is food insecure and 35% of people have poor dietary diversity (WFP, 2013b). Agriculture provides employment for 35% of Egypt's population and contributes to 13.5% of GDP (Karimi, Molden, Notenbaert & Peden, 2012). Food production does not seem to be the main cause of food insecurity as there has been an upward trend in production over the past decade. The country's top exports include oranges, cotton lint, refined sugar, cheese and potatoes [Figure 6] (Food and Agriculture Organization [FAO], 2014). Yet, agriculture land remains vulnerable to urban encroachment (Breisinger et al., 2013). Egypt is currently the world's largest importer of wheat, importing up to 55% of its wheat each year (Breisinger et al., 2013). Other top imports include maize, soybeans, palm oil, and raw sugar (FAO, 2014).

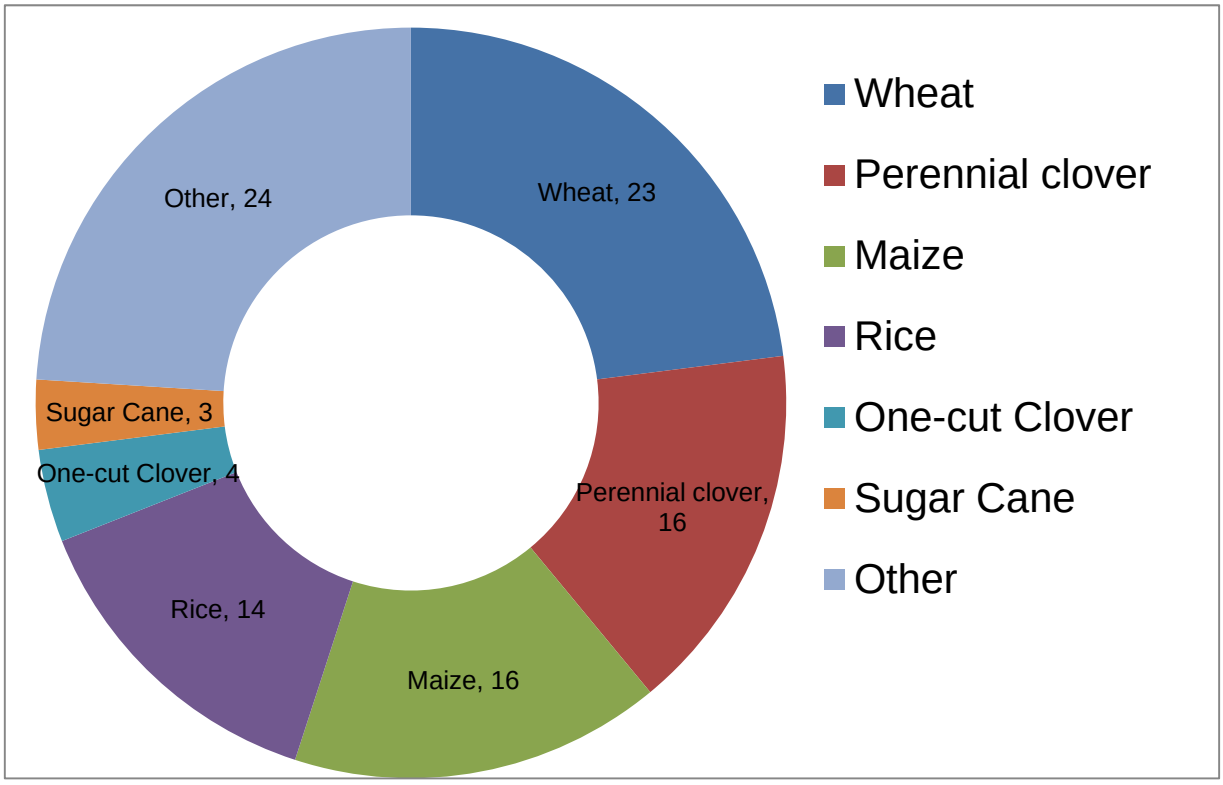


Figure 6. Crop coverage in egypt

Poverty is at the root of food insecurity and malnutrition; 86% of vulnerable households in Egypt claim their monthly income is insufficient for their needs (WFP, 2013a). Egypt has established food subsidies as part of its safety net to protect the poor, however, a study by the International Food Policy Research Institute found that 17% of the most vulnerable households are still excluded from the national ration system (Breisinger et al., 2013). The IFPRI also found that losses along the baladi bread supply chain, which also receives subsidies from the national government, are as high as 30% (Breisinger et al., 2013). Recent reforms by the government, such as the introduction of a smart card system to keep track of purchases and the elimination of subsidies for bakers, have attempted to address these problems. The goal of these reforms is to prevent waste from the over purchasing of wheat (Ahmed, 2014). The reforms are also meant to improve the targeting of social programs. Food rations currently cover 73% of the non-poor households but exclude 17% of the most vulnerable households (Breisinger et al., 2013). These reforms have been introduced in the Suez Canal and Alexandria regions of Egypt and are set to reach Cairo in upcoming months (Ahmed, 2014).

