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Using the water-energy-food nexus to enhance Egypt’s cooperation with Nile Basin countries

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Using the Water-Energy-Food Nexus to Enhance Egypt's Cooperation with Nile Basin Countries

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To my mother and father who have always given me endless support

To my wife Dina who has supported me throughout the course of my study

To my children Tameem and Lina

I dedicate this thesis…

"The only matter that could take Egypt to war again is water."

Mohamed Anwar El-Sadat, 1979

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Abbreviations

AGECC	The Secretary-General’s Advisory Group on Energy and Climate Change
BCM	Billion Cubic Meters
BG	British Gas
BMU	German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety
BMZ	German Federal Ministry for Economic Cooperation and Development
BP	British Petroleum
CAPMAS	Central Agency for Public Mobilization and Statistics
CBE	Central Bank of Egypt
CHP	Cogeneration of Heat and Power
CIA	Central Intelligence Agency
CNG	Compressed Natural Gas
CPI	Consumer Price Index
CSP	Concentrated Solar Power
CTL	Coal to Liquid
ED	Electrodialysis
EDI	Electrodionization
EEHC	Egyptian Electricity Holding Company
FAO	Food and Agriculture Organization of the United Nations
GERD	Grand Ethiopian Renaissance Dam
GDP	Gross Domestic Product
GW	Gega Watt
HIECS	Household Income, Expenditure, and Consumption Survey
IEA	International Energy Agency

IFPRI	International Food Policy Research Institute
IMF	International Monetary Fund
IRENA	International Renewable Energy Agency
IWRM	Integrated Water Resources Management
kWh	Kilo Watt Hours
LDC	Least Developing Countries
MED	Multi Effect Distillation
MOU	Memorandum of Understanding
MSF	Multi Stage Flash
MW	Mega Watt
OPEC	Organization of the Petroleum Exporting Countries
PPM	Parts per Million
R&D	Research and Development
RO	Reverse Osmosis
UN	The United Nations
UN ESCAP	United Nations Economic and Social Commission for Asia and the Pacific
UNEP	United Nations Energy Program
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
UNDP	United Nations Development Program
U.S. EIA	United States Energy Information Administration
US$	United States Dollars
WB	The World Bank
WEF	Water – Energy – Food
WFP	World Food Program

WMO	World Meteorological Organization

Abstract

In the coming decades, the World will be facing severe challenges in terms of water, energy and food through increased water use, increased energy demand and increased food demand and shifting diets. Those challenges are foreseen to be amplified due to climate change effects. Egypt is a country struggling to achieve water, energy and food security, which are key issues in achieving national security. Egypt is facing another major challenge regarding its main water resource Nile River. Ethiopia is currently undergoing the construction of a huge dam on the Blue Nile which is the Grand Ethiopian Renaissance Dam (GERD). The purpose of the research is to attempt to mitigate the effect of the GERD on Egypt through cooperation with the Nile Basin countries on their Water-Energy-Food Nexus (WEF Nexus).

The grand Ethiopian Renaissance dam (GERD) is a mega hydro-electric project currently under construction on the Blue Nile. It is planned to have a 74 BCM capacity reservoir and a power generation capacity of 6,000 MW. If not agreed appropriately, the filling of the GERD reservoir might have significant impacts on the Aswan High Dam.

A policy framework was developed for the water-energy-food nexus for Egypt and the Nile Basin. In Egypt, it is suggested to create a Supreme Council for Water, Energy and Food which includes all the relevant ministries. For the Nile Basin, a Nile Basin WEF is suggested, whose decisions should be legally binding for Nile Basin countries. Examples were provided on the project/programme level that could have benefited from the WEF synergy, like the reclamation of 1.5 million feddans and the expansion of the electricity generation sector. An institutional arrangement was developed, which is applicable for Egypt and the Nile Basin countries. The arrangement is done through a methodology which encourages the prioritization of projects that take into consideration the WEF nexus. On the Nile Basin level, examples were given for potential projects that could benefit from the WEF synergy if the basin is thought of as one unit. Examples provided included the expansion of green water utilization and integration of electricity grids. The policy framework showed that the GERD itself can be

viewed as an opportunity for cooperation if the right policy framework is developed among the basin countries.

Chapter One: Introduction and Research Problem

1.1 Global Challenges in the Water, Energy and Food Sectors

Water, energy and food security are far from being achieved globally. A large number of people globally lack basic services. About 0.9 billion people do not have access to an improved water source, 2.6 billion are deprived of safe sanitation, 1.3 billion do not have electricity access, 1.5 billion lack access to modern cooking energy forms and 1 billion suffer from hunger regularly (BMU and BMZ, 2011). Many people are deprived of basic human rights and are not even given any opportunity for development. Nevertheless, and despite this situation, the world has reached and exceeded sustainable limits of resource consumption. The world is in need to the development of innovative and well-integrated solutions to achieve sustainable growth.

In the coming decades, the world will be facing severe challenges in terms of water, energy and food:

- Increased water use: Historically, freshwater withdrawals have increased at rates higher than population growth rates. This implies that the growth in freshwater demand will increase even more than the population growth rate (World Economic Forum, 2011). A recent study suggested that the World could be facing a shortage of 40% in available freshwater as compared to the water demand by 2030 (McKinsey & Company, 2009). A large number of countries are already using ground water at rates faster than renewed, including Mexico, China, India and Jordan (UNDP, 2007). If water continues to be used in this unsustainable manner, it is expected that two thirds of the world’s population will suffer from water stress by 2030 (FAO, 2007).
- Increased energy demand: It is forecasted that the world will need 40% more energy by 2030 compared to the current levels (IEA, 2009). For example, by 2030, China is expected to expand its electricity generation capacity by at least 1,300 GW, while India will need an additional 400 GW (Project Catalyst, 2009). Many countries prioritize access to energy. Currently, 1.5 billion people lack

electricity access, while more than 3 billion people still utilize biomass for their thermal requirements (AGECC, 2010).

- Increased food demand and shifting diets: The demand for food will continue to increase in the coming decades due to the growth of the World population by an additional 2.7 billion people, increasing incomes, and additional meat consumption. The growing population of the world will need more and different types of food. As the living standards improve and population become more urban, the demand will increase for resource intensive types of food such as meat. The global meat demand is expected to increase by 50% by 2025, leading also to a 42% increase in the demand for grain (UNEP, 2009). This is expected to limit the purchasing power of the poor even further in a world where currently one billion people suffer from hunger (World Economic Forum, 2011).

The above-mentioned challenges are even expected to be amplified by climate change effects. Climate change is expected to increase water stress in large parts of the World, causing 75-220 million people to suffer from fiercer water shortages by 2020. Shrinking agricultural land, distorted growing seasons and increased uncertainty on suitable crops to grow are expected to reduce agricultural productivity. Crops depending on rain are expected to drop by as much as 50% by 2020. This is expected to worsen the situation of food security, pushing more people into hunger in the coming few decades (UNFCCC, 2007). For example, in East Africa small farmers depending on marginal land are already suffering from big variations in rainfall patterns. In addition, they are facing low yields due to dropping soil fertility, erosion and drought. People in these areas depend on maize and beans for their livelihood, but are currently highly vulnerable to adverse climate change effects (WMO, 2012).

Climate change is expected to increase nexus challenges. Temperatures are expected to increase, soil is expected to dry out, storms are expected to intensify and glaciers are expected to reduce in size. Power production especially that is based on hydroelectricity is threatened as a result of droughts. Both the energy and food sectors are contributing sectors to climate change through emitting greenhouse gases and they will also be affected by climate change (BMU and BMZ, 2011).

1.2 The Egyptian Context

Egypt is a country struggling to achieve water, energy and food security. Achieving security in these three sectors is a key issue in achieving national security. The failure of the State to provide the population's water, energy and food requirements might be a reason for social instability leading to riots and political instability.

In terms of water, Egypt is mainly relying on the Nile River, from which it currently receives 55.5 BCM per year as per the 1959 Nile Waters agreement. Egypt's total annual renewable water resources are currently around 700 m^3 per capita, which puts Egypt in the water scarcity zone as per the United Nations classification (UN, 2014). This figure is expected to reach 550 m^3 per capita per year by 2025 (The Brookings Institution, 2012).

In the energy sector, Egypt has experienced during the years following the 2011 revolution its worst energy crisis in decades. In addition to the fact that the current installed capacity of around 27 GW does not meet the peak demand, there are huge shortages of fossil fuels, mainly natural gas. This has led to major blackouts during the years after the 2011 revolution. The country is also unable to keep regular energy supply to the industry especially energy intensive industries. By the end of April 2014, the government owed its oil & gas foreign partners US$ 6 billion (Adel, 2014) . In order to overcome an expected deficit of 2.4 billion cubic feet per day of natural gas, the government is heading towards importing coal, a carbon intensive fuel (Adel, 2014). The cement industry is currently opting for importing coal, to overcome the irregularities of the supply of natural gas from the government.

Looking at food security, Egypt is a net importing country; it currently imports 45-55% of its wheat consumption (IFPRI, 2013). This makes Egypt highly vulnerable to international price fluctuations. With higher international prices and lower foreign currency income in the years post the 2011 revolution from tourism, exports and foreign direct investments, the balance of payments deficit has become much wider (IFPRI, 2013). The current situation thus places serious question marks on Egypt's energy, water and food security.

1.3 Research Problem

In addition to the above challenges, Egypt is facing another major challenge regarding its main water resource Nile River. Ethiopia is currently undergoing the construction of a major dam on the Blue Nile: The Grand Ethiopian Renaissance Dam (GERD). Other dams are also planned to be built as the total potential for hydropower in Ethiopia is estimated around 45,000 MW of which only 3% is being currently utilized. The purpose of the research is to study possible mitigation of the effect of the GERD on Egypt through developing its WEF nexus locally and the cooperation with the Nile Basin countries using the WEF nexus.

Chapter Two: Conceptual Framework and Methodology

The aim of this section is to explain how the key research questions in this thesis were developed. It will also explain the methodology followed in order to reach the answers to the research questions through a systematic research approach.

2.1 Research Problem

Egypt is already facing huge challenges in terms of energy, water and food security. The three sectors are very well interconnected and deficiencies in one sector cause shortages in the other two sectors. The Grand Ethiopian Renaissance Dam (GERD) is expected to have negative impacts on Egypt's water security. This will in turn affect Egypt's food security and energy security due to the interconnections between the three sectors.

2.2 Main Research Question

The main research question is whether developing a policy framework for a WEF Nexus for the Nile Basin can help Egypt overcome the additional stress on its water resources caused by the GERD. The hypothesis is that developing such a nexus will help Egypt both internally through coordinating its policies in the three sectors and on the Nile Basin level will help overcome the problem and open new opportunities for cooperation among the Nile Basin countries in the three sectors.

Egypt has always held the position that it will not give up on one drop of its "historical rights" in the Nile water. In addition, all previous agreements and initiatives have been focused solely on the water issue. The problem is that when looking at the water alone, the negotiation process turns into a win-lose process. Since the Nile water is a finite resource, whatever water Ethiopia gains Egypt has to lose. The main hypothesis in this thesis is that the situation with the Nile Basin countries can be turned into a win-win situation if we zoom out to include the water, energy and food sectors into the equation. This means for example that Ethiopia can withhold part of the Nile water in return for power transmitted through the integration of the power grids of the Nile Basin countries or through giving Egypt the opportunity to plant parts of the Ethiopian land which receives adequate rainfall for agriculture.

2.3 Minor Research Question

In addition to the main research question mentioned above, the thesis also examines whether creating a policy framework for a WEF nexus for Egypt can help the country face the upcoming challenges in the three sectors. It also tackles whether it is possible to have a complete integration with the Nile Basin countries through the concept of virtual water trade.

2.4 Research Design

The research conducted in this thesis relies mainly on a desk study of a literature review including the following sources:

- Reports from international organizations on the WEF nexus and its global emergence in the past few years. Those included UNESCO, UN ESCAP, UNDP, FAO, the World Bank and the World Food Program.
- Journal articles and studies to assess the issue of virtual water trade in the Nile Basin. Those included the Journal of Global Environmental Change, the Journal of Hydrology, studies by FAO and the Nile Basin Initiative, a PhD Thesis from Delft University and a study from King's College in London.
- Journal articles and studies to assess Ethiopia's water, energy and food security situation and its plans to build dams on the Blue Nile. Those included the Journal of the American Water Resources Association, Journal of Asian and African Studies, Water Policy, Hydrology and Earth System Sciences, Mountain Research and Development, Journal of Water Resources Planning and Management, in addition to reports from Oxfam, the World Water Council, UNDP, the World Bank, FAO, World Food Program

After the above literature is examined and analyzed, a policy framework for the WEF nexus in Egypt and the Nile Basin countries will be developed. There were no previous attempts to propose such a policy framework for Egypt or the Nile Basin. The framework will tackle cooperation from a WEF nexus perspective and will not be only limited to water issues.

Chapter Three: Literature Review

3.1 Emergence of the Water-Energy-Food Nexus Globally

During the period from the 16th till the 18th of November, 2011, roughly 550 people gathered in Bonn in order to attend a conference called "The Water, Energy and Food Security Nexus – Solutions for the Green Economy". The German government organized the conference in order to bring key stakeholders from the three sectors together, with the aim of collaboration and brainstorming solutions for cross-cutting problems. The conference gave the first opportunity for both experts and politicians from a large number of countries from all three sectors to collectively develop the nexus steps (Martin-Nagle et al., 2011).

The nexus approach offers huge potential to improve resource efficiency and provide benefits related to production and consumption through addressing externalities across the sectors. The nexus focuses on overall system efficiency and not merely isolated sectors productivity, and hence maximizes benefits provided to societies. A better integrated process of developing policy accounting for cross-sectoral external costs will improve overall resource efficiency and provide more equitable benefit sharing, as opposed to conventional approaches which only improve sectoral resource productivity (Martin-Nagle et al., 2011).

The benefits from the Nexus approach should encourage governments, private sectors, and the civil society to collaborate. Those include for example addressing intensive agriculture which utilizes less water but uses more energy than traditional agriculture. The nexus approach would address the energy intensity of desalination, water requirements for renewable energy production and water requirements for afforestation. Management across the sectors can help improve overall resource efficiency. It is possible in multi-use systems to utilize waste and un-useful by-products to be resources to other products and services. The nexus approach can also use economic instruments to improve resource efficiency. Governance, institutions and policy coherence can help guide investments that minimize negative externalities. Capacity building is also needed to manage the complexity of cross-sectoral approaches (Hoff, 2011).

The WEF Nexus has become part of the international development efforts and is acknowledged as a policy paradigm. Table 1 examines how the WEF nexus is portrayed in different documents and initiatives of international organizations.

Table 1 - Nexus Elements in Major Documents and Initiatives (UN ESCAP, 2013)

	Entity	Views on the Nexus	Documents/Meeting
1	Food and Agriculture Organisation of the United Nations	The FAO views the energy-agriculture as a coherent system. Bioenergy could be used to improve agricultural productivity for rural development. It links between energy, biomass and carbon flows.	The Energy and Agriculture Nexus, 2000. Energy and Natural Resources Working Paper No. 4
2	United Nations Economic and Social Commission for Asia and the Pacific	WEF security is considered as one of the resource efficiency strategies.	Low Carbon Green Growth Roadmap for Asia and the Pacific, 2012
3	Asian Development Bank	Adopts the nexus perspective as one its 12 key messages.	Asian Water Development Outlook 2013: Measuring Water Security in Asia and the Pacific
4	Transatlantic Academy	Looks at the WEF security from a broader perspective which includes land and minerals.	The Global Resource Nexus: The Struggles for Land, Energy, Food, Water and Minerals, 2012
5	Stockholm Environment Institute	Pushes for reducing trade-offs and generating more benefits among the nexus elements.	Prepared the background paper for Bonn 2011 Nexus
6	International Food Policy	Publishes article on the food-water-climate change	A co-organizer of the Bonn

	Research Institute	nexus in a number of scientific journals.	2011 Nexus Conference
7	International Energy Agency	Focuses on water requirements for energy generation and estimates freshwater needs by energy source and region.	World Energy Outlook 2012
8	The World Bank	Issued a report on the importance of river resources for the WEF nexus.	Overcoming Barriers to International Cooperation of River Basins Critical for Food, Water, Energy Security, 2012
9	United Nations Conference on Sustainable Development	Covered the topics of food security, water and sanitation, and energy.	Outcome document "The Future We Want", 2012
10	Asia- Pacific Center for Water Security, Tsinghua and Peking Universities	Collaborated with ADB for publishing the Third Water Development Outlook for Asia and the Pacific.	Established a regional program on R&D on WFE security, 2013

3.2 Linkages among Water, Energy and Food

Connections among food, energy, and water are numerous and complex. This section examines the most important links among the three sectors. The main inter-relationships between water, energy and food are shown in Figure 1.

