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# Mitigating the Mediterranean's Climate Change Crisis: Egypt as a Case Study

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## Introduction

Egypt's climate is arid, hot, and desert-dominated (*USAID*, 2018). The winters are warm, with rain falling along the shore, and the summers are scorching and dry (May to September). The temperature of the day varies depending on the season and the direction of the wind. Temperatures in the coastal regions range from average winter lows of 14°C (November to April) to average summer highs of 30°C (May to October). In the interior desert areas, temperatures can fluctuate from 7°C at night to 43°C during the day, mainly during the summer.

Temperatures in the desert change less significantly throughout the winter but can reach 0°C at night and 18°C during the day. Egypt also gets "khamsin," or scorching windstorms that transport sand and dust and blow across Africa's northern shore. These khamsin storms are most common between March and May, and they may raise the temperature by 20°C in two hours, lasting several days. Egypt faces a high risk of natural disasters and is particularly sensitive to the effects of climate change. One of the world's three 'severe' vulnerability regions is Egypt's Nile Delta. According to future forecasts, Egypt will face rising sea levels, water scarcities and deficits, and an increase in the frequency and intensity of extreme weather events such as heat waves, sand and dust storms, flash floods, rockslides, and heavy rains. Under the forecasted future climate, the country will become frequently hotter and drier. Egypt is already suffering from and vulnerable to droughts, which are likely to become more frequent and severe in the future.

Furthermore, owing to a combination of flooding and erosion, sea level rise is expected to result in the loss of a significant amount of the northern half of the Nile Delta, resulting in the loss of agricultural land, infrastructure, and urban districts.

## Climate Related Natural Hazards

Egypt faces a high risk of natural disasters and is particularly sensitive to the effects of climate change (*World Bank Group*, 2021). Water resources, agriculture, fishing, health, housing, biodiversity, telecommunications, electricity, tourism, and coastal zones are among the key sectors affected. Natural disasters have caused roughly 1,500 fatalities in the last 20 years, causing $346.7 million in economic losses.

Increased disaster risks are predicted to worsen current water resource conflicts between agricultural and animal demands and human population needs, particularly during periods of extreme aridity and drought (*UNDP*, 2018). The current quality of accessible water, including surface and groundwater, is likely to change. The agriculture industry is also projected to be impacted by water scarcity and shifting weather patterns. Increased heat and deteriorating agricultural conditions will have a negative impact on 'working days', affecting disadvantaged communities' livelihoods and economic resilience. The majority of the country's people and infrastructure are in the Nile Delta and along the Mediterranean coast, leaving the latter particularly vulnerable to the effects of rising sea levels, especially flooding and saltwater intrusion.

Egypt's water-, agricultural-, energy-, and health sectors remain very sensitive to climate variability and change in the short and long term. Climate change impacts are at present being felt across the country, which is already extremely dry. Drought and water shortages are projected to raise the likelihood of food insecurity, as well as to escalate conflict over finite resources, settlements, and population migrations. Furthermore, environmental degradation, water scarcity, and biodiversity loss are key impediments to the country's sustained growth and poverty reduction efforts, increasing sensitivity to risks and hazards while also emphasizing the significance of environmental protection.

## Egypt’s National Climate Change Strategy 2050

The strategy (*Egyptian Ministry of Environment*, 2022) – which was launched on the sidelines of the United Nations Conference of Parties on Climate Change (COP26) in Glasgow – aimed to achieve five main goals. They include: (i) increasing energy efficiency by enhancing the efficiency of thermal energy stations, distribution networks, and oil and natural gas-related operations, (ii) achieving sustainable economic growth by reducing emissions across various sectors, (iii) promoting the use of new energy resources, (iv) producing energy from waste, and (v) using alternative energy sources such as green hydrogen.

These goals are to be achieved by reaching the following objectives:

a. to increase resilience, promote adaptation to climate change, and mitigate the negative effects of climate change by protecting citizens from the negative health effects of climate change, promoting the health sector's ability to combat diseases caused by climate change, and developing studies and training for health professionals.

b. to improve climate change governance and business management, bolstering Egypt's international standing in terms of attracting more foreign investment and climate change finance opportunities.

c. to improve the infrastructure for financing climate action, particularly by promoting green banking activities at the local level, green credit lines, and innovative financing strategies that prioritize adaptation measures like green bonds, private sector participation in climate action, and green job creation.

d. to improve scientific research, knowledge management, technology transfer, and climate change awareness, particularly among policymakers, people, and students.