Opportunities for a Nexus Approach in Egypt

Even this brief introduction to the water, energy and agriculture sectors in Egypt introduces areas where a nexus approach would benefit development. The overwhelming diversion of water for agriculture makes water shortages an issue for food production and security throughout the country (Fick & Bushra, 2014). A look at Egypt's cultivated land will show that close to 20% of land is used to grow water-intensive crops, such as rice and sugar (Soliman, Capitanio, & Cerciello, 2013). Additionally although irrigation efficiency averages 73%, efficiency is as low as 40% in some parts of the country (Nour el-Din, 2013; Neumann, 2014). Furthermore, the role clean water plays in preventing malnutrition cannot be forgotten (UNICEF, 2012). These facts, along with Egypt's desire to increase wheat production, present opportunities to use the nexus model to produce multi-sectoral benefits (Fick & Bushra, 2014). Egypt's current Sustainable Agriculture Development Strategy introduces the nexus approach for decreasing water use in agriculture. The plan includes stabilizing rice cultivation at 1.2 million feddan, introducing irrigation on old agriculture land and the rehabilitation of irrigation systems in reclaimed land. These proposed changes are estimated to save Egypt 13.5 bcm of water per year ("Water and Agriculture in Egypt", 2011).

There are also opportunities for a nexus approach to link the water and energy sectors as well. Hydropower currently makes up 83% of installed renewable energy capacity in Egypt and the government has plans to increase total installed renewable energy capacity from its 11% to 20% (RCREEE, 2013b). How these changes will impact the flow of the Nile and the availability of energy to power irrigation pumps, transport services and food production processes is remained to see but it is almost certain that these changes will have an impact on the nation's food security in some way. Additionally, the government's desire to diversify its renewable energy supply by increasing wind and solar energy may encourage more environmentally-friendly approaches to energy production and uses in several sectors. Lastly, water is not only a potential source of energy but water is also a vital component in energy generation. Water is used during abstraction, fuel production and electricity generation. In Egypt, 25% of electricity capacity processes

depend on freshwater cooling (Siddiqi & Anadon, 2011).

Egypt's growing demand for water, energy and food security will only be exacerbated by outside pressures such as population growth, urbanization and climate change. The United Nations Intergovernmental Panel on Climate Change predicts a 1 to 2 degrees Celsius increase in temperature in Egypt by 2030 (Fick & Bushra, 2014). An increase of 1 degree Celsius may increase water evapo-transpiration rates by 4 to 5%, as well as decrease agriculture productivity and increase pressure on energy sources (Nour el-Din, 2013; Parry, Canziani, Palutikof, van der Linden & Hanson, 2007).

The recent changes made by the Government of Egypt to energy subsidies and the proposed changes to wheat subsidies suggest that the government is willing to make changes and consider new approaches to development including the nexus model. Moving forward, the role of participatory approaches in the nexus model should not be forgotten. These recent changes are a step forward but stakeholder engagement and community development should be considered along with the multi-sectoral approach of the water, energy and food security nexus. The following section will introduce development projects that have incorporated the nexus approach and policy recommendations.

Participatory Approaches and Knowledge Sharing

The nexus approach is at its core a management and governance tool. The model uses collaboration and coordination to achieve holistic success across sectors. A main component of the nexus approach is the use of participatory measures. Stakeholder engagement is crucial to ensuring that projects and policies are not only environmental sustainable but also socially acceptable and supported by those groups affected and involved. The case studies reviewed above display different levels of stakeholder engagement and knowledge sharing. Despite their different technical strategies, each of these groups realized the importance of knowledge sharing and participatory planning and made it a critical component of their projects (Bizikova et al., 2013).

Participatory planning is not a linear process, rather it a cycle with internal feedbacks that ensure the constant participation of each stakeholder in the planning and implementation process. Figure 7 shows an example of an extended participatory planning cycle.