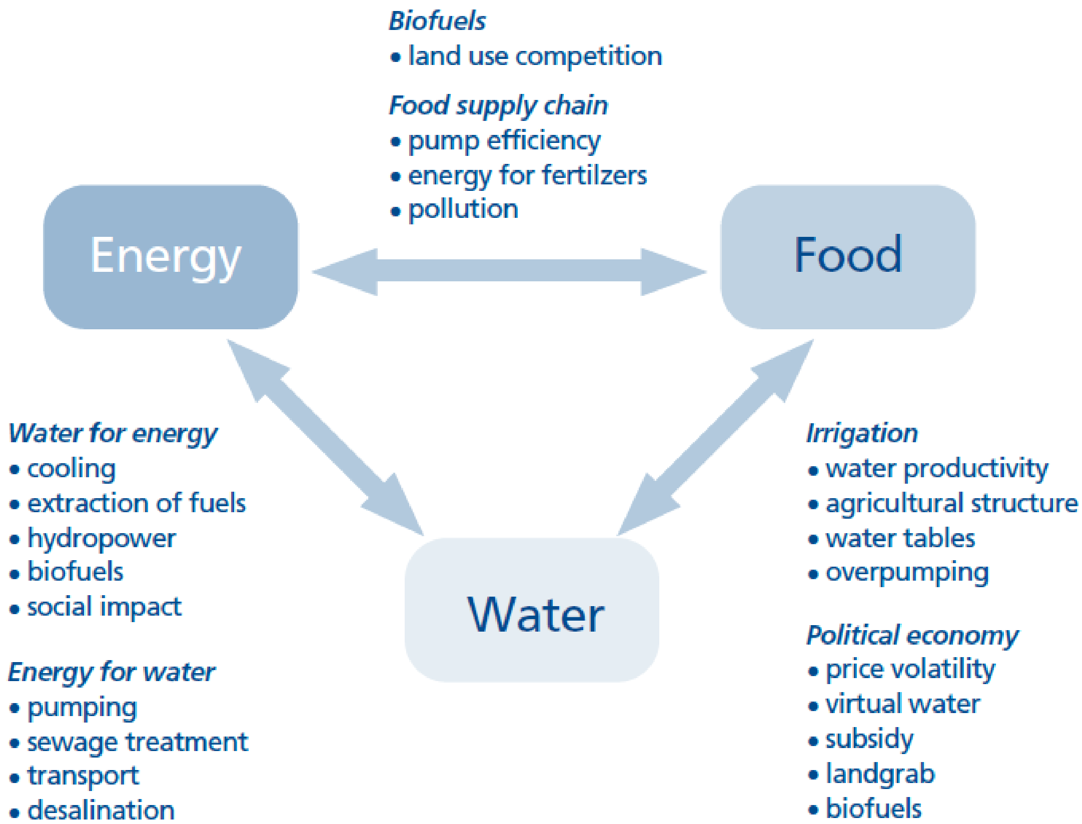

Figure 1 - Schematic of the WFE nexus and its constituent issues (UN ESCAP, 2013)

3.2.1 Water for Food and Water for Energy

The most evident inter-relation in the WEF nexus is agriculture, which has been practiced by humans for many thousands of years. The largest consumer of freshwater worldwide is agriculture for food and fiber production. Table 2 shows that the amount of water withdrawals for agriculture worldwide is around 69%. Large amounts of water are also used for energy production. That includes extraction of fossil fuels, mining, refining processing and electricity generation. Water is also used for growing biofuel feedstock. On the other hand, energy is used for water pumping, treatment and distribution as well as for the treatment of the resulting waste water. We should however differentiate between electricity generation which returns most of the withdrawn water and agriculture which does not (Finley & Seiber, 2014). Between 15% and 35% of global water withdrawals are not sustainable, meaning that water usage is used faster than it can be replenished (Dupont & Thirlwell, 2011).

Table 2 - Water withdrawal by sector, around 2007 (FAO, 2014)

Region	Total withdrawal by sector						Total water withdrawal (BCM/year)	Total freshwater withdrawal (BCM/year)
	Municipal		Industrial		Agricultural			
	BCM/year	%	BCM/year	%	BCM/year	%		
Africa	27	13	11	5	174	82	213	199
Americas	130	15	288	34	430	51	847	843
Asia	228	9	244	10	2035	81	2507	2373
Europe	72	22	188	57	73	22	333	332
Oceania	5	26	3	15	11	60	18	17
World	462	12	734	19	2722	69	3918	3763

3.2.2 Energy for Food

The food sector is globally also highly dependent on energy. The production of food and the associated supply chain consume around 30% of the World energy consumption. That includes the energy required for primary production; energy used for drying, cooling and storage; energy used for food transportation; processing of food and beverage; and preparation and cooking (FAO, 2011).

In agriculture, farmers use energy inputs to improve processes that occur naturally so that a given piece of land or amount of water would actually yield more product than it would naturally do. The significant fossil fuel consumption in all phases of the food system helped meet the amount of food required globally by a growing population in the past 100 years. Transportation of food in vessels, tractors, trucks and other vehicles consume oil products. Chemical fertilizers and pesticides consume natural gas. Electricity and heat generated by fossil fuels are used to process, refrigerate and package food. Cooking also consumes a wide range of fossil fuels (FAO, 2011).

The interconnections between energy and food are best shown through the prices. The boom in food prices reached its peak during July 2008, when the average price of crude oil went up 94% from a year earlier reaching US$ 133/barrel. Within only five months of 2008, rice prices increased from US$ 375/ton in January to $757/ton in June (Baffes & Haniotis, 2010). The IMF's index for internationally traded food commodities prices increased 56% during the period from January 2007 to June 2008 (Mitchell, 2008).

Figure 2 shows how commodity prices tend to be linked with energy prices. During the period from 2000 to 2010, wheat and crude oil prices have nearly tripled, and rice and corn prices have almost doubled. Increases in oil prices since 2003 have resulted in more demand for biofuels. The process of converting vegetable oil to biodiesel is cost-effective if vegetable oil is much cheaper than diesel. It is also possible for farmers to switch to vegetable oil crops from food crops in case it is more profitable for them. Therefore, cereals prices are connected to vegetable oil prices, and hence to crude oil prices (Kim, 2010).

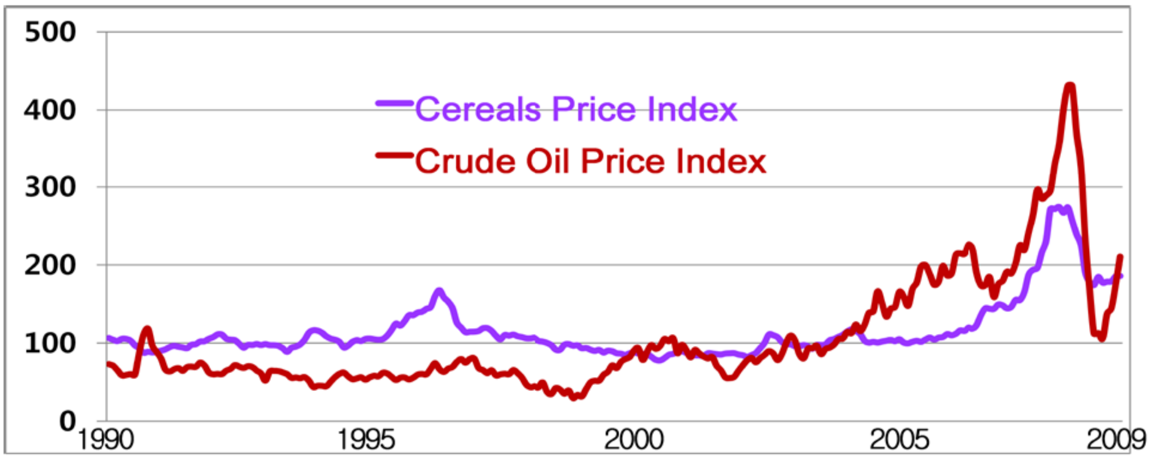

Figure 2 - Comparative trends of crop commodity and oil price indices from 1990 to 2009 (with 2004 as baseline) (Kim, 2010)

3.2.3 Desalination: Energy for Water

Desalination is an energy intensive process. Given the advancement of desalination technologies, desalinated water can now be produced at a cost lower than US$ 0.50/m^3. It is also expected that the advancement of new state-of-the-art desalination technologies like adsorption desalination will bring the required amounts of energy and the associated cost down in the future (Ghaffour et al., 2012). The growth rate of the desalination capacity worldwide is currently at an astonishing annual rate of 55% (Global Water Intelligence, 2014).

There are two main types of desalination technologies: thermal desalination using thermal energy and/or electricity and membrane desalination using only electricity. Thermal desalination depends on processes which change the physical state of water or distillate via evaporation. On the other hand, membrane desalination utilizes processes which use a membrane employing the concept of filtration (Al-Karaghouli et al., 2009). Currently the most dominant desalination technologies are the Reverse Osmosis (RO), a membrane technology, constituting 60% of the global capacity and the Multi Stage Flash (MSF), a thermal technology, constituting 27% of the global capacity. The distribution of the desalination technology market is shown in Figure 3. The suitability of each technology depends on a lot of factors like energy availability and pricing, water quality and technical resources available in the region (IRENA, 2012). The main sources of water for desalination are sea water and brackish groundwater which amount to 58% and 23% of feed water for desalination globally respectively (Al-Karaghouli at al., 2009). The types of desalination technologies are shown in Figure 4.

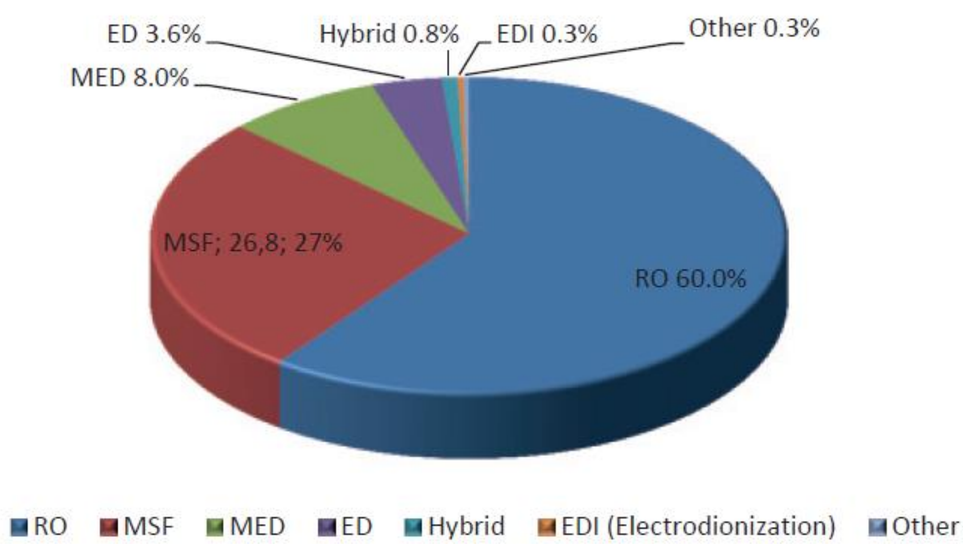

Figure 3 - Desalination Technology Market (Koschikowski, 2011)

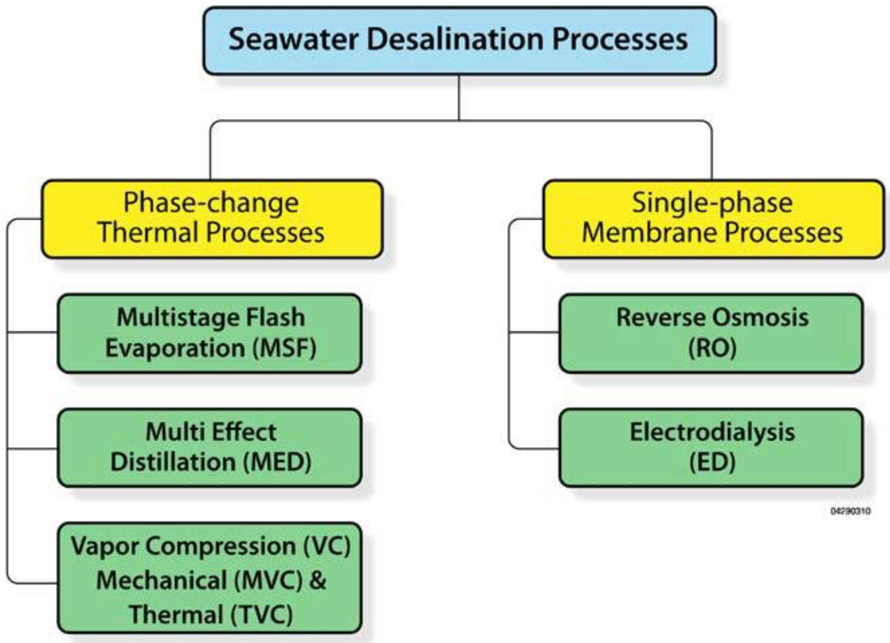

Figure 4 – Seawater Desalination Processes (Al-Karaghouli et al., 2009)

3.2.4 Biofuels: Food for Energy

The term biofuel refers to solid, liquid or gaseous fuels that are produced from bio-renewable or combustible renewable feedstock (Demirbas, 2007). The two main biofuels used as transportation fuels are bioethanol and biodiesel. Those two can potentially replace gasoline and diesel fuel respectively. The feedstock used for producing bioethanol is almost only food crops. Demand for biodiesel has increased in some markets due to its low carbon emissions. The main idea behind biofuels is that they are carbon neutral because their carbon emissions are re-absorbed by the plants in the photosynthesis process as the plants are renewable (Demirbas, 2006). Biofuels are classified according to their production technologies as shown in Table 3.

Table 3 - Classification of renewable biofuels based on their production technologies (Demirbas, 2009)

Generation	Feedstock	Example
First generation biofuels	Sugar, starch, vegetable oils, or animal fats	Bioalcohols, vegetable oil, Biodiesel, biosyngas, biogas
Second generation biofuels	Non-food crops, wheat straw, corn, wood, solid	Bioalcohols, bio-oil, bio-DMF, Biohydrogen, bio-

	waste, energy crops	Fischer–Tropsch diesel, wood diesel
Third generation biofuels	Algae	Vegetable oil, biodiesel
Fourth generation biofuels	Vegetable oil, biodiesel	Biogasoline

The most commonly used biofuel is ethanol, which is an alcohol fermented from sugar, starch or cellulosic biomass. Its production on the commercial level comes mainly from sugar cane and beet root because starch and cellulosic biomass need costly preparation. In addition to its use as a biofuel, it is used in the manufacturing cosmetics, pharmaceuticals and alcoholic beverages.

3.3 Danger of Ignoring the Water-Energy-Food Nexus

The mismanagement of the Water-Energy-Food Nexus globally was one of the main reasons of the 2008 global food crisis. In 2008, the World Bank warned that 33 countries were vulnerable to social unrest due to the rapid increase in food prices, as 105 million people were pushed into poverty. Finance ministers gathered in April 2008 to discuss the global food shortages. It was reported that in informal discussions they blamed the U.S. policies on biofuels. The U.S. methanol made from corn could have been exported to feed the hungry (Davis & Belkin, 2008). Demand for biofuels was one of the main reasons for the sharp increase in food prices during the period from 2006 to 2008. The high global energy prices pushed developing countries' governments to support the production of biofuels though a set of policy instruments. The global biofuels production tripled during the period from 2000 to 2007 (Dupont & Thirlwell, 2011). According to Baffes and Haniotis (2010), prices of agricultural commodities were affected by both unfavorable weather conditions and the shift of food commodities to biofuels production, especially maize in the U.S. and edible oils in Europe. The danger biofuels pose on food security is best illustrated by the fact filling a car tank with biofuel uses as much as the annual cereals consumption of a poor person (Kim, 2010).

The growing demand for food has in many cases affected both water quality and quantity. Poor irrigation management has previously caused water depletion, water quality deterioration, waterlogging and salinization. In addition, extraction of groundwater at unsustainable rates for agriculture has caused lowering of water tables and saltwater intrusion at coastal areas. For example, in North China groundwater levels are falling by around 1 meter per year. Water withdrawals for agriculture have caused severe water quality problems through changes in stream flows. On the other hand, contaminated water supplies have affected food quality leading to health hazards, as untreated waste water and contaminated surface water were often used in agriculture in developing countries (Rosegrant et al., 2002). It has been reported that untreated waste water was used for irrigating more than 500,000 hectares in Latin America only (Cavallini, 1996). The average irrigation efficiency is very low in developing countries, well below what can be achieved (Rosegrant et al., 2002).

3.4 Examples of the Inevitable Water-Energy-Food Interconnections from the World

Saudi Arabia is an example of an arid developing country rich in energy resources. It is estimated that 9% of the electricity consumption of the country is used for obtaining water either through groundwater pumping or desalination (Siddiqi & Anadon, 2011). Abderrahman (2010) demonstrates how in Saudi Arabia, the scarcity of water resources was solved by the abundance of energy resources. In order to meet the growing demand for water for domestic, industrial and agricultural purposes, 35 dual purpose desalination plants, multi-stage ash distillation (MSF) and Reverse Osmosis (RO), were constructed on both the Red Sea and the Gulf coasts for water production. In addition, the MSF plants contribute about 20% of Saudi Arabia's national electricity. Moreover, energy is used to pump water from 85,000 wells that were drilled to meet the demand for irrigation water.

Jordan is one of the most water stressed countries in the World with annual renewable water supplies of just 161m^3 per capita. Jordan shares most of its surface water with neighboring countries, whose practices have deprived Jordan of its fair water share. The problem was even intensified by high population growth rates and the large number of refugees Jordan hosts (Michel et al., 2012). Although water desalination seems like the logical approach to be adopted, Hadadin et al. (2010) highlight that water desalination is currently confined to a small number of industrial facilities which desalinate water for their own use. The main source of water used for desalination is brackish water available throughout the country and seawater at the Gulf of Aqaba. They argue that desalination should be one of the major measures Jordan has to implement, given that the technology is available and proven. Its cost has decreased from US$1.50 to around US$0.63 per m^3 under ideal conditions. Østergaard et al. (2014) study energy sytem's impacts of different desalination technologies in Jordan. They use the Energy PLAN model to model the entire energy system including electricity, cooling. heating, cooling, and industrial energy demands. They conclude that reverse osmosis (RO) driven by electricity and Multi Stage Flash (MSF) desalination driven by Cogeneration of Heat and Power (CHP) are similar in fuel use. As a heavily water stressed country, Jordan should pay more attention to the WEF nexus which can help it mitigate its water scarcity problem.