## Emission Context in Egypt

For the period between 2005 (the final year covered by the TNC GHG Inventory) and 2015, a national GHG inventory (GHGI) was compiled using the 2006 Intergovernmental Panel on Climate Change (IPCC) GHGI Guidelines. The GHGI (*Ministry of Environment of Egypt*, 2018) is divided into four categories, according to IPCC guidelines: energy, industrial process, and product use (IPPU), agriculture, forestry, and other land use (AFOLU: Agriculture Forestry and Other Land Use), and waste. It details Egypt's anthropogenic GHG emissions by carbon dioxide ($CO_2$), methane ($CH_4$), nitrous oxide ($N_2O$), hydro fluorocarbons (HFCs), perfluorocarbons (PFCs), and sulphur hexafluoride (SF6), as well as precursors (NOx, CO, NMVOCs, $SO_2$).

During the period covered by the report, Egypt's GHG emissions amounted to 325,614 Gg $CO_2$e. $CO_2$ emissions account for 237,871 Gg $CO_2$e, $CH_4$ emissions account for 41,483 Gg $CO_2$e, and $N_2O$ emissions account for 38,574 Gg $CO_2$e. Between 2005 and 2015, total GHG emissions climbed by 31%, with an average annual growth rate of 2.35 %. Over the same period, GHG emissions from the Energy, IPPU, and Waste sectors have climbed by 40%, 49%, and 34%, respectively, while emissions from the AFOLU sector have declined by 7%. $CO_2$ from the burning of fossil fuels in energy industries is the highest contributor to GHG emissions (20.16 %), followed by $CO_2$ from road transportation (15.0%), and $N_2O$ from direct $N_2O$ emissions from managed soils (6.87%).

## Impacts of Climate Change on the Energy Sector

Egypt is Africa's largest non-OPEC oil producer, with fossil fuels powering the country's energy infrastructure. The Gulf of Suez, the Nile Delta, the Western Desert, the Eastern Desert, Sinai, and the Mediterranean Sea all contribute to Egypt's oil output. The vast bulk of output comes from production sites that are linked to bigger regional production networks. The country's overall output is declining

(*USAID*, 2018) and stems mainly from older fields in the Gulf of Suez and the Nile Delta. Small new discoveries, mainly in the Western Desert and offshore locations, have somewhat countered the decreasing production.

The present infrastructure is ill equipped to deal with the predicted consequences of climate change, particularly when combined with growing energy demand. Due to inadequate supply capacity, existing energy systems are at danger of system failures, rising outages, and brownouts. Dams planned upstream of Egypt, which are intended to boost energy supply throughout the continent, might potentially cut water flows to Egypt dramatically. This might affect not only agricultural, industrial, and household water uses, but also hydropower output at the country's largest dam, the Aswan Dam. Climate change and international pressures on the Nile River have the potential to damage not just Egypt's economic activity and water supply, but also to exacerbate conflicts among the river water's users.

Egypt's long-term energy demand changes (seasonal expansion, longer consumption need). This includes more frequent peak hour consumption patterns, including increases in the need for air conditioning and expanding high energy demand for water desalination activities. This will result in further problems for satisfying energy needs as temperatures rise and rainfall decreases. Increased evaporation rates from current water storage facilities would also raise production costs of crops, which will be passed on to consumers. Cooling Degree Days depict the link between daily heat and cooling demand, which is normally met by active cooling or evaporation. Seasonal increases in cooling demand (power consumption) are projected to grow throughout a longer summer period, as measured by the change in cooling degree days (mainly during the months of May to October). The Warm Spell Duration Index measures the number of days in a row when the daily maximum temperature exceeds the 90th % of daily maximum temperature (*Pérez J. C.*, 2016).

## Mitigation of the Climate Change Crisis

Egypt's government is attempting to diversify its energy supply and boost the amount of electricity generated from renewable sources, mainly wind and solar energy, because of the country's expanding domestic energy demand (see above). The nation is also encouraging the development of nuclear power. Electricity demand continues to outstrip generation capacity and expansion. Imports of coal are increasing to satisfy urgent demand. Through energy savings programmes and new transmission and accounting systems, the country is working on creative new regulatory models to boost energy production and usage efficiency, particularly for utilities and, ultimately, their consumers. Egypt has committed to performing thorough energy sector studies to establish the impact that climate would play in energy demand in order to increase its adaptive capability in the energy sector *(World Bank*, 2021).