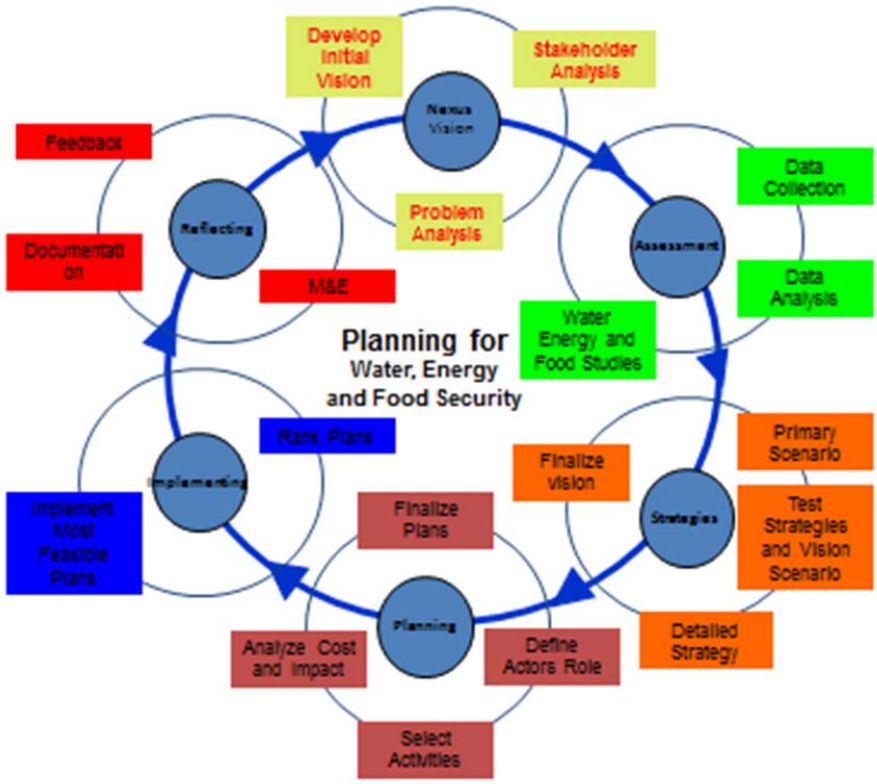


Figure 7. Extended Participatory Planning Cycle
Source: Abdel-Meguid, 2014 based on EMPOWERS planning Cycle

Policy Recommendations

Based on the landscape analysis of the water, energy and food security nexus in Egypt the following recommendations have been put forth in order to promote the sustainable development of each of these three sectors:

1) The development of a national grant award for development projects utilizing the nexus approach to promote coordination and collaboration across sectors.

2) The creation of a national nexus knowledge platform to enable information sharing.

3) The implementation of a Nexus steering committee(s) comprised of policymakers, researchers, and civic organizations to oversee development projects in these three sectors.

4) A portion of the expenses saved from the removal of energy and bread subsidies should be earmarked for renewable energy, sustainable agriculture and water conservation projects.

5) Attention must be paid to extending the life cycle of food, water and energy by increasing energy efficiency and the improved management of wastewater and organic waste.

Conclusion

Egypt is at a critical point in its development. Moving past the recent years of political turmoil will not be an easy task and it will only be complicated further by population growth, urbanization and climate change. The nexus approach presents an opportunity for Egypt to make strides in three sectors without comprising its natural or social environment. Effective governance in the water, energy and food security sectors and the use of participatory approaches will set the stage for Egypt to continue making strides towards poverty reduction and economic growth.

Annex
Case Studies Highlights

Jain Irrigation Systems Limited- India

Jain Irrigation Systems Limited (JILS) is an Indian company specializing in micro-irrigation systems, such as, drip irrigation and sprinklers. Agriculture is the biggest user of water in India and demand is set to grow as living standards improve. India currently has 17% of the world's population but only 4% of it water resources. Inefficient conventional irrigation methods are still used on the majority of India's cropland. JILS sought to address the inefficiency of India's irrigation system, as well as decrease energy demand by promoting the use of drip irrigation. By partnering with farmers, universities, central and state government, JILS used integrated agriculture management and stakeholder participation to teach farmers about the benefits of switching to drip irrigation. Drip irrigation has an efficiency rate of 70 to 90% compared the 40 to 50% efficiency rate of conventional irrigation methods. Drip irrigation's higher efficiency comes from its ability to minimize runoff and deep percolation of water. Not only does drip irrigation save water but it also saves energy by reducing the amount of energy needed to power water pumps (Deshmukh, 2012).