China is listed by the United Nations as one of 13 countries suffering from severe water scarcity. Although China has 21% of the World population, it only has 6% of freshwater supply. However, due to the cheap water prices, desalination still remains as an economically infeasible solution (Wong, 2013). Kahrl & Roland-Holst (2008) examine the relationships between energy and water in China, with a special focus on energy requirements for water use. They conclude that energy used for providing water not used for agriculture is only a minor portion of the Chinese energy consumption, but it is expected to increase together with the increase in water treatment capacity. They also found energy-water price interactions of minor relevance to policy makers because of low water prices, but this is likely to change by time due to the high energy intensity of water treatment facilities. Finally, they concluded that shifting of water from agricultural to non-agricultural uses will have significant energy implications. Regarding water use for energy purposes, the National Development Reform Commission has officially cancelled plans for the construction of coal-to-liquids (CTL) plants in response to concerns about drought problems. This is due to the fact that CTL processes are highly water intensive, so they are likely to affect both water availability and quality (Xinhua News, 2006).

Sovacool & Sovacool (2009) highlight the locations in the United States most likely to face severe water shortages resulting from additions of thermoelectric capacity.

They argue that many electric utilities have paid little attention to water scarcity issues and have continued to include in their plans new water intensive nuclear and fossil fuel based power plants. They focus on Houston, Texas; Atlanta, Georgia; Las Vegas, Nevada; and New York, to have a deep understanding of the likely water and electricity challenges they might soon face. Their policy recommendations include improving the cooling cycles of conventional power plants, discontinuing the construction of power plants which have once-through cooling cycles, modifying provisions of the National Environmental Policy Act concerning the licensing of new power plants, seeking quick demand side energy efficiency improvements and implementing renewable energy projects to replace thermal power plants.

Stillwell et al. (2011) examine the energy-water nexus in Texas, specifically the relation between electricity generation and water resources. They study water requiremenets for electricity generation and energy requirements for water supply and waste water treatment. They included the following policy recommendations:

1. Applications for new power plants should include an assessment of the implications of the different alternatives for cooling options in terms of both water and energy efficiency.
2. New fossil fuel based or CSP power plants should clearly demonstrate water availability at the selected site. The demonstartion should take into consideration average rainfall and the availability of water during extreme drought.
3. The State should provide incentives for power plants implementing water efficient cooling technologies like air-cooling or hybrid wet-dry cooling.
4. The State should provide guidance to water suppliers and waste water treatment providers for the quantification of energy use and water conservation benefits.

3.5 Egypt's Water Challenges

3.5.1 Water Shortage

Egypt's location is in a dry climate area; its rainfall is rare and most of its land is desert. Egypt has a fixed water quota from the Nile and a deep non-renewable groundwater aquifer, which will be depleted if used in a non-sustainable manner. Water shortage is an important constraint facing Egypt's economic development (Allam & Allam, 2007). In addition, Egypt faces rapid population growth and massive levels of water pollution. Water scarcity issues are expected to have severe impacts on national economy, social stability, human health and livelihoods of citizens (Luzi, 2010). Egypt is currently meeting its water demand which exceeds its available resources by more than 25% through re-using agricultural wastewater as shown in Table 4. The vast majority of the Nile water (around 88%) is used in agricultural fields, while municipal and industrial uses account for about 7% and 5% respectively. Water not used up by crops seeps through the soil to the drainage system. Figure 5 shows how drainage water is recycled both officially and unofficially (Barnes, 2012). Along the Nile, drainage canals discharge water into the river. Moreover, pumps are used to lift water from the drainage canals to the irrigation system for re-use at multiple points. This represents the official re-use of the drainage water. Illegal uses are represented by farmers using the drainage water directly for irrigation.

Table 4 – Egypt's Water Uses and Available Resources in Year 2000 (Allam & Allam, 2007)

Water Uses (BCM/year)		**Water Resources (BCM/year)**	
Sector	**Amount**	**Resource**	**Amount**
Municipalities	5.25	Nile river	55.50
Industry	3.50	Groundwater (Delta and Valley)	5.50
River Transport	0.25	Deep Groundwater	0.80
Agriculture	63.00	Drainage Water Reuse	
		- Canals in the Delta Region	4.50
		- Nile river and Bahr Youssef	5.00
		- Illegal Uses	3.00
		Wastewater Reuse	0.20
		Rain fall and Flash Floods	0.50
		Evaporation Losses	-3.00
Total	**72.00**	**Total**	**72.00**

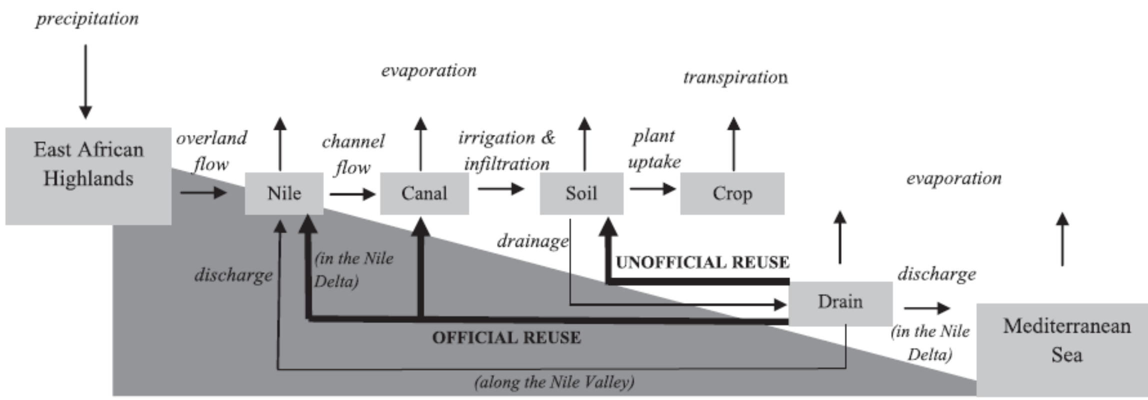

Figure 5 – The Nile's water cycle (Barnes, 2012)

3.5.2 Water Pollution

Although drainage water is in important resource in facing water scarcity, its re-use in the irrigation system causes significant change in the water quality. Pollutants existing in the drainage system can cause harm to the environment and public health. In addition, this jeopardizes the possibility of exporting Egyptian products to markets having stringent quality standards. This also causes troubles to water treatment plants which produce drinking water to the population. Although the different pollutants are of concern for specific crops, water salinity is one of the main concerns for all farmers. The average salinity of water in the main drains is 565 ppm, but can reach up to 6000 ppm. For most crops, irrigation with saline water leads to lower yields. For example, irrigating with a water of salinity 1000 ppm causes the yield to be around 70% of that with fresh water (Barnes, 2012).

In addition to the water pollution due to re-using drainage water, the continuous increase in the population associated with the expansion in industry and urbanized areas has caused deterioration in water quality in Egypt. The southern part of Lake Nasser has the best water quality as it is clear of any pollution sources except for few agricultural activities on its banks. In the Nile valley area from Aswan to Cairo, the Nile is exposed to numerous pollution sources which include untreated and semi-treated industrial wastewater, sewage water, agricultural drainage water, and solid liquid waste from Nile cruise activities (Allam & Allam, 2007). In addition, levels of bacteria are higher than the acceptable limits for municipal use and irrigation. In the Rosetta branch, bacterial pollution is present with a high level of ammonia. Damietta branch also has high salinity and ammonia levels (Drainage Research Institute, 1996).

3.6 Egypt’s Energy Challenges

Egypt is a major producer of oil in Africa, as it is the largest non OPEC (Organization of the Petroleum Exporting Countries) oil producer in Africa. It is also the second largest producer of Natural gas in Africa after Algeria (U.S. EIA, 2014). However, Egypt’s large population and economic growth have significantly increased the demand for energy in all sectors including the residential, transportation and industrial sectors. Energy consumption has thus increased considerably during the previous few decades. Energy production in Egypt has been dominated by fossil fuels: oil and natural gas. However, Egypt has never been a major oil producer when compared to the Gulf states (Bahgat, 2013).

In 2013, Egypt’s total primary energy consumption was around 1.7 million bbl/d of oil equivalent (BP, 2014). Natural gas and oil are the main fuels used to meet the energy demand and constitute around 94% of the total consumption. While oil is the dominant fuel in the transportation sector, natural gas is used in power generation sector, industry sector and transportation sector in the form of compressed natural gas (CNG) (U.S. EIA, 2014). The primary energy consumption by fuel for Egypt in 2013 is shown in Figure 6.

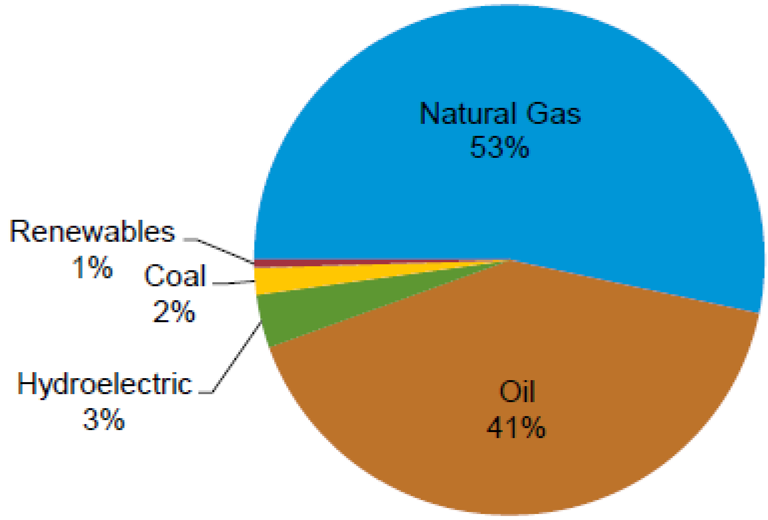

Figure 6 - Primary energy consumption in Egypt, by fuel, 2013 (U.S. EIA, 2014)

3.6.1 Oil

Egypt's annual oil consumption has increased by almost 3% during the last decade. It averaged around 770,000 bbl/d in 2013. Egypt was able to meet its oil demands domestically till the year 2010 when consumption surpassed the production, as shown in Figure 7. On the other hand, Egypt's oil production averaged just below 700,000 bbl/d in 2013. Egypt's oil production has been declining for over 10 years now from a peak of over 900,000 bbl/d in mid 1990s. Although the year 2008 witnessed an increase of production, mainly from the Western Desert and some offshore areas, the total production returned to the declining pattern afterwards (U.S. EIA, 2014).

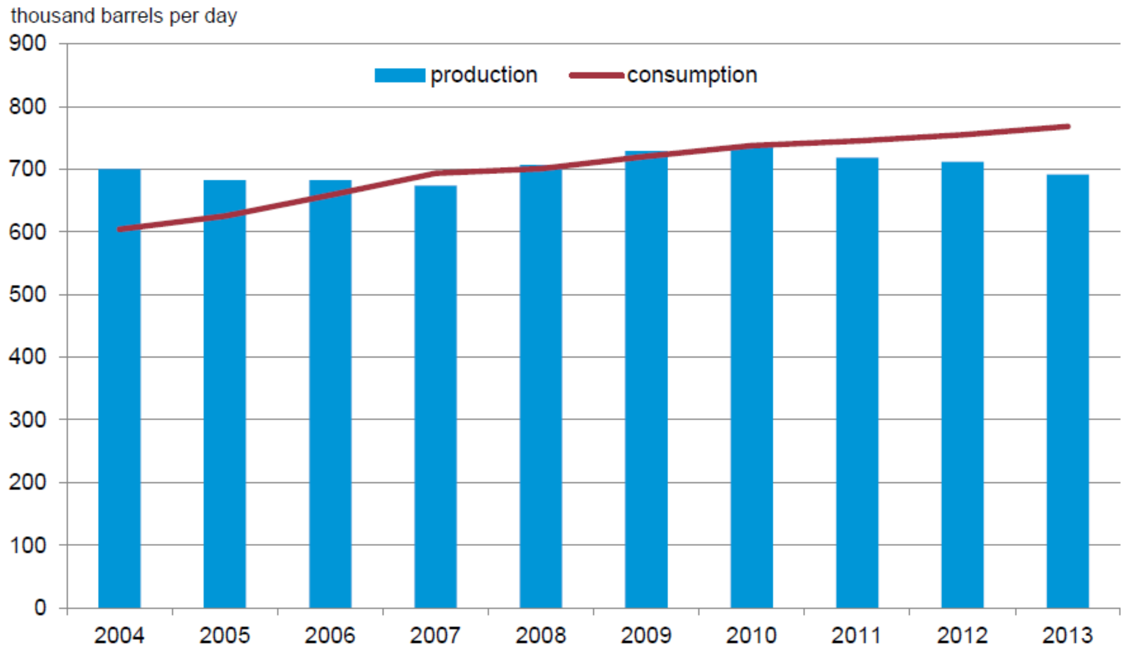

Figure 7 - Oil production and consumption in Egypt (U.S. EIA, 2014)

3.6.2 Natural Gas

Egypt's production of natural gas has declined annually by an average of 3% from 2009 to 2013 (U.S. EIA, 2014). In 2013, Egypt produced around 2.0 Tcf of natural gas of which 1.9 Tcf was consumed locally and while 0.1 Tcf was exported. Although significant gas discoveries have been made in the off shore Mediterranean and other areas, those fields have not been developed due to the low price the government is willing to pay to foreign operators. Another barrier to increasing gas production is the huge debt that Egypt owes foreign operators, amounting US$ 7.5 billion as of June 2014 (U.S. EIA, 2014). In order to meet the rising domestic demand, the government has been diverting natural gas supply from exports to the domestic market especially the power generation sector. As a result, Egyptian gas exports have declined at an annual rate of 30% between 2010 and 2013. In January 2014, BG Group declared Force Majeure notices regarding its LNG agreements in Egypt as a result of diversions of gas volume to the domestic market beyond the contracted arrangements (BG, 2014). Figure 8 shows the natural gas production and consumption in Egypt through the last decade.

Natural gas shortages were the main reason for the energy crisis in Egypt in the previous years. The power sector is dependent on natural gas by as much as 70%, and the energy intensive industries which are the cement, iron & steel and fertilizers industries are almost exclusively dependent on natural gas. For that reason, the natural gas shortages caused huge problems in both sectors during the last four years.

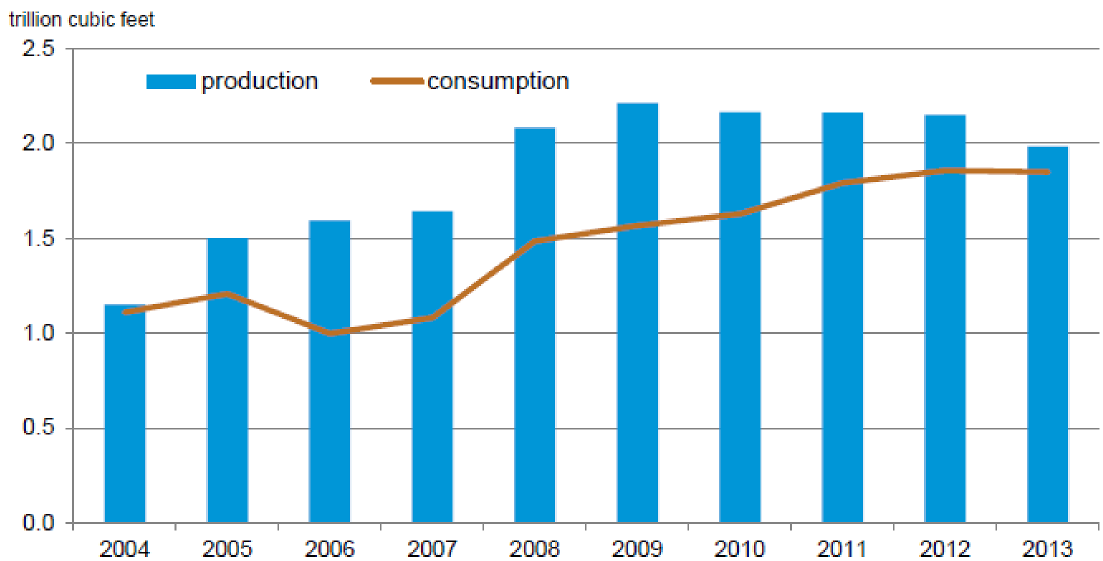

Figure 8 - Natural gas production and consumption in Egypt (U.S. EIA, 2014)

3.6.3 Coal

In 2013, Egypt consumed around 2.2 million tons of coal (BP, 2014). However, coal is not used as an energy source but rather as a raw material for the coke and aluminum industries. However, due to the energy crisis, consecutive governments started from 2012 considering importing coal for utilization in the cement and power generation sectors. The main motivation was the low prices of coal when compared to importing natural gas or heavy fuel oil. By 2013, most of the cement plants in Egypt had already started taking serious steps towards fuel switching to coal after they had been having several natural gas cuts which sometimes lasted for many weeks. In April 2014, responding to huge pressure from the troubled cement industry, the cabinet officially approved using coal for the cement industry (Reuters, 2014). In December 2014, the Ministry of Electricity and Energy announced the intention of the Egyptian Electricity Holding Company (EEHC) to sign seven agreements with Chinese coal-power generation companies (Mada Masr, 2014). It is evident that importing coal is one of the main pillars the government is considering for solving the energy crisis in Egypt.