The Egyptian government stated that a sustainable energy mix is required to meet rising demand as well as to transition to a more ecologically friendly and varied electrical industry. The importance of renewable energy use is emphasized in the 2035 Integrated Sustainable Energy Strategy (*New and Renewable Energy Authority (NREA)*, 2020), which builds on earlier policies. By 2035, Egypt plans to increase the %age of electricity generated from renewable sources to 42 %, with wind accounting for 14 %, hydropower 1.98 %, photovoltaic (PV) 21.3 %, concentrating solar power (CSP) 5.52 %, and conventional energy sources accounting for 57.33 %. This plan is now being amended and awaits approval by the supreme council for energy, with the goal of generating 33% of energy from renewable sources by 2025, 48% by 2030, 55% by 2035, and 61% by 2045.

As a result, and considering the approach, between 2014 and December 2021, a total capacity of 28 229 MW was added to the system, resulting in a total installed capacity of 59.5 GW, which comprises both conventional and renewable energy sources. This was done with a USD 2.7 billion fast-track project that was utilized to install 3 636 MW of energy in 8.5 months. A deal was signed with Siemens in March 2015 for the building of three mega combined power cycle plants, resulting in the addition of 14 400 MW in 2.5 years. Converting old simple cycle power facilities to mixed cycle provided another 1 850 MW.

Egypt has constructed several energy interconnectors (i.e., high-voltage cables that connect the electricity systems of neighbouring countries) in order to achieve its objective of becoming an energy hub. Jordan has one with a capacity of 250 megawatts, with plans to expand it to 450-500 megawatts in the future. Sudan has a smaller one with an 80-megawatt capacity that will be enlarged to 300-megawatt capacity in the future. A third interconnector with Libya currently has a capacity of 200 MW. Furthermore, the government is working on completing an interconnector with Saudi Arabia. In 2019, a Memorandum of Understanding was signed with Cyprus and Greece to create a 2 000 MW interconnector divided into two sections of 1000 MW each. From a technological aspect, the deal is presently being investigated.

Egypt is well-positioned to further maximize its potential in energy production and market liberalization, with plans to increase its connections to Europe, Africa, and the Middle East. The 2015 Power Law made fundamental changes to the electricity market, making it completely competitive. Unbundling the ownership of production, transmission, and distribution operations, giving third parties grid access without bias, and guaranteeing the energy regulatory agency's independence, competency, and responsibility were among the measures taken.

The Ministry of Electricity and Renewable Energy has updated Egypt's transmission lines (*Ministry of Electricity & Renewable Energy*, 2020), which have increased from 2 364 kilometres of total length of 500 KV grid in 2014 to 6 006 kilometres of total length of 500 KV grid by the end of 2020. In addition, Egypt has 18 500 KV substations in 2014, with a total capacity of 9 800 MVA. The country had 48 substations with a total capacity of 5 450 MVA total 500 KV capacity by adding 30 substations with a total of 44250 MVA, more than 4 times the existing one in 2014.

The government plans to establish six more grid control centres, bringing the total number of grid control centres to seven. Egypt's government invested about EGP 24 billion (around USD 1.5 billion) on the distribution system between 2017 and 2020. Currently, it needs around EGP 19.5 billion (USD 1.2 billion) to enhance its distribution networks. Furthermore, the government is modernizing 47 distribution control centres around the country. The Ministry of Electricity has begun replacing 38 million outdated electricity meters with smart pre-paid meters as part of the government's attempts to manage energy use. Ten million units have been installed, with the remaining units will be put over the next five years.

Egypt has roughly 1 375 MW of wind power plants in operation as of the third quarter of FY 2020/2021 (*New & Renewable Energy Authority*, 2020), mostly by the New & Renewable Energy Authority (NREA) and one project by the private sector producing around 250 MW. There are 1623 MW of PV energy and 20 MW of CSP installed. There are 2,832 MW of installed hydropower, which is the maximum capacity that can be generated until the government builds pumper storage stations (still under study). This has resulted in a 1 000-ton decrease in $CO_2$ emissions. By the end of 2021, various renewable energy sources have been installed with a total capacity of 5872 MW. By the end of 2024, the capacity is predicted to have grown to 10 GW, covering an area of 7 637 square kilometres for wind and solar.