JILS has experienced some problems while promoting their product. The cost of drip irrigation varies depending on crop type, soil texture, etc. and may prove to be cost-prohibitive for some farmers. Additionally, not all farmers are willing to accept new technology (Deshmukh, 2012). To help increase the acceptability of drip irrigation JILS has set up training centers to teach farmers how to use their products and are considering working with agriculture extension workers to further promote the use of drip irrigation (Deshmukh, 2012; International Finance Corporation [IFC], 2012). JILS' use of stakeholder participation and the nexus approach has had positive benefits for farmers. Farmers have been able to increase their income by $100 to $1000 per acre and save over 500 million cubic meters of water per year (IFC, 2012).

CityBlues++- Vientiane, Laos

CityBlues++ is a research and practitioner partnership that aims to improve Vientiane's urban wastewater management system. The initiative is comprised of three phrases. The first phrase, which began in 2012, is a series of workshops with policymakers, practitioners, researchers and other stakeholders to obtain a clear picture of the state and challenges of Vientiane's current wastewater management system. The workshops are also meant to establish the priorities of each stakeholder. The second phase is the creation of a detailed report about the feasibility and benefits of citywide implementation. The last phase is the planning and implementation of the CityBlues++ vision. CityBlues++ envisions a system where organic waste from the city's wastewater is used for local biogas production and process sludge is used as fertilizer for agriculture ("Background," 2012). CityBlues++ presents a different perspective to the WEF nexus by addressing the issue of waste and the reuse of resources. Rather than focusing on conservation like JILS in India, CityBlues is promoting smart resource use by advocating for the extension of the lifecycle of water in order to produce energy and organic inputs for agriculture.

Juwi Hybrid System- Wadi el Natroun, Egypt

Halfway between Egypt's two largest cities, Cairo and Alexandria, lies Wadi el Natroun, a desert oasis where the University of Alexandria has been performing research on arid soil. The oasis is home to an agriculture community that

grows tomatoes, olives and dates and is slowly growing as farmers reclaim desert land. In 2012 Juwi, German renewable energy specialists, was hired by the University to build an off-grid hybrid system to power the local desalination plant and agriculture water pumps. The community had been reliant on an old diesel generator for their energy needs (Juwi, 2012).

The entire system was built in two weeks and completed in November 2012. The final system is made up of 50kWp free-field photovoltaic modules, four wind turbines producing a total of 52kW and a battery unit capable of storing 500kW to ensure consistent access to energy. A portion of the system, 100kVA, is integrated with the already existing diesel generator. The entire system is monitored remotely in Germany in real-time to ensure the efficient resolution of any problems. The University of Alexandria and Juwi partnership represents innovative progress in the water, energy and food nexus. This off-grid system provides farmers with a clean energy source to pump water to produce food. The power eliminates the need for traditional sources of energy that often degrade the surrounding environment by creating air and water pollution Norbert Borchert, of Juwi's Off-grid department stresses that this project was more than using clean energy to bring water to Wadi el Natroun. "We haven't just brought water into the desert, we have also transferred our know-how to people who can directly apply the knowledge. For this reason alone it was worth pursuing the project," Borchert says (Juwi, 2012).

Renewable Energy & Water Pumping: the basis for a Nexus Approach to Agricultural Development in the Bahareya Oasis – Egypt

In the Bahareya Oasis of Egypt, a young private company 'Karmsolar' worked at the implementation of solar water pumping for agricultural production. This case study aims at highlight renewable energy's role in improving water governance, tackling climate change, and facilitating sustainable agricultural development for food production in the MENA region. A case study of the activities of KarmSolar, a Cairo-based Solar Technology Provider, demonstrates the relevance of solar energy system integration into these important spheres.

In off-grid desert locations, water extraction is the primary stage of the agricultural process. KarmSolar's development and operation of High-Capacity Off-Grid Battery-Free Solar Water Pumping ("SWP") systems places them as an important actor in 1) the cost of the supply of water (which is directly affected by energy costs incurred by running pumping systems), 2) groundwater withdrawal rates, and 3) the administration of aquifer and climate data (through the use of the Solar Management Interface – "SMI").

To comprehensively tackle the water-energy-food nexus and climate change debate, the off-grid agricultural sector's water management regime, which begins with the extraction of water from underground aquifer systems, must be addressed. KarmSolar's development and operation of the SWP system must be given prominence within the discourse due to the direct social and economic effect it has on participants and stakeholders within the agricultural sector, but also the environment and the natural resources.

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