The main challenge to coal utilization in Egypt is the absence of the infrastructure. That includes ports, storage facilities and transportation. A number of ports are currently preparing to receive coal. Cement plants are also constructing storage facilities for the coal. This is of course in addition to the environmental impacts associated with its handling, transportation and combustion. Utilization of coal has sparked considerable public debate regarding the expected environmental impacts. A number of social movements were mobilized like "Egyptians against coal" in opposition of coal and supporting. The Ministry of Environment has already approved a number of cement plants switching to coal, in addition to a number of new coal operated power plants.

3.6.4 Electricity

Since 2010, Egypt has been facing electricity blackouts due to rising demand, declining natural gas production, poorly maintained infrastructure, and inadequate generation capacity. Egypt's power generation capacity was 27 GW by the end of 2013, which is higher than the peak demand of 24 GW. In 2012, Egypt generated about 152 billion kWh of electricity of which 70% came from natural gas, 20% from oil and 10% from renewables, mainly hydropower. Political and social unrest since the 2011 revolution has slowed the governmental plans to expand power generation capacity by 30 GW by 2020. Accordingly, the demand is rising at a rate much higher than capacity expansions (U.S. EIA, 2014).

3.7 Egypt's Food Challenges

Although Egypt's area is about 1 million km^2, agricultural land is about 8 million feddans (Abdelhakam, 2005). Egypt is considered as an agricultural country where agriculture is a main component of the national economy. The agricultural sector employs around 31% of the labor force in Egypt (Kruseman & Vullings, 2007) and generates about 14% of the GDP (Morgan, 2010). Despite the positive impact the agricultural sector has on food security and the economy, it faces serious challenges. Those challenges include land and water problems; outdated cultivation methods; lack of marketing knowledge by the farmers; poverty; degradation of natural resources; water and soil contamination; climate change; and inadequacy of policies for agricultural development (Shalaby et al., 2011).

Egypt is a net food importer, importing more than half its wheat needs. Egypt's foreign currency reserves reached US$ 15.43 billion by the end of January 2015 (CBE, 2015), which covers three months of imports. This causes a supply risk. Inflation also causes considerable pressure on consumers as the Consumer Price Index (CPI) has increased by an average of 9.23% within 2014 (CBE, 2015). This has been coupled with static income and an unemployment rate of 13.1% in the third quarter of 2014 (CAPMAS, 2015).

3.7.1 Food Availability

Food production in Egypt has had generally an upward trend over the last decade as shown in Figure 9. For example, wheat production has annually increased between 2002 and 2011. However, in the longer term, Egypt is facing lots of challenges regarding food production. Those include an increasing population, limited agricultural land, small holder farming, degradation of land, construction on agricultural land, desertification and climate change (WFP, 2013). Between 2001 and 2010, cultivated land increased by 0.7% annually which is equal to 8% over the 10 years. However, after the revolution, the trend was reversed and cultivated land decreased by 1% between 2010 and 2011 (CAPMAS, 2012). This was mainly due to illegal construction on agricultural land in Greater Cairo and the Nile Delta (Attia & Raslan, 2011). In addition to that, rural areas in Upper Egypt have suffered in the previous years from unpredictable weather leading to crop failure. This caused farmers to utilize the already stressed natural resources in an unsustainable manner (WFP, 2013).

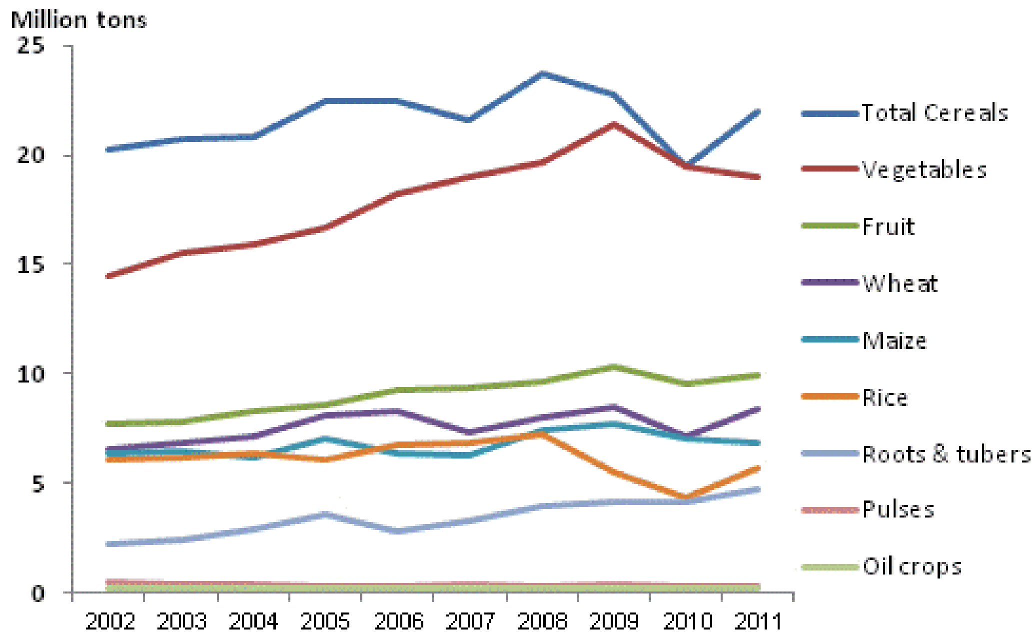

Figure 9 – Production of Selected Crops in Egypt (million tons) (WFP, 2013)

While consecutive governments have promoted and worked for self-sufficiency, Egypt is far from being self-sufficient in terms of food production, particularly key serials. Table 5 shows Egypt's Self Sufficiency of selected crops and the corresponding per capita consumption. Egypt is a net importer of food, which makes it vulnerable to both global food prices and exchange rates fluctuations (WFP, 2013).

Table 5 - Self Sufficiency of selected crops and per capita consumption (WFP, 2013)

Crops	Self Sufficiency, %			Per Capita Consumption (kg/year)		
	2009	**2010**	**2011**	**2009**	**2010**	**2011**
Cereals	69.06	63.90	53.96	266.8	253.0	244.6
Vegetable	104.70	106.46	106.11	164.3	122.5	135.9
Wheat	53.15	47.86	42.60	135.4	133.9	135.0
Fruit	111.14	111.11	116.70	93.1	89.7	83.8
Maize	62.24	60.70	51.04	66.3	71.7	67.3
Rice	112.49	116.21	98.25	65.2	39.6	35.4
Meat	88.78	84.76	85.96	10.9	9.8	30.0
Vegetable Oils	42.64	43.18	36.67	9.4	8.5	15.7
Pulses	41.72	36.00	43.24	9.8	9.1	7.2

Crops	Self Sufficiency, %			Per Capita Consumption (kg/year)		
	2009	2010	2011	2009	2010	2011
Sugar	100.03	100.01	100.01	9.1	7.7	7.2

Wheat is the key strategic crop in Egypt, as it is a major constituent of the Egyptian diet. Egypt's average annual wheat consumption was around 18 million tons over the last five years. Out of that, Egypt imported 9-10 million tons annually. Although the wheat availability was not an issue in Egypt during the previous decades, there is considerable risk in its supply given the fall in the value of the Egyptian Pound against foreign currencies (WFP, 2013). The U.S. Dollar rose against the Egyptian Pound from 6.15 EGP/USD in December 2012 to 8.88 EGP/USD in April 2016 (almost 45% increase) (XE, 2016). Egypt's foreign currency reserves reached US$ 15.43 billion by the end of January 2015 (CBE, 2015). Wheat is mainly used for the production of the heavily subsidized *baladi* bread. The whole supply chain is full of losses, starting from poor storage of wheat to the leakage of subsidized flour through the black market (WFP, 2013).

3.7.2 Rising Food Insecurity

A number of events started from 2006 caused a decline in food security and resulted in the deterioration in the nutrition status impacting the most vulnerable households. The first event was the response to the avian influenza epidemic in 2006 which involved a mass culling of poultry. This affected the livelihood and dietary diversity of the most vulnerable households. The second event was the food and fuel prices of 2007-2008 which increased the food crisis pushing more Egyptians into poverty. Even after the crisis the prices did not return back to normal. The third event was the rising of food prices in 2010 which was coupled with constant incomes as a result of the 2011 revolution (WFP, 2013). The revolution caused a decline in the economic performance of the country, causing the economic growth to slow down from an average of 6.2% in the period 2005-2010 to just 2.2% in 2011/2012 (Ministry of Finance , 2013).

Data from the Household Income, Expenditure, and Consumption Survey (HIECS) shows that the most considerable shock noted by 74.7% of the households was the rise in food prices, as shown in Figure 10. The expenditure on food constitutes 40.6% of the average household income in Egypt, with the figure rising up to 51% for the most vulnerable households. This is an indication that households are significantly vulnerable to rising food prices (WFP, 2013). Prices of food and non-alcoholic beverage increased at a rate higher than the overall Consumer Price Index (CPI) during the period 2010-2012 (CAPMAS, 2013).

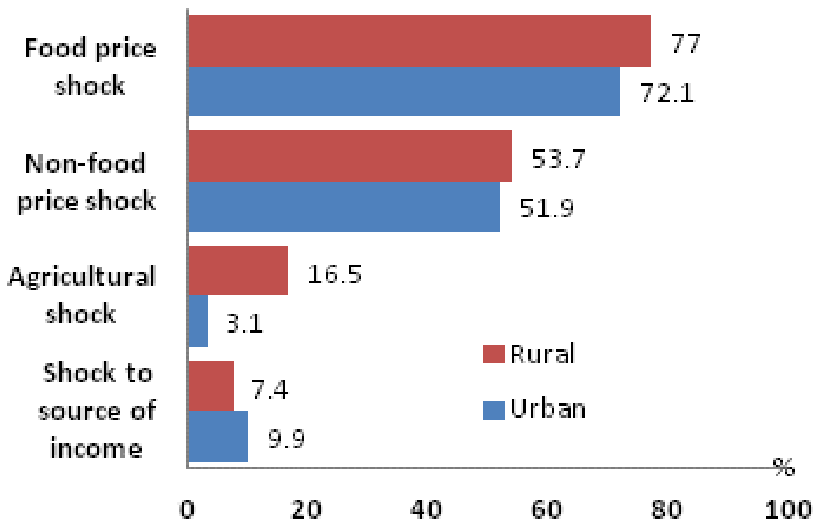

Figure 10 – Percentage of households citing shocks affecting their financial status after the revolution by region (WFP, 2013)

Chapter Four: Analysis of Virtual Water Trade in the Nile Basin and the Ethiopian Situation

4.1 The Concept of Virtual Water

Virtual water refers to the water consumed in the production of any commodity (Allan T. , 1997). When this commodity is traded, the embedded water in the product can be considered to be also traded. In that sense, international food trade may be considered as a massive pipeline. It is important though to differentiate between rain-fed agriculture (green water) and irrigated agriculture (blue water). Crops grown using irrigation are considered as a load on water resources in a given country, as this blue water could have been used for other activities. On the other hand, it is not possible to utilize the green water used in rain-fed agriculture for other purposes (Zeitoun et al., 2010).

4.2 The Nile Basin

River Nile runs through 11 countries in East Africa. The White Nile which originates from Burundi and the Blue Nile which originates from Ethiopia are the two main tributaries forming the Nile. The total area covered by the basin is 3,257,434 km2 with the largest shares in Sudan (64%), Ethiopia (11%), Egypt (9%) and Uganda (7%); and smaller shares in Tanzania, Kenya, Congo, Rwanda, Burundi, Eritrea and South Sudan. Around 437 million people live in the Nile Basin countries, 57% of them in rural areas (Nile Basin Initiative, 2015). The total cultivated area in the basin is more than 26 million ha, 84% of them rain-fed. Crops grown include sorghum, millet, maize, groundnut, and wheat. An important income generating activity is also livestock.

The Nile basin countries face a number of challenges, the most serious of which are poverty, lack of food and water security, water pollution and land degradation. Further challenges include increased deforestation, soil erosion, lakes and reservoirs sedimentation, and loss of biodiversity (Sulser, et al., 2010). The hydrological and political borders of the Nile Basin are shown in Figure 11.

Figure 11 – The Nile Basin Hydrological and Political Borders (LWRG, 2007)

The Blue Nile River originates from Lake Tana in Northwest Ethiopia. It is then joined by a number of tributaries before it reaches Sudan. Rain is concentrated in the summer season as almost three quarters falls between the months of June and September (Conway, 2000). The Blue Nile continues flowing afterwards in Sudan towards the North West where it is joined by the Dinder-Rahad River through the Gezira and then it converges with the White Nile at Khartoum. The main Nile flows afterwards towards the

North where it is joined by Atbara River from the East. The Nile then enters Lake Nasser at the Sudanese Egyptian border which is created by the High Dam and flows afterwards towards the North till the Mediterranean Sea (Zhang et al., 2015). The Blue Nile together with River Atbara (which also originates in Ethiopia) contribute 84% of the water flowing to Lake Nasser in Egypt (Block & Strzepek, 2010).

Water security has been previously defined in narrow terms based on water resources. When looking at the Nile Basin, the water present in the soil profiles in the basin is actually more than the water in the channels. In addition, the groundwater lying below the water channels has rarely been quantified. The volumes of water embedded in the international trade of crops and livestock is so large that it cannot be overlooked (Zeitoun et al., 2010). In terms of political economy, virtual water trade and water security have important implications on the Nile Basin states beyond the basin itself (Chapagain, 2006). For example, when a water scarce country imports crops and livestock, it depends on the international market to achieve food security and free it from its local scarcity conditions (Hoekstra & Hung, 2005). On the other hand, a country with a surplus of water resources may utilize virtual water trade to improve its relation with other countries thus improving its national security (Allan J. , 2003).

Green water, or soil water, is of particular importance when examining the Nile Basin. In general, most of the food produced globally is based on green water (Falkenmark & Rockstrom, 2006; Schiermeier, 2008). The Nile Basin countries collectively import around 39 bcm/year of crops, mostly soya bean and wheat from North and South America, in addition to 2 bcm of livestock, mostly cattle from Brazil, Australia and Ireland. The above-mentioned imports are based on green water from other basins. The major virtual water movements within the Nile Basin are also based on green water used to raise tea and coffee in Kenya and Uganda (Zeitoun et al., 2010). The estimated total amount of green water used in the Nile basin for the production of crops is about 229 bcm/year, excluding the green water consumed by natural vegetation (FAO, 2006).

On the other hand, the blue water used through irrigated agriculture is particularly significant for Egypt and Sudan. Around 90% of the freshwater use in the Nile river system is through irrigated farming (Appelgren et al., 2000). Significant amounts (around

0.25 bcm/year) are used though for growing citrus and vegetable exported to European markets (Zeitoun et al., 2010). The freshwater resources of the Nile are shown in Table 6. Due to the arid climate of the downstream riparians Egypt and Sudan, both countries are largely dependent on blue water from the Nile. Upstream riparians, on the other hand, receive lots of green water from rain and hence are less dependent on blue water from the Nile.

Table 6 - Freshwater resources of the Nile (Zeitoun et al., 2010)

	Average annual precipitation (mm)	Nile River freshwater flows		Soil water consumption (for agriculture) (BCM /y)	Groundwater Production (BCM /y)
		Inflow (BCM/y)	Outflow (BCM/y)		
DR Congo	1,245	0	1.5	31.9	421
Burundi	1,110	0	1.5	6.1	2.1
Rwanda	1,105	1.5	7	11	3.6
Tanzania	1,015	7	10.7	31.6	30
Kenya	1,260	0	8.4	20.4	3
Uganda	1,140	28.7	37	45.8	29
Eritrea	520	0	2.2	0.8	-
Ethiopia	1,125	0	80.1	31.1	40
Sudan	500	117.1	55.5	50.3	7
Egypt	15	55.5	< 10 (to sea)	0	13
Total in system		approx. 100		approx. 229	

4.2.1 Virtual Water Trade in the Nile Basin

Virtual water trade within the Nile Basin countries is small when compared to virtual water trade arising from imports from outside the basin. As shown in Table 7, approximately 0.9 bcm/year of virtual water is traded annually with the Nile Basin, three quarters of which is based on green water. Egypt alone imports about 0.4 bcm/year out of the virtual water traded within the basin. On the other hand, the Nile Basin countries import around 39 bcm/year of virtual water in the form of crops, out of which Egypt alone imports approximately 30 bcm/year, as shown in Table 8. The virtual water traded internally in the Nile Basin is only about 2.3% of the virtual water the basin imports from outside its borders. The basin exports around 11 bcm/year of virtual water to countries outside the basin, 90% of which is based on green water. Unless the Nile Basin countries take measures for better utilization of green water in the basin, the basin cannot achieve water and food self-sufficiency even if intra-basin trade is improved. There is currently a strong net virtual water trade deficit between the Nile Basin and the rest of the world amounting to about 28 bcm/year (Zeitoun et al., 2010).

Table 7 - Imports' within the Nile Basin, main trade items only, average values 1998–2004 (Zeitoun et al., 2010)

Imports by	Total VW trade (M m3)	From	Volume and major crop (M m3)	Est. rain-fed Portion (M m3)	Est. irrigated Portion (M m3)
Egypt	372	Kenya	255 tea	240	15
		Sudan	55 cotton	10	45
			28.6 wheat	0	28.6
			6.2 groundnut	4.5	1.7
Kenya	197	Uganda	21 soya	21	0
			12 maize	12	0
			7.8 tobacco	7.8	0
		Tanzania	21 maize	20	1
			12 cotton	12	0
			6.4 groundnut	6.4	0
		Egypt	26 sugar	0	26
			13 rice	0	13
		Sudan	29 sugar	0	29
Sudan	184	Kenya	87 tea	82	5
			11 coffee	11	0
		Uganda	78 coffee	78	0
			Total	**505**	**165**

Table 8 - Imports from the rest of the world, main trade items only, average values 1998–2004 (Zeitoun et al., 2010)

Imports by	**Total VW trade (M m3)**	**Specific VW 'trade' (M m3)**	**Crop**	**Volume and origin (M m3)**	**Est. rain-fed Portion (M m3)**	**Est. irrigated Portion (M m3)**
Egypt	30,195	19,700	Soybean	8,512 Argentina	6,384	2,128
				5,100 US	3,825	1,275
				1,050 Brazil	788	1,012
		5,213	Wheat	2,885 US	2855	0
				755 Australia	755	0
				592 France	592	0
				357 Russia	357	0
		3,400	Maize	2,653 US	1,990	663
				439 Argentina	330	109
				133 Brazil	100	33
Sudan	3,565	2,523	Wheat	953 Australia	953	0
				522 Canada	522	0
				172 US	172	0
Tanzania	1,818			Wheat, rice, maize	1,454	364
Kenya	1,817			Wheat, rubber, maize, rice	1,454	363
				Total	**22,531**	**5,974**

There are strong discrepancies among the Nile Basin countries in terms of whether they are net importers or exporters of virtual water, as shown in Figure 12. Egypt and Sudan are clearly net importers of virtual water, while the Southern countries in addition to Ethiopia and Eritrea are net exporters. The virtual water traded annually within the basin cannot remedy the freshwater deficits the northern arid riparian countries suffer from. Most of the intra-basin trade is actually in the form of tea and coffee from Kenya and Tanzania to Sudan and Egypt (Zeitoun et al., 2010). The greater potential actually lies in the improvement of the productivity of rain-fed agriculture.

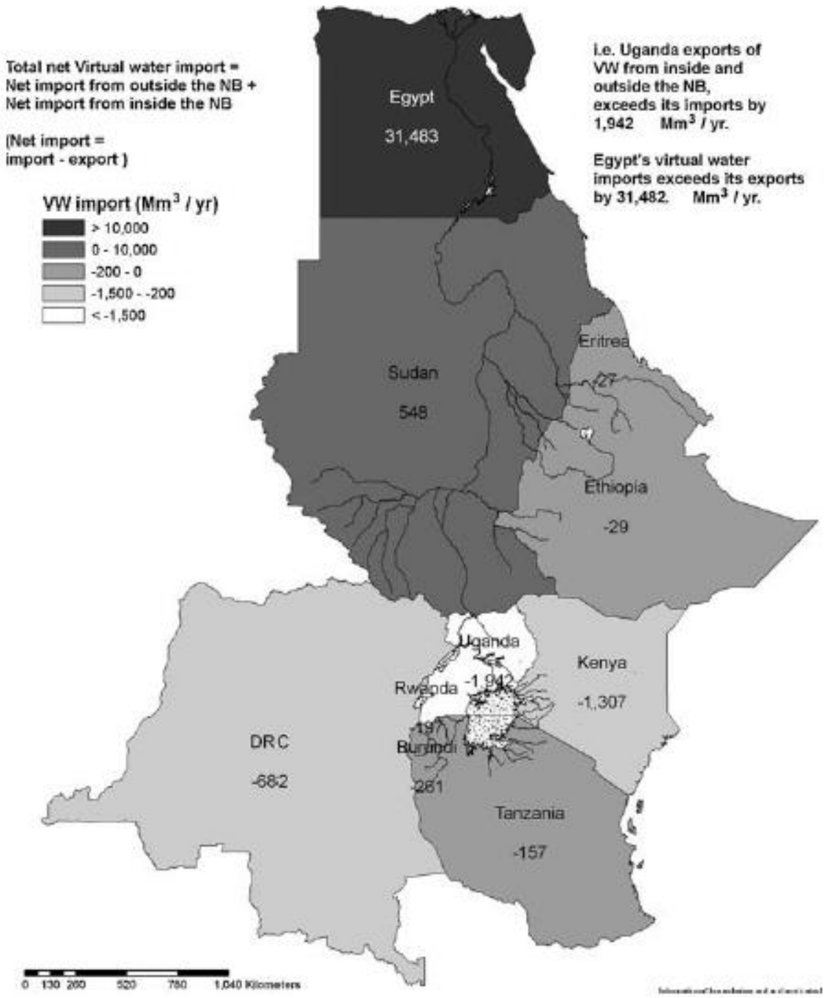

Figure 12 – Average annual total virtual water crop and livestock 'trade' between Nile Basin states and the rest of the world, imports and exports, 1998–2004 (Mm3/y) (Zeitoun et al., 2010)

4.3 Analysis of the Ethiopian Situation

Ethiopia is one of the World's Least Developing Countries (LDCs), though it has numerous resources including huge human resources. With a population of 96 million people in 2014 (CIA, 2015), Ethiopia produced a GDP of only 54.80 billion US dollars (Trading Economics, 2015). Egypt, on the other hand, with a population of 87 million people in 2014 (CIA, 2015) produced a GDP of 286.54 billion US dollars (Trading Economics, 2015). Ethiopians have the right to hope for a better future through rapid economic development. This economic development can only be attained through boosting electricity generation capacity and thus using more energy in much needed economic activities.

In the past, Egypt had power over the other Nile riparian countries through the 1929 water treaty signed between Britain and Egypt. Britain, having control over many of the riparian countries, negotiated with Egypt on behalf of its colonies and gave Egypt the upper hand in the access and usage of the Nile water (Flintan & Tamarat, 2002). Several factors have later loosened the Egyptian grip on the Nile water. Those include independence of the riparian countries, high population growth, political developments, droughts and other natural disasters. These factors have recently forced Egypt to re-negotiate water treaties in a direction that will likely decrease its control over the Nile (Ashton, 2002).On the other hand, water resources' shortages in Ethiopia have pushed it to reconsider the Egyptian access to the Nile. Ethiopia's growing population has caused its water demand to double in just a decade (Berman & Paul, 1999). The total reliance on the Nile water resources over centuries has resulted in the depletion of the Nile basin, which lead to unemployment, the spread of diseases and hunger. The resource depletion in the basin is the result of climate change, land use and land management (Goulden & Declan, 2009).

Ethiopians, already living in poverty, are now also suffering from climate variability and extreme weather events (Oxfam, 2010). Development along the Nile has caused water pollution in riparian countries. For example, the Ethiopian Eritrean war in the late 1990s polluted the Nile basin with military and missile remnants (Kim & Kaluarachchi, 2009). This pollution was coupled with excessive population growth in the

Nile basin which is also increased by migrations to the basin (World Water Council, 2006). Farming, one of the major sources of income in the basin, has been impacted by drought, famine and land degradation. Land degradation and deforestation have caused agriculture to be a very difficult task in many parts of the basin (EPA, 2010).

Egypt, as a result of the 1929 mandate, has historically had absolute control over the Nile water resources. There was little conflict over the Nile water before the 1950s. However, due to declining water resources and population growth, riparian countries have grouped themselves up to access the Nile Water. These efforts were mainly lead by Kenya and Ethiopia (Rahman, 2012). For example, in 2010 Ethiopia announced a major hydro-electric project to supply the country's electricity needs, which is currently under construction. The project was met by resentment by Egypt which attempted to veto any such project (Cascão, 2011).

4.3.1 Energy Security

Ethiopia is categorized by the United Nations as one of the Least Developed Countries in the World (UN, 2015). Having an average annual income of US$ 120 per capita, 40% of Ethiopians live below the poverty line (UNDP, 2015). The population growth has been exceptional, with the population rising from 66 to 96 million between the years 2000 and 2014. By 2020, it is expected to reach 110 million (UN, 2013). Biomass is the main source of energy for the Ethiopian population with a share of 93.2% of total energy consumption (IEA, 2012). Only 26% of the Ethiopian population has access to electricity, while the average electricity consumption per capita is 52 kWh per capita (compared to 100.0% and 1,743 kWh per capita for Egypt). The electricity installed capacity in Ethiopia was 2060 MW in 2010, which covers only 10% of the national demand (WB, 2015).

4.3.2 Food Security

Food security is a big challenge in Ethiopia. Land degradation and seasonality of rainfall are serious factors influencing achieving food security in Ethiopian highlands (FAO, 2011). Inappropriate land use practices coupled with rainfall seasonality have caused land degradation. About 82% of the annual rainfall occurs in just 3-4 months causing erosive runoff (Conway, 2000). Practicing farming on steep slopes together with the seasonal rainfall has increased soil erosion (Haileet al., 2001). Consequently, decades of consecutive soil degradation have worsened the seasonality of the water availability necessary for food production and reduced soil fertility necessary for the agricultural activities needed for the livelihood of a big and rapidly growing population (Zeleke & Hurni, 2001). Rain variability has been affecting agricultural yield for several decades in Ethiopia (Bewket, 2009).

Based on a 2014 WFP report, more than 30% of Ethiopia's population is below the food poverty line. This portion of the population is unable to secure the minimum calorific intake required for having a healthy diet. Chronic malnutrition is a serious challenge in Ethiopia, as 44% of children below five are stunted and 10% affected by acute malnutrition. Regarding diet quality, half of the population sourced most of their calorific intake (more than 75%) from starchy staples, i.e. their diet is highly unvaried. 30% of households used three or fewer of the seven food groups over a continuous week. In terms of diet adequacy, one out of four households consumed unacceptable diets based on the food consumption score. Out of these 10% had poor food consumption and 17% had borderline food consumption (WFP, 2014).

Several other indicators show the severity of the food insecurity problem in Ethiopia. Almost half of the household expenditures were on food. 35% of the households reported to have gone through at least one shock in the past year, including food price increases and food shortages. Rainfall is the single most important determinant for food production in Ethiopia. Most of the households in Ethiopia reported lack of rainfall as the major cause of their vulnerability. In general rainfall has declined between the months of March and September from 1980 to present (WFP, 2014).

4.3.3 Water Security

Ethiopia is characterized by having huge discrepancy between its abundant water resources and the widespread water scarcity and drought among its population. The country has suffered from decades of extensive water pollution and rapid population increase. Although Ethiopia enjoys large quantities of renewable water resources, it has a very low capacity of water storage. In general, water withdrawals come from water storage. Therefore, poor storage is associated with low withdrawals. The seasonality and variability of rainfall has increased the incidence of floods and droughts. Due to the poor storage, Ethiopia's abundant water resources are available only during few months of the year (Kloos & Legesse, 2010).

In the Ethiopian rural areas, women and children might have to walk up to six hours to bring water. Most of the water is collected from shallow ponds shared with animals. People may also get water from shallow wells. Those are sources are heavily subjected to contamination as rainwater runoff collects contaminants from surrounding areas pouring them into the source. In Ethiopia, 49 million people lack access to safe water, while 76 million lack sanitation services (water.org, 2015).

4.3.4 Ethiopia's Grand Renaissance Dam

Ethiopia has significant water resources, providing it with an estimated hydro power potential of 45,000 MW (Salman, 2013). Such hydropower capacity can drive the Ethiopian economic growth in the coming years as it presents a reliable and cheap electricity source (Verhoeven, 2011). The Grand Ethiopian Renaissance Dam (GERD) is a mega hydro-electric project currently being constructed on the Blue Nile. Its location is close to the Sudanese border as shown in Figure 13. It is planned to have a 74 BCM capacity reservoir and a power generation capacity of 6,000MW. Construction started in 2011 and it is expected to be inaugurated in 2017 (Ethiopian Electric Power Corporation, 2013).

Figure 13 - Nile basin showing the expected GERD (Zhang at el., 2015)

The main concern of Egypt regarding the GERD is the access to the Nile water which is its primary water source (Swain A. , 2011). In order to assess the dam impacts on downstream countries, an international 10-person committee was formed and it submitted its conclusions in May 2013. The studies are not public but it has been reported that the Egyptian President has commented on the current studies that they are not adequate (Reuters, 2013). On the other hand, Sudan has shown support to the project in order to get access to affordable power and reduce silt and sediment downstream. This would lead to a significant reduction in the cost of removing mud in the Jazeeera Scheme due to the dam blocking of silt and sediments (MoFA, 2012).

The GERD will undoubtedly become an important resource for energy production, food production and economic development in Ethiopia. It has also become a political statement by the Ethiopian government that they are no longer bound to the previous colonial water agreements. The GERD has become a symbol Ethiopian nationalism and their foreseen “renaissance”. This can be seen evident from the way the dam is being financed: 30% from China (The Economist, 2011) and the rest from the Ethiopian government through local and international bonds and donations (Water Technology.net, 2014).

In order to understand the impact of filling the GERD reservoir on the flow of water to Egypt, a hydrology-hydropower modeling study was conducted by Zhang et al (2015). Although there is no publicly announced filling policy for the reservoir, the study revealed that the reservoir filling will cause a reduction in the stream flow at the Jazeeera Scheme and Lake Nasser. The reduction extent varies significantly according to the filling policy, climate variability and climate change during the filling period. The study concluded that whether the reservoir is filled through a policy agreed with downstream riparian countries or through a one-sided policy dictated by Ethiopia will largely affect the impact on the water reaching Lake Nasser.

Another study was conducted to assess the GERD filling and operation effect on Aswan High Dam. Its conclusions were as follows (Mulat & Moges, 2014):

- The 6 years filling period of the GERD will not cause impact to the Aswan High Dam water availability.
- Power generation from Aswan High Dam will decrease by 12% during filling and 7% during the dam operation.
- Evaporative water losses from Aswan High Dam and GERD reservoirs will decrease by 16% due to the Aswan High Dam operating at reduced water level.

- Aswan High Dam will operate at 96% reliability level in terms of performance efficiency.

El Bastawesy et al. (2015) studied the effect of the GERD using different hydrological scenarios with the purpose of estimating the dam impact on the downstream discharge. Their analysis stressed on the fact that the effect of the GERD on the downstream discharge might be signifant if the GERD reservoir gets filled in low-flood seasons over a short duration. They strongly recommended to reach an agreement regarding storage capacities of all the dams on the Nile to satisfy the populations' water requirements.

Ramadan et al. (2013) used a hydrological model (MODSIM) developing different operational scenarios in order to study the impacts of GERD construction on the Egyptian water resources. Their results showed that the negative impacts are more likely to occur. They concludde that the GERD impounding at the normal flow scenario through 2, 3 and 6 years would reduce the water reaching Lake Nasser by around 37, 25 and 13 BCM per year respectively. This would cause a significant negative impact on Egypt's water resources.

In addition to the GERD, Ethiopia has plans to build on its huge hydropower capacity. The Ministry of Water and Energy listed the hydropower projects to be implemented.

Table 9 – Potential hydropower projects in Ethiopia (Derbew, 2013)

	Name of the project	**Installed capacity (MW)**	**Status**
1	Tekeze II	450	Under feasibility study
2	Derbu I & II	250 + 325	Feasibility study completed
3	Geba I & II	366	Feasibility study completed
4	Gojeb	153	Feasibility study completed
5	Genale V	100	Reconnaissance
6	Beko Abo	1,700	Under feasibility study
7	Baro I & II and Genji	900	Feasibility study completed
8	Mendeya (Blue Nile)	2,000	Under feasibility study
9	Tams	1,060	Reconnaissance
10	Dabus	425	Reconnaissance

11	Birbir R	467	Reconnaissance
12	Gibe V	660	Under feasibility study
13	Gibe IV	1,400	Under feasibility study
14	Lower Didessa	613	Reconnaissance
15	Wabishebele 18	87	Feasibility study completed
	Total	**10,956**	

Chapter Five: Proposed Policy Framework for the WEF Nexus in Egypt and the Nile Basin Countries

Since ancient history, the Nile River has been a key resource for socioeconomic activities for the communities that live along it. However, the water flowing in the River is a finite resource. The 1929 water agreement between Britain and Egypt was more like an order imposed by a colonial power in favor of its own interests. The 1959 water agreement was similar, as it was an agreement between Egypt and Sudan which deprived the other countries from utilization the Nile water (Kindleberger, 1986). The first disturbance of the Nile regime was in 1988 after the second Ethiopian famine. At that time, Ethiopia committed itself to providing more hydroelectricity and water for its people. Ethiopia announced launching Tana-Beles Project which would take water from Lake Tana (the main source of Blue Nile) to the Beles River which would transport it to 200,000 farmers in new settlements. In 1990, Egypt succeeded to block the financing from the African Development Bank to the project (Lemma, 2001).

Egypt has recently been attempting to work on the growing consensus towards forming a new Nile Basin regime. The water in the Nile River does not have equal importance to all the riparian countries, as some of them receive adequate rainfall for agriculture. However, due to the foreseen change in economic conditions in upstream countries, Egypt has recognized that reaching a current deal might be better than reaching a deal in the future. As a result, Egypt is changing its water policy and pushing towards basin-wide cooperation (Tesfaye, 2014). While decreasing its claims on historic rights in the Nile water, Egypt however continued changing the actual situation on the ground; constructing massive new water projects unilaterally within its borders, with continued dependence on the Nile Water (Swain A. , 2002).

Historically, Egypt succeeded in building viable relations with some of the key upstream countries. Egypt has worked with Uganda in several projects for many years. Those include the Owens Dam and clearing Lakes Victoria. Egypt also enjoyed good relations with Kenya through the cooperation in developing ways to increase Kenya's dependence on ground water. In addition, Egypt helped Tanzania plan and develop a water research center (Tesfaye, 2014). However, Egypt's relation with Ethiopia, from which 86% of the Nile water originates, was not as good. Egypt has managed to block a number of multilateral institutions' funds to develop Ethiopia's water resources. This is because multilateral institutions require the consent of downstream riparian countries to finance project on trans-boundary rivers (Lemma, 2001). In fact, there has been a historical nationalistic rivalry between Egypt and Ethiopia over the Nile. However, there are also historical and cultural elements to build on like for example the relationship between the Coptic Church and the Orthodox Ethiopian Church (Rubenson, 2009). Although all Nile Basin countries are important forces in reaching a new Nile Basin agreement, satisfying both Egypt and Ethiopia remains the most challenging task (Tesfaye, 2014).

Throughout the negotiations in the previous decades, Egypt has so far negotiated based on historical rights in the Nile water. The GERD has been under construction since 2011 and is expected to be operational in 2017. Although Ethiopia repeatedly announced that the aim of the GERD is only to generate electricity and that it will not be used to withhold the Nile water, there are serious doubts regarding this announcement. With a population of 96 million people in 2014 (CIA, 2015), Ethiopia has to achieve water, food and energy security. Ethiopia is one of the poorest countries in the World. The GERD is their national mega project which is supposed to boost their economy and turn the country around as suggested by its name. The Egyptian Ethiopian relations have suffered since Ethiopia announced the construction of the GERD in 2010.

The reason why the negotiations so far not been successful is that they were mostly win-lose negotiations: whatever water Ethiopia wins Egypt has to lose. Integrated Water Resources Management (IWRM) has been thought to be the solution to the crisis during the previous decade. However, this idea has been refuted repeatedly for trans-boundary rivers (Biswas, 2010). The main disadvantage of IWRM is the fact that it tackles water policy as if it is a commodity while ignoring the crucial human and social issues. Water disputes are more complicated than disputes over commodities; they are closely tied to the pursuit of justice and fairness (Anand, 2007).

Although the Nile Basin countries are net importers of virtual water, there is a huge potential to improve the overall situation if a policy framework is created for the WEF nexus and the basin is thought of as one unit. Cooperation within the basin can help upstream countries improve the yield they get from green water through using the Egyptian expertise in agriculture. If we also add electricity generation and distribution to the equation, synergy is even improved. Having populations with very low electricity access percentages in the upstream countries opens for the possibility of harnessing more hydropower and utilizing the Egyptian expertise in electricity transmission and distribution. In return, through the integration of electricity grids, Egypt can get cheap and clean hydropower. In fact, the GERD itself can be viewed as an opportunity if the right formula is introduced between the countries. The project will produce a considerable amount of clean electricity and at the same time store water at climatic conditions causing much less evaporation than that occurring at the High Dam.

In this section, a policy framework will be developed for the WEF nexus. The policy framework will not only tackle the Nile Basin, but will also attempt to develop the WEF nexus for Egypt. It will be demonstrated how mega projects in Egypt like the 1.5 million feddans reclamation program and the expansion of the power generation sector have the potential of benefitting from the WEF synergy.

5.1 Policies Framework within the Egyptian Context

In Egypt, the policies related to the water, energy and food sectors are incoherent and uncoordinated. As shown in Table 10, the three sectors are planned independently. Even the years determined for the implementation of the policies are different.

Table 10 – Policies of the water, energy and food sectors in Egypt (Trinex, 2015)

National Water Resources Strategy (2009-2017)	National Energy Strategy (2008-2020)	National Agricultural Development Strategy (2001-2017)

• Development of national water resources • Protection of national water resources • Efficient utilization of national water resources	• Securing the supply of electrical energy • Minimizing electricity prices • Expanding utilization of renewable energy sources • Environment protection and climate change limiting • Restructuring electricity sector and developing operations and manpower	• Sustainable use of agricultural natural resources • Improving agricultural productivity • Increasing competitiveness of the agricultural products in local and foreign markets • Achieving higher rates of food security in strategic goods • Improving opportunities for agricultural investment

Such uncoordinated policies prevent Egypt from harnessing the synergies among the three sectors. There is a need to develop one integrated strategic plan for the WEF nexus, according to which the three sector policies will be aligned. The WEF nexus strategic plan will come up with integrated and sectoral projects prioritized in coordination with national development priorities. Examples will be presented later in this chapter to demonstrate how Egypt can benefit from having coordinated WEF nexus policies.

5.2 Institutional Framework and Methodology for WEF Nexus in Egypt and the Nile Basin Countries

Egypt has a Supreme Energy Council which is headed by the Prime Minister and includes the Ministers of Electricity, Petroleum, Finance, Defense, Tourism, Transport, Industry and Trade, Investment, Planning, International Cooperation, Environment and Housing (Alfajr, 2014). It is recommended that the Supreme Council for Energy be expanded to be the Supreme Council for Water, Energy and Food, through the introduction of the Ministry of Water Resources and Irrigation and the Ministry of Agriculture. The mandate of the Supreme Council of WEF should include coordination between all the governmental agencies for Water, Energy and Food, including alignment of policies and plans, exchange of information, review of projects and programs in each sector, and the monitoring of implementation and operation of these projects and programs.

A Similar institutional framework should be developed for the Nile Basin Countries. This can take the form of a Nile Basin WEF Council, which can be formed of the Prime Ministers and the Ministers of water resources, agriculture and energy in the Nile Basin Countries. The Council should take strategic decisions and approve projects and plans, and should have a number of technical committees for each sector and for policies, planning and project monitoring and evaluation. In addition, the decisions taken by the proposed Nile Basin Council should be legally binding to all the Nile Basin countries. The purpose of having its decisions legally binding is to avoid the situation of the Nile Basin Initiative which has been operational since 1999 but has had minimum achievements since then.

The aim of the institutional framework developed is to coordinate sectoral and integrated policies, develop strategic plans and prioritize, monitor and evaluate projects that take into consideration the WEF nexus. The idea is to get decision makers to think about projects in a holistic manner instead of thinking about them in a single dimensional manner. The framework is designed to be developed in a highly participative manner so that the different decision makers take ownership of the developed policies, strategic plans and selected projects. The operational methodology of how the framework works is shown in Figure 14.

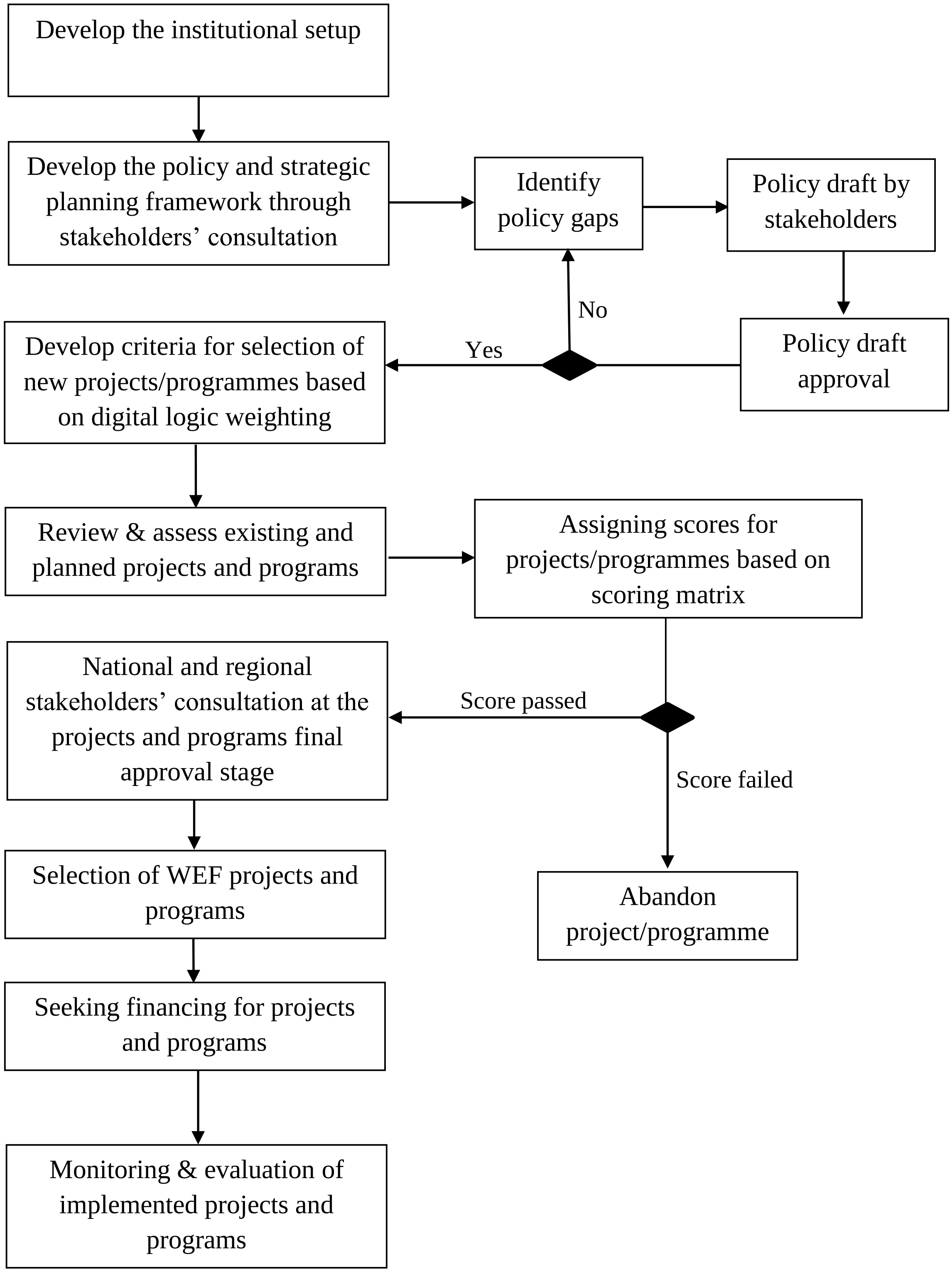

Figure 14 – Operational Methodology for WEF Nexus at Egypt and/or Nile Basin Level

The development of the policy framework shall follow a participatory approach involving the different stakeholders during the stage of developing the policy and strategic planning framework. Although the process will be led by governmental entities, it is very important to realize that the success of the policy framework also depends on some key players. Those include other governmental entities, private sector, NGOs, academic institutions and the public. It is of utmost importance to involve all the relevant players early on in the planning process. Events targeting specific stakeholders and public hearing sessions shall be organized. Consultation with relevant international organizations is very important as well. It helps to develop global support for the proposed policies, projects and programs, which is expected to be reflected in the willingness of international and regional financial institutions to support these projects.

The purpose of the stakeholders' consultation at the policy and strategic planning framework stage is to gather as much input as possible from the different stakeholders at a very early stage to feed into the process of projects and programs prioritization. In order to ensure a sound stakeholders' consultation process, participatory workshops will be held to ensure gathering input from grass root population into the strategic planning process. In order to do that, one national workshop and eight regional workshops will be conducted. In addition to receiving input from the stakeholders, the purpose of the workshops is also to raise awareness of the public about the cooperation mechanism and the topic of the WEF nexus in general. During the process, policy gaps will be identified and policy draft will be developed by stakeholders. The policy drafts will have to be approved by the government, otherwise they should be returned back for more stakeholders' consultation.

In order to make sure the policy planning framework does not result in duplication of effort, all relevant existing and planned projects and initiatives relevant to the WEF nexus will be assessed and evaluated. It is very important to align the selection process of projects and programs with the local national priorities of each country in order to guarantee the maximum level of support from the government.

The methodology selected for the selection of projects and programs under the cooperation mechanism is the digital logic method. In order to adequately allocate a weight for every criterion, proper assessment of all criteria concerning their significance with respect to objectives must be done. The allocation must also take into consideration the importance of each objective with respect to the other. In case weight allocation is done arbitrarily, it would lead to inaccuracies of decision due to having a large number of criteria.

The digital logic method is adapted for the process of selection in order to allocate calculated weights for each criterion. The digital logic method has the advantage of simplifying a complex decision by breaking it apart into smaller and simple logic decisions of yes or no outcomes. The process bases its technique on comparing every criterion with the other and deciding which is more important with a yes or no. In this case the number of criteria is 8, and when comparing each with the other, the number of logical decisions that need to be made is $\frac{n(n-1)}{2}$ which computes to 28. The yes or no decision is numerically translated to 1 and 0. For each criterion, a row of 1 or 0 decisions is formed where each row must have 7 values as per number of comparisons made with respect to the other criteria. The values of 1 and 0 are summed up for each criterion and divided by the total number of decisions (28) to allocate the weight. The process is demonstrated in Table 11.

In order to identify the best projects/programmes for implementation, they should be evaluated under pre-defined criteria. The criteria are based have the most significant impact on water, energy and food security, in addition to other important factors like alignment with national policies, relevance to climate change, environmental impacts and sustainability of the projects. Sub-criteria have also been developed for each criterion. The sub-criteria under each criterion are given equal weight. The criteria and sub-criteria and that are used are discussed below.

1. Relevance to water security
    a. Sustainability of the water resource
    b. Quantity of water needed/produced
2. Relevance to energy security
    a. Energy resources availability

b. Electricity access to populations
c. Availability of affordable energy to populations

3. Relevance to food security
    a. Impact on food availability
    b. Ability of most vulnerable households to withstand food prices shocks
4. Relevance to climate change
    a. Relevance to climate change mitigation
    b. Relevance to climate change adaptation
5. Sustainability of the project
    a. Whether a feasibility study has been completed
    b. Availability of management capacity
    c. Availability of maintenance capacity
6. Alignment with other national policies & development priorities including poverty reduction and other social objectives
    a. Relevance to national policy framework/strategies/plans
    b. Alignment with poverty reduction policies
    c. Alignment with social justice and social inclusion
7. Cost effectiveness & economic viability
    a. Availability of budget for implementing the project
    b. Economic indicators for the project
8. Environmental Impacts
    a. Whether the project has an approved environmental impact assessment / strategic environmental assessment study
    b. Impacts on air quality
    c. Impacts on water quality
    d. Impacts on soil

The evaluation criteria presented will have the following benefits:

- Facilitate the selection of projects that will meet each country's most urgent and immediate needs
- Prioritize projects which have a high ranking on the WEF nexus

- Blend with national plans and policies
- Take into consideration all pillars of sustainable development

Table 11 – Digital Logic Weighting

Criteria/ Decision	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	# of positive decisions	Weight Allocation
Relevance to water security	1	0	1	0	1	1	1																						5	17.9%
Relevance to energy security	0							0	1	0	0	1	1																3	10.7%
Relevance to food security		1						1						1	0	1	1	1											6	21.4%
Relevance to climate change			0						0					0					1	0	0	0							1	3.6%
Sustainability of the project				1						1					1				0				1	1	0				5	17.9%
Alignment with national policies					0						1					0				1			0			0	1		3	10.7%
Economic Viability						0						0					0				1			0		1		1	3	10.7%
Environmental Impacts							0						0					0				1			1		0	0	2	7.1%
Total																														100%

The weights obtained from the digital logic weighting will be further divided into equal weight sub-criteria to have the matrix ready for projects/programmes evaluation. The full matrix is presented in Table 12.

Table 12 –Matrix for Projects/Programmes Evaluation including sub-criteria

Criteria	Criteria Weight	Sub-Criteria	Sub-Criteria Weight
Relevance to water security	17.9%	Sustainability of the water resource	8.95%
		Quantity of water needed/produced	8.95%
Relevance to energy security	10.7%	Energy resources availability	3.57%
		Electricity access to populations	3.57%
		Availability of affordable energy to populations	3.57%
Relevance to food security	21.4%	Impact on food availability	10.71%
		Ability of most vulnerable households to withstand food prices shocks	10.71%
Relevance to climate change	3.6%	Relevance to climate change mitigation	1.79%
		Relevance to climate change adaptation	1.79%
Sustainability of the project	17.9%	Whether a feasibility study has been completed	5.95%
		Availability of management capacity	5.95%
		Availability of maintenance capacity	5.95%
Alignment with national policies	10.7%	Relevance to national policy framework/strategies/plans	3.57%
		Alignment with poverty reduction policies	3.57%
		Alignment with social justice and social inclusion	3.57%
Economic Viability	10.7%	Availability of budget for implementing the project	5.36%
		Economic indicators for the project	5.36%
Environmental Impacts	7.1%	Whether the project has an approved environmental impact assessment / strategic environmental assessment study	1.79%
		Impacts on air quality	1.79%
		Impacts on water quality	1.79%
		Impacts on soil	1.79%

Criteria	Criteria Weight	Sub-Criteria	Sub-Criteria Weight
Total			100.00%

At this stage, the projects and programs prioritization process has reached some results which should be presented to the different stakeholders and the public. Similar to the public consultation process conducted at the strategic planning stage, one national workshop and eight regional workshops will be conducted at the final approval stage. The results reached will be presented and input will be received again from the stakeholders regarding the results. All comments and concerns will be recorded and used as an input to the projects and programs prioritization process.

Once the stakeholders' consultation process is completed and input received, the prioritized list of projects and programs is ready to be finalized. The final list will be completed by the project team in anticipation of securing the necessary funds.

The ultimate goal of the policy framework is to implement projects and programs that prioritize the WEF nexus and at the same time contribute to the national priorities of each of the Nile Basin countries. In order to do so, it is necessary to secure the necessary funds. It is proposed to create a fund or development bank for the Nile Basin countries. The fund will be financed by the Nile Basin countries with returns going back also to the funding countries.

5.3 Examples of projects and programs that could benefit from WEF synergy in Egypt

5.3.1 The Reclamation of 1.5 Million Feddans Project

In November 2014, President Abdel-Fattah Al-Sissy announced the launch of a project for the reclamation of 1 million feddans at 11 areas at the Western Desert. The project was scheduled to be completed in 10 months as per the Ministry of Agriculture which was responsible for the file at that time (Youm7, 2014). This is exactly the type of project which needs the WEF nexus to ensure its success. There is no possible way the Ministry of Agriculture can handle this project without very close coordination with the Ministry of Water Resources and Irrigation and the Ministry of Electricity and

Renewable Energy. For that reason, the project was delayed significantly. In May 2015, it seems that the project ownership was shifted to the General Organization for Physical Planning at the Ministry of Housing, Utilities and Urban Development. This was concluded from the media reporting that a Memorandum of Understanding had been signed between the Ministry of Housing and a Chinese company to fund the infrastructure required for the land reclamation and the development of the new urban communities within the 1 million feddans project (Daily News Egypt, 2015). In October 2015, a source at the Ministry of Water Resources and Irrigation announced that the project was assigned to it and that the Ministry of Agriculture will only play a consultative role only. The decision was attributed to the Prime Minister (Reda, 2015). It was later announced that the project has been expanded to cover 1.5 million feddans.

The key success factors in a project like the reclamation of 1.5 million feddans are availing both the water resources and energy needed for the project. In December 2015, the Ministry of Water Resources and Irrigation announced that the project will depend 88.5% on ground water through 5114 wells and 11.5% on Nile water. It also announced that the technical studies have confirmed that the sustainability of the ground water for the first and second phases of the project has been confirmed for 100 years and that the studies are in progress for the third phase (Al-Wafd, 2015).

Although it is considered a positive step that the management of the project has been transferred to the Ministry of Water Resources and Irrigation, the project still needs the WEF nexus approach. Had it been implemented from the beginning of the project, it would have saved lots of time and effort. The project has now passed the planning stage for availing the water resources, but still has several missing links. No details were announced to the public regarding the plan to desalinate the ground water given the fact that the ground water in Egypt is brackish with salinities ranging from 1,000 to 10,000 mg/l (Nasr & Sewilam, 2015). Apart from the normal regular energy requirements for primary production; drying, cooling and storage; and crops transportation, desalination is an energy intensive process and hence requires the intervention of the Ministry of Electricity and Renewable Energy. For that reason, it is expected that a nexus approach, if implemented, would guarantee the adequate intervention from all the required stakeholders.

5.3.2 Expanding the Power Generation Sector

During the past year, Egypt has been working on expanding its power generation sector. During the 2015 Egypt's Investment Conference, Egypt's Electricity Minister signed MOUs worth USD 22 billion for power generation projects. Those included coal, natural gas, solar and wind projects (Atlantic Council, 2015). In addition, Egypt has plans to build a nuclear power plant at El Dabaa. In 2015, Egypt and Russia signed a deal to build the nuclear power plant with 4 reactors each producing 1,200 MW (EIA, 2015).

While expanding the power generation sector, it is clear that the government did not have the water scarcity problem into consideration. Combined power generation and desalination plants can highly improve the overall efficiency of the process. A study made on Al-Zour gas turbine power plant in Kuwait showed that the introduction of a desalination unit improved the overall thermal efficiency of the process by 25% (Alsairafi et al., 2013). In the Arabian Gulf countries, combined power generation and desalination is very common. This is made institutionally possible by the fact that one Ministry in responsible for the production of both power and water. This is another example of lost opportunities due to the absence of the WEF nexus approach in Egypt.

5.4 Examples of projects and programs that can benefit from WEF synergy on the Nile Basin Level

5.4.1 Expanding Green Water Utilization in the Basin

Groundwater is widely used for domestic use in the Nile Basin. It is the main source for drinking water for rural communities in the basin. Around 70% of the population in Ethiopian Highlands and the Nile Equatorial Plateau depend on groundwater. Thus percentage reaches 80% in Sudan, almost 100% in South Sudan, but only 13% in Egypt. Groundwater is also widely used for agricultural purposes in the Northern parts of the basin (Sudan and Egypt) (Nile Basin Initiative, 2012). Its use is limited in the Southern parts due to the abundance of rainfall as well as the availability of surface water bodies.

In general, groundwater is underutilized in the basin as shown in Table 13. Although the groundwater quality in the Nile Basin is highly variable, the groundwater across the region in general is fresh and suitable for human consumption in terms of physical and chemical parameters. The main exception is the Nile Delta area in northern Egypt where the groundwater is highly saline due to the intrusion of salt water from the sea (Nile Basin Initiative, 2012).

Table 13 – Groundwater Potential of Nile Basin Countries (Hassan et al., 2004)

Country	Groundwater (BCM/year)	Renewable groundwater (BCM/year)	Non-renewable groundwater (BCM/year)	Groundwater annual extraction (BCM /year)
Burundi	0.40	0.18	0.22	0.03
D R Congo	51.9	46.75	5.15	0.21
Egypt	4.00	0.09	3.91	0.90
Ethiopia	7.23	5.50	1.73	0.40
Kenya	2.34	1.01	1.33	0.42
Rwanda	0.40	0.32	0.09	0.04
Sudan	6.40	1.75	4.65	0.50
Tanzania	5.23	4.00	1.23	0.38
Uganda	2.12	1.95	0.17	0.18

Nile Basin countries have the potential for increasing the rain fed areas. Figure 15 shows the expected increase in harvested areas rain fed in the Nile Basin countries in 2030 and 2050.

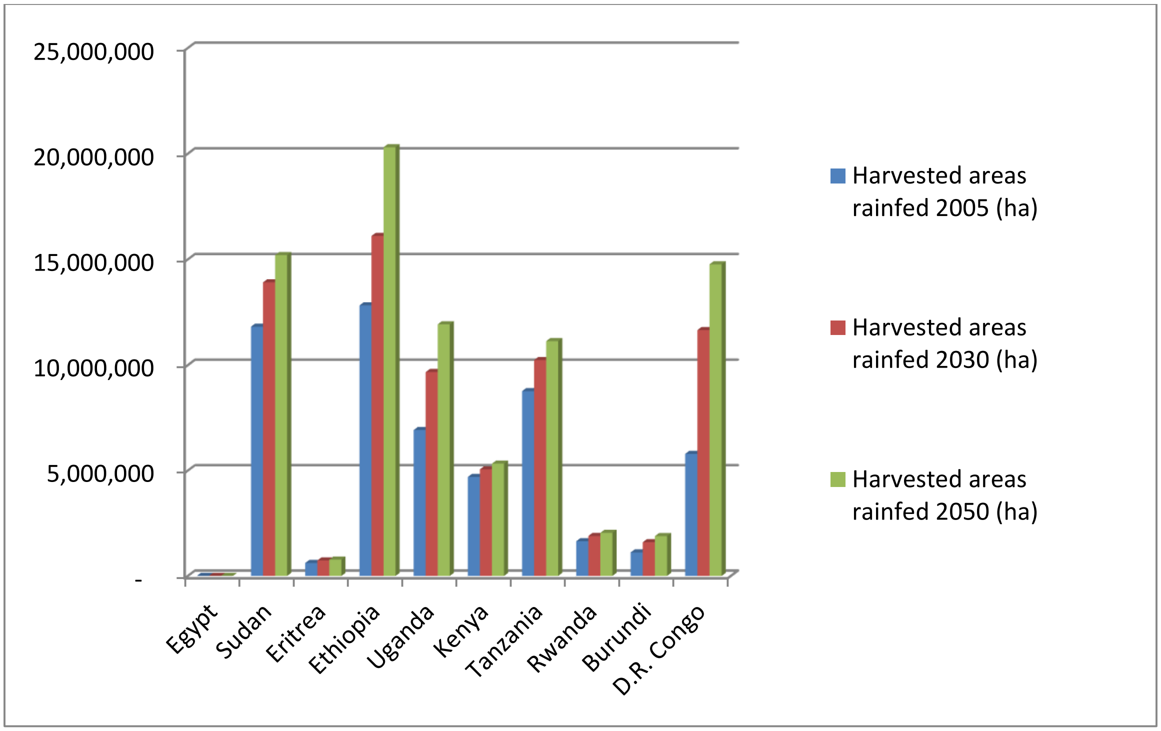

Figure 15 – Harvested rain fed areas in the Nile Basin countries including projections – developed from (FAO, 2011)

5.4.1.1 Using water footprint comparative advantage to grow crops using the least possible water

As a smart choice, it is recommended to grow crops at the areas which have the lowest water footprint for that specific crop. Based on that, the following opportunities exist:

- The Nile Basin countries are collectively net importers of cereals. Increasing the production of cereals is an important target for these countries to improve their food security situation. In that sense there are huge opportunities to improve the yield of rain-fed cereals including maize in Ethiopia and Uganda as well as wheat in Tanzania and DR Congo. This can be done without using any additional blue water.
- All Nile Basin countries are net importers of rice (Nile Basin Initiative, 2012). The water footprint of rice in Egypt is much lower than upstream countries due to the much higher yield in Egypt. If Egypt gets more cereals intake from upstream Nile Basin countries, there is an opportunity.

- Although Uganda, Tanzania, Burundi and Rwanda are the biggest producers of bananas in the basin, they have the lowest yields (Nile Basin Initiative, 2012). This presents an opportunity for improving the yield in upstream countries and helping them export to Egypt.
- Egypt has the lowest yield among the Nile Basin countries in the production of mangoes, even though it is the largest producer. On the other hand, huge amounts are wasted in South Sudan and Uganda due to inadequate infrastructure required for transportation and storage (Nile Basin Initiative, 2012). Egypt can help these 2 countries with improving infrastructure and thus can import from them and decrease its production.
- Except for Kenya, Rwanda and Sudan, all the other Nile Basin countries have a relatively low water footprint for production of sugar cane (Nile Basin Initiative, 2012). This highlights the opportunity for expanding production and exporting.

5.4.1.2 Using Egyptian expertise to improve the yield of upstream countries

The productivity of rain fed agriculture is poor in the Nile Basin. The productivity is limited by poor soil, water and bad crop management. There is room for improvement of agriculture based in green water in the Nile Basin. Farmers are unable to use the optimal quantities and quantity of fertilizers. They also do not use improved seeds. A study conducted on maize in the Ethiopian part of the Blue Nile showed that the grain yield of maize increased by an average of 51% with near optimal and non-limiting soil fertility conditions. The study concluded that enhancing soil fertility coupled with the usage of high yield crop varieties have the potential of improving overall productivity through the reduction of evaporation and the increase of transpiration (Erkossa et al., 2011). Compared to Egypt, the Nile Basin countries has very low crop yields. Figure 16 shows comparative yields for selected food crops in Egypt compared to the rest of the Nile Basin countries. The yield in upstream countries is between 15 to 50% of the yield in Egypt. The figure shows the huge potential for improving yield at the Nile Basin countries if only the Egyptian expertise is utilized (Nile Basin Initiative, 2012).

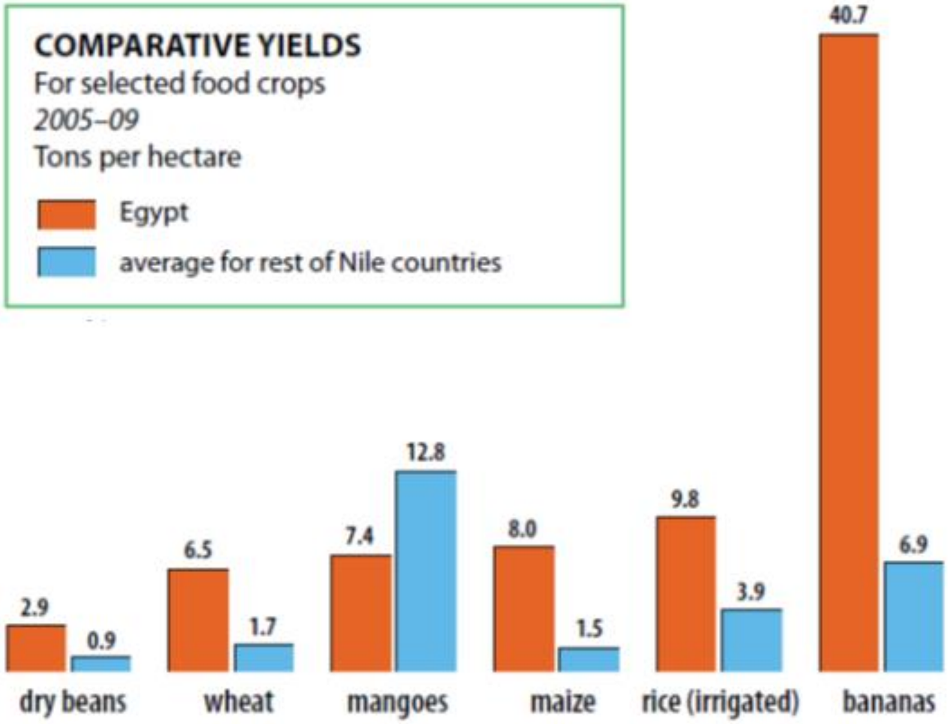

Figure 16 – Comparative yields for selected food crops 2005-2009 (Nile Basin Initiative, 2012)

One of the main reasons behind the low yield in upstream Nile Basin countries is the lack of fertilizers. Figure 17 shows the 2005 fertilizers consumption in the Nile Basin countries. It shows that the Egyptian rate of fertilizers usage is more than twenty fold the rate of the second best country which is Kenya. Egypt has a number of fertilizers factories and is well-experienced in the production and usage of fertilizers. In order to improve the yield in those countries it is recommended that Egypt either exports fertilizers to Nile Basin countries or even build fertilizers factories at these countries. This is a clear win-win situation which can benefit all countries.

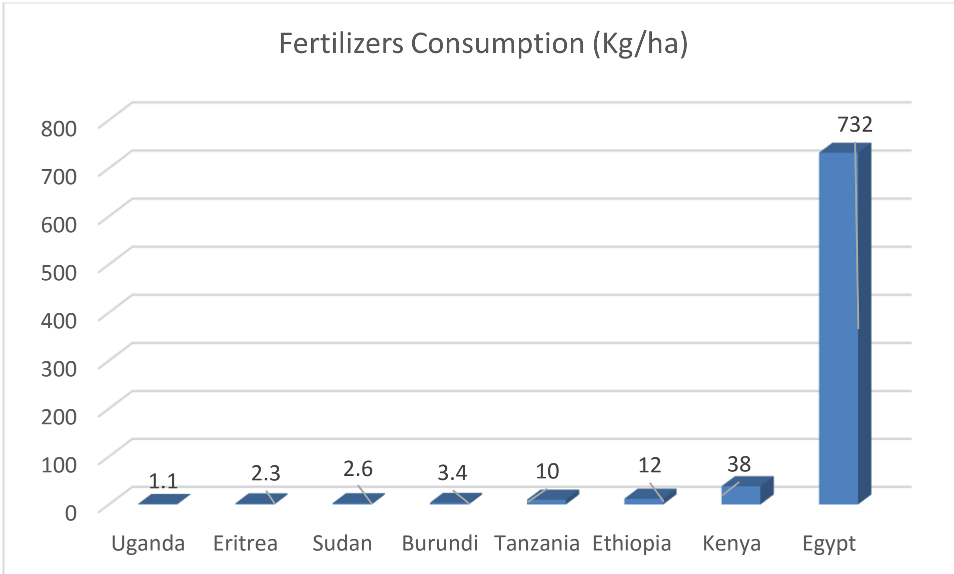

Figure 17 – Use of fertilizers in the Nile Basin – 2005 data – developed from (Nile Basin Initiative, 2012)

In addition to improving the use of fertilizers, there is a number of measures that can be taken in order to improve the yield at upstream countries, including improved seeds, adjusting crop intensity and improving water conveyance. Egypt can also through its Ministry of Water Resources and Irrigation perform research and technology transfer through the cooperation between research institutions. Farmers at upstream countries need extensive capacity building particularly in the area of soil management. Rain-fed areas can make use of improving soil cover and setting up water harvesting structures. This would minimize soil erosion and hence improve the soil conditions (Nile Basin Initiative, 2012).

5.4.2 Integration of electricity grids

Nile Basin countries are endowed with a number of renewable and clean energy resources. Nevertheless, most of these countries, especially upstream countries have very low levels of electricity access. Excluding Egypt, the rates of electrification range between 2 and 30%, with an average consumption of just 77 kWh per capita per year (Economic Consulting Associates , 2009), which represents one of the lowest consumption rates in the World. The power generation capacities of all Nile Basin countries including Egypt is expected to grow significantly over the next few decades.

Figure 18 shows the forecasted demand for electricity for the Nile Basin countries up to 2045. The rise in demand is expected due to improving economic conditions as well as population growth. This represents a huge opportunity for cooperation among all the basin countries.

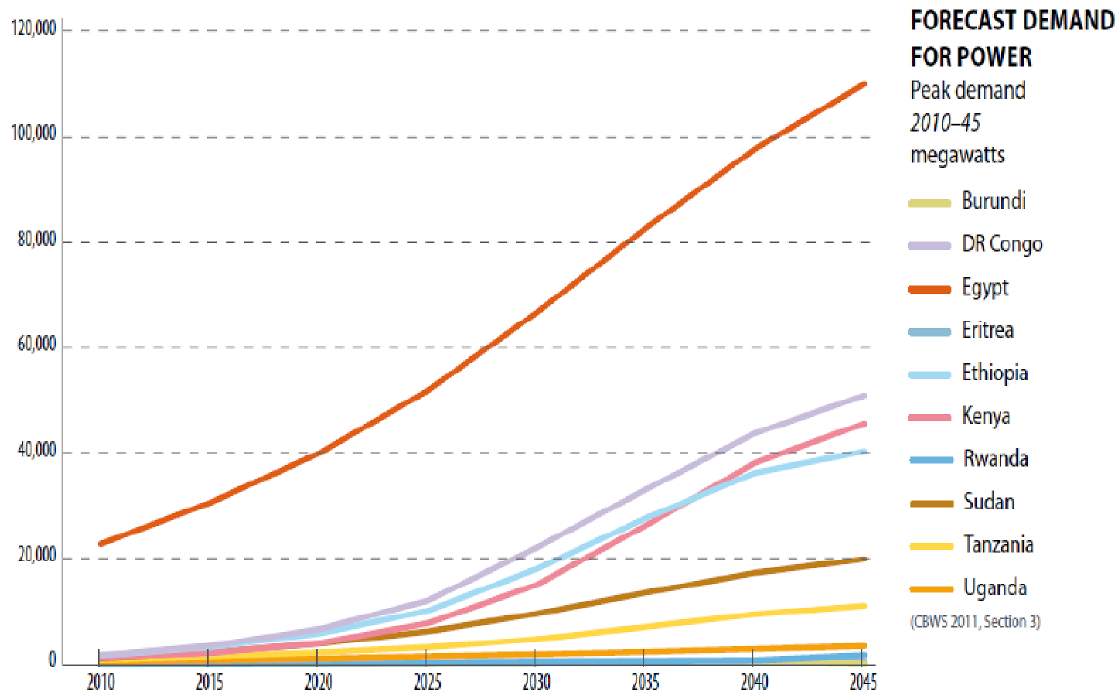

Figure 18 – Forecast demand for power for Nile Basin countries 2010-45 (Nile Basin Initiative, 2012)

The cheapest and most abundant power source in the Nile Basin is hydropower, with a potential of more than 20 GW, with only 26% of the potential utilized (Nile Basin Initiative, 2012). The building of hydropower facilities should be accompanied with other huge investments in transmission and distribution. Through the integration of electricity grids in the Nile Basin countries, Egypt can invest in the infrastructure needed for transmission and distribution in return for electricity later on delivered to Egypt. This can actually be a very successful cooperation model with Ethiopia in the Renaissance Dam project.

5.5 Applying the policy framework to national projects in Egypt and international projects in the Nile Basin

5.5.1 Applying the policy framework to the reclamation of 1.5 million feddans project

To start assessing this project, it should be first discussed at the Supreme Council for Water, Energy and Food. During this stage, the roles of each of the concerned Ministries should be clear. It is anticipated that the following roles should be agreed by the different ministries:

- Ministry of Agriculture:
    - Plan for the crops that will be cultivated in each of the selected regions for the project. In doing so, it should select crops needing minimum water requirements.
    - Estimate quantities of water and fertilizers needed based on the selected crops.
    - Estimate the quantities of energy needed for water pumping, crop harvesting, transportation and processing.
    - Estimate the budget needed for the reclamation of land.
- Ministry of Water Resources and Irrigation:
    - For each region of the project, determine the source of water.
    - In case brackish groundwater will be used, determine the quantities of fuel needed for desalination.
    - Determine the budget needed for availing the water resources for the project.
- New and Renewable Energy Authority, under the Ministry of Electricity and Renewable Energy:
    - Determine the budget needed for pumping of groundwater using solar energy.
    - Study the possibility of groundwater desalination using solar energy and determine the needed budget.

- Ministry of Petroleum and Mineral Resources:
    - Determine the sources of fossil fuel needed for the implementation of the project and the corresponding budget.
- Ministry of Industry and Trade:
    - Determine which fertilizers plants that will supply the needed fertilizers for the project, and in case the existing capacity is not enough determine the budget needed for the construction of new plants.
- Ministry of Planning, Monitoring and Administrative Reform:
    - Coordinate the overall planning of the project.
- Ministry of Environment:
    - Determine the environmental impacts of the project.
    - Propose suitable mitigation measures for the expected impacts in coordination with the other Ministries.
- Ministry of Finance:
    - Calculate the total budget needed for the project based on input from the different Ministries.
    - Determine the overall economic feasibility of the project.

Upon completing the proper Ministerial coordination, the scoring matrix should be used to give a ranking to the project as shown in Table 14.

Table 14 – Ranking the 1.5 million feddans project based on pre-defined scoring matrix

Criteria	Criteria Weight	Sub-Criteria	Sub-Criteria Weight	Sub-Criteria Score (out of 10)	Sub-Criteria Score	Justification	Criteria Score
Relevance to water security	17.9%	Sustainability of the water resource	8.95%	4	3.58%	The project mainly relies on groundwater whose sustainability is questionable.	5.4%
		Quantity of water needed/produced	8.95%	2	1.79%	The project is expected to put more stress on the national water resources.	
Relevance to energy security	10.7%	Energy resources availability	3.57%	4	1.43%	The projects will require significant energy resources for primary production, transportation and processing.	4.3%
		Electricity access to populations	3.57%	4	1.43%	The project will put more stress on Egypt's energy resources	
		Availability of affordable energy to populations	3.57%	4	1.43%	The project will put more stress on Egypt's energy resources	
Relevance to food security	21.4%	Impact on food availability	10.71%	10	10.71%	The project will improve food availability in Egypt.	21.4%

Criteria	Criteria Weight	Sub-Criteria	Sub-Criteria Weight	Sub-Criteria Score (out of 10)	Sub-Criteria Score	Justification	Criteria Score
		Ability of most vulnerable households to withstand food prices shocks	10.71%	10	10.71%	Availability of food produced locally will make the most vulnerable households in a better situation since food prices will not be subject to international price fluctuations.	
Relevance to climate change	3.6%	Relevance to climate change mitigation	1.79%	4	0.72%	Agricultural activities cause considerable greenhouse gas emissions from the use of energy and fertilizers.	2.5%
		Relevance to climate change adaptation	1.79%	10	1.79%	Since the project is expected to implement new agricultural technologies, it will help with climate change adaptation.	
Sustainability of the project	17.9%	Whether a feasibility study has been completed	5.95%	0	0.00%	No feasibility study was announced.	11.9%
		Availability of management capacity	5.95%	10	5.95%	Egypt is a well experienced country in managing agricultural projects.	
		Availability of maintenance capacity	5.95%	10	5.95%	Egypt has enough human capacity and expertise to aintain the project.	
Alignment with national policies	10.7%	Relevance to national policy framework/strategies/plans	3.57%	10	3.57%	The project is in line with the policies of the Ministry of Agriculture.	10.7%
		Alignment with poverty reduction policies	3.57%	10	3.57%	The project is expected to have positive social impact due to creatin of jobs.	

Criteria	Criteria Weight	Sub-Criteria	Sub-Criteria Weight	Sub-Criteria Score (out of 10)	Sub-Criteria Score	Justification	Criteria Score
		Alignment with social justice and social inclusion	3.57%	10	3.57%	Some areas of the project are marginalized areas which will help with their social inclusion.	
Economic Viability	10.7%	Availability of budget for implementing the project	5.36%	8	4.29%	The Egyptian government has allocated budget for the project.	5.4%
		Economic indicators for the project	5.36%	2	1.07%	Due to the arid nature of Egypt and the high cost of obtaining fresh water, the project is not expected to be economically attractive.	
Environmental Impacts	7.2%	Whether the project has an approved environmental impact assessment / strategic environmental assessment study	1.79%	0	0.00%	No EIA/SEA was developed for the project.	2.9%
		Impacts on air quality	1.79%	8	1.43%	Impacts on air quality are restricted to nenergy use which does not make it a significant impact.	
		Impacts on water quality	1.79%	4	0.72%	If the project leads to unsustainable groundwater withdrawals, this will have severe impact on groundwater quality.	
		Impacts on soil	1.79%	4	0.72%	Agriculture leads to the deterioration of soil quality due to the use of fertilizers and pesticides.	
Total			100.00%				64.4%

After that, the project is ready to move to the second round of stakeholders' consultation. Now there is enough information and studies to be presented to the stakeholders. This round of stakeholders' consultation should be done in all governorates where the project is planned. The purpose is to present the results of the previous stages and receive input from the local populations on their concerns and requirements from the project. This will ensure their engagement and give them a sense of ownership of the project. After that the project should move to the financing stage where the Ministry of Finance should allocate the necessary budget for the project. Then the project should move into implementation and monitoring.

5.5.2 Applying the policy framework to the GERD

The project should first be discussed at the Nile Basin WEF Council, which is formed of the Prime Ministers and the Ministers of water resources, agriculture and energy in the Nile Basin Countries. Each country should mention its concerns over the project and they should be discussed accordingly. On that basis, technical committees should be formed to study the impact of the project on Ethiopia and downstream countries. The technical studies should be the basis on which the ranking should take place. The scoring matrix should be used to give a ranking to the project as shown in

Table 15. It should be noted that the scoring in the Table is done from a regional perspective of all the countries affected. It was not done from the Egyptian perspective only.

Table 15 – Ranking the GERD project based on pre-defined scoring matrix

Criteria	Criteria Weight	Sub-Criteria	Sub-Criteria Weight	Sub-Criteria Score (out of 10)	Sub-Criteria Score	Justification	Criteria Score
Relevance to water security	17.9%	Sustainability of the water resource	8.95%	5	4.48%	The project will improve the water security situation of Ethiopia but will threaten that of Egypt.	11.6%
		Quantity of water needed/produced	8.95%	8	7.16%	The GERD's reservoir will store water at better climatic conditions than that at Aswan High Dam, with much less evaporation.	
Relevance to energy security	10.7%	Energy resources availability	3.57%	8	2.86%	The project will have an installed capacity of 6000 MW, but might affect the production of electricity at Aswan High Dam.	10.0%
		Electricity access to populations	3.57%	10	3.57%	The project will improve electricity access to populations at Ethiopia and its neighboring countries.	
		Availability of affordable energy to populations	3.57%	10	3.57%	Large hydro projects produce cheap electricity which makes it affordable to populations.	
Relevance to food security	21.4%	Impact on food availability	10.71%	5	5.36%	The project will improve the food security situation of Ethiopia but will threaten that of Egypt.	13.9%
		Ability of most vulnerable households to withstand food prices shocks	10.71%	8	8.57%	The project will help Ethiopia overcome the recurring famines.	

Criteria	Criteria Weight	Sub-Criteria	Sub-Criteria Weight	Sub-Criteria Score (out of 10)	Sub-Criteria Score	Justification	Criteria Score
Relevance to climate change	3.6%	Relevance to climate change mitigation	1.79%	9	1.61%	The project will produce 6000 MW of electricity with zero GHG emissions.	2.7%
		Relevance to climate change adaptation	1.79%	6	1.07%	The project will help Ethiopia with climate change adaptation through improved production.	
Sustainability of the project	17.9%	Whether a feasibility study has been completed	5.95%	5	2.98%	Ethiopia has done its feasibility study, but another one should be done from a regional perspective.	12.5%
		Availability of management capacity	5.95%	8	4.76%	Operation of large hydro projects is not expected to be a challenge.	
		Availability of maintenance capacity	5.95%	8	4.76%	Maintenance of large hydro projects is not expected to be a challenge.	
Alignment with national policies	10.7%	Relevance to national policy framework/strategies/plans	3.57%	7	2.50%	The project is aligned with Ethiopia's national policies, but is in conflict with that of Egypt.	7.1%
		Alignment with poverty reduction policies	3.57%	7	2.50%	The project is expected to have a great impact om poverty reduction in Ethiopia, but might have a negative social impact in Egypt.	
		Alignment with social justice and social inclusion	3.57%	6	2.14%	The project will improve the social status of marginalized populations in Ethiopia.	
Economic Viability	10.7%	Availability of budget for implementing the project	5.36%	10	5.36%	Ethiopia has allocated the required funds for the project.	10.7%

Criteria	Criteria Weight	Sub-Criteria	Sub-Criteria Weight	Sub-Criteria Score (out of 10)	Sub-Criteria Score	Justification	Criteria Score
		Economic indicators for the project	5.36%	10	5.36%	Large hydro projects produce cheap electricity which makes it economically viable.	
Environmental Impacts	7.2%	Whether the project has an approved environmental impact assessment / strategic environmental assessment study	1.79%	5	0.90%	Ethiopia has completed the project's EIA, but another one should be done from a regional perspective.	5.5%
		Impacts on air quality	1.79%	10	1.79%	The project is not expected to have any significant impact on air quality.	
		Impacts on water quality	1.79%	8	1.43%	The project will have positive impact on water quality at Jazeera scheme at Sudan due to the removal of silt.	
		Impacts on soil	1.79%	8	1.43%	The project is not expected to have any significant impact on soil quality.	
Total			100.00%				74.1%

The project should now move to a regional stakeholders' consultation process, since the project will be implemented on a transboundary river. In addition to the governmental entities that were involved at the at the initial stage through the Nile Basin WEF Council, the stakeholders' consultation should be attended by the civil society, representatives of the public (possible parliament members) and the public at large. Ethiopia, the implementing country should try to present evidence that the project will not harm Egypt in terms of its water security. In case this is not achieved, Ethiopia can present incentives in terms of food and/or energy. The project should be funded by the Nile Basin fund only in case a unanimous decision is reached by the member countries.

Chapter Six: Conclusion and Recommendations

Water, energy and food security are far from being achieved globally. A large number of people globally lack basic services, with 0.9 billion people lacking access to clean drinking water, 2.6 billion people having no safe sanitation, 1.3 billion people without access to electricity, 1.5 billion lacking access to modern forms of energy for cooking and 1 billion suffering from hunger regularly. In the future those challenges are expected to be even more severe. FAO expects that two thirds of the world's population will suffer from water stress by 2030. It is forecasted by the EIA that the world will need 40% more energy by 2030 compared to the current levels. The global demand for meat is expected by UNEP to increase by 50% by 2025, leading also to a 42% increase in the demand for grain. Climate change is expected to increase nexus challenges. Temperatures are expected to increase, soil is expected to dry out, storms are expected to intensify and glaciers are expected to reduce in size.

Egypt is a country struggling to achieve water, energy and food security. In terms of water, Egypt is mainly relying on the Nile River, from which it currently receives 55.5 BCM per year as per the 1959 Nile Waters agreement. In the energy sector, Egypt is currently experiencing its worst energy crisis in decades. Looking at food security, Egypt is a net importing country; it currently imports 45-55% of its wheat consumption, which makes it highly vulnerable to international price fluctuations. Egypt is facing another major challenge regarding its main water resource Nile River. Ethiopia is currently undergoing the construction of a major dam on the Blue Nile: The Grand Ethiopian Renaissance Dam (GERD).

Egypt has so far negotiated repeatedly using the argument of its historical rights in the Nile water. However, it should be acknowledged that the demography has also changed a lot. The Ethiopian population is now already more than the Egyptian population. Nevertheless, Ethiopia produces only a fraction of the energy produced by Egypt and also a fraction of the GDP produced by Egypt.

It was demonstrated that the Egyptian policies in the three sectors are incoherent and uncoordinated. Accordingly, it is recommended to develop one integrated strategic plan for the WEF nexus, according to which the three sector policies will be aligned. It is recommended to initiate a Supreme Council for Water, Energy and Food. The mandate of the Supreme Council of WEF will include coordination between all the governmental agencies for Water, Energy and Food, including alignment of policies and plans, exchange of information, review of projects and programs in each sector, and the monitoring of implementation and operation of these projects and programs. Similarly, a Nile Basin WEF Council is recommended for the Nile Basin countries, in order to take strategic decisions and approve projects and plans. The Nile Basin WEF Council decisions should be legally binding to all Nile Basin countries.

A policy framework was developed to prioritize projects that are beneficial to the WEF nexus. The development of the policy framework shall follow a participatory approach involving the different stakeholders during the stage of developing the policy and strategic planning framework. In order to assess and prioritize the different projects, a digital logic method is used, where the criteria included relevance to water security, relevance to energy security, relevance to food security, relevance to climate change, sustainability of the project, alignment with national policies, economic viability, and environmental impacts. Afterwards the final projects approval process involves another stakeholders' consultation process, followed by seeking funding for the selected projects.

In order to show the importance of the WEF policy framework both on the local level in Egypt and the Nile Basin level, several examples were shown that could benefit from having the WEF nexus approach. On the local level, it was demonstrated that the lack of coordination caused huge delays to the reclamation of 1.5 million feddans project. When applying the policy framework to the project, it was demonstrated that the project could have taken a much faster track had the necessary coordination among governmental entities been done at an early stage. Another example given was the expansion of the power generations sector in Egypt, whose efficiency could have been improved by 25% if combined power generation and desalination plants were introduced.

On the Nile Basin level, it was demonstrated that the water footprint comparative advantage can be used to grow crops using the least possible water. In addition, the Egyptian expertise in agriculture could be used to improve the very low agricultural yield in upstream countries. Integrating electricity grids in the Nile Basin is also a very interesting project. The Egyptian expertise can be utilized in the field of electricity generation and transmission from hydropower in return for part of the generated electricity going to Egypt. The policy framework suggested was implemented to the GERD project. It was demonstrated how Ethiopia can provide incentives to Egypt through power and food to compensate Egypt for water shortages due to the dam construction. Although the project received a satisfactory score from a regional perspective, it is strongly recommended that Egypt makes good use of the project by adopting the virtual water concept (e.g. by planting crops and raising cattle in Ethiopia), in addition to the integration of electricity grids with Sudan and Ethiopia.

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