In addition, the solar industry is benefiting as the government decreases net metering and self-consumption limitations ahead of COP27. Incentives for net metering and self-consumption solar power systems have been granted (*EgyptEra*, 2022). The proposed changes, according to the Ministry of Electricity, are part of the state's drive to transition to clean energy and boost renewable investment in the run-up to the COP27 meeting in Sharm El Sheikh in November 2022.

The Egyptian Electric Utility and Consumer Protection Regulatory Agency (EgyptERA) introduced incentives to remove some of the previously imposed net metering restrictions. This comprises a rejection of a 2020 decision that imposed a restriction on how much solar energy private-sector players may create under net metering, a pay-as-you-go invoicing method used by renewable energy producers. The constraint, which was originally intended to discourage renewable energy output amid a supply excess, restricted installed solar capacity per distribution business at 1.5 % of the company's maximum distribution capacity during the prior fiscal year.

## Climate Change and Water Scarcity

Water shortage and drought are anticipated to become more common and severe because of climate change. Water, agriculture, forestry, human health, and livestock are the main sectors affected. Floods, riverbank overflow, and flash flooding will all be more likely as the frequency of strong precipitation events increases. This might lead to soil erosion and water logging of crops, lowering yields and perhaps increasing food insecurity, especially among small-scale farmers. Increased aridity, along with higher temperatures, may cause cattle stress and lower agricultural production. Economic losses, destruction to agricultural areas and infrastructure, and human deaths are all possible outcomes. Furthermore, agricultural productivity is negatively impacted by land degradation and soil erosion, which is worsened by periodic floods and droughts, further impacting the rural poor's lives. Because they have less resources with which to influence and strengthen their adaptive capacity, small rural farmers are more vulnerable to natural hazards (floods, drought times) than larger agricultural units.

Egypt's most important resource is water (*Egyptian Environmental Affairs Agency (EEAA)*, 2016). Only the North Coast, which runs parallel to the Mediterranean, receives adequate rainfall. The intensity ranges from 300 mm/year in Rafah, in the extreme east, to 200 mm/year in Port Said, 150 mm/year in Alexandria, and 250 mm/year in El-Salloum, near the Libyan border. Rainfall decreases rapidly as one travels south and inside the nation, reaching 30 mm/year in Cairo and nearly none at Aswan in the deep south.

At the southern end of the Red Sea, rain intensity can reach 500 mm/year in Halayeb, Shalatin, and Abu Ramad, whereas rain intensity in the northern touristic towns of Hurgada, Kousair, Safaga, and MarsaAlam is less than 100 mm/year. Flash floods in the Red Sea area can occur once every few years (5–10) due to pressure differences between chilly Europe and warm Asia. Flash flood fluids are also useful for recharging groundwater aquifers and storing water for human and animal use. Egypt relies exclusively on the Nile River for water because the rest of the nation is made up of a vast desert area that is mainly uninhabited.

This wide range of water use raises concerns and vulnerabilities about climate change trends, which may have an impact on the natural flow of the Nile River due to lower rainfall in the upper Nile Basins, lower rainfall along the east Mediterranean coast, and the effect of sea level rise on the quality of groundwater in coastal aquifers. The Egyptian government decided to diversify the water supply options by boosting the reuse of treated wastewater and desalination. Desalination is a climate adaptation option as its costs is becoming more competitive than ever, and Egypt could rely on the large coastal areas on the Mediterranean and the Red Seas shores. Despite being energy intensive technology, the IPCC lists desalination as an “adaptation option” (*IPCC*, 2014). Obviously, more efforts must be spent to improve water demand management and improve water use efficiency in agriculture.

## Climate Change Impacts

Climate change is expected to have a significant impact on Nile River flows (Omar et al., 2021) , with some studies suggesting that increased evaporation rates due to rising temperatures could reduce water availability by up to 70%, while other studies suggest that increased rainfall in the Ethiopian highlands and Blue Nile Basin could increase flows by 15% to 25%. Because the Nile River's headwaters lie beyond Egypt's boundaries, the country is very exposed to shifting climatic conditions and shocks both within and outside its borders. Furthermore, the bulk of the population lives near the Nile River, putting them at greater risk of flooding, with the urban poor being particularly susceptible.

Increased water demand is projected because of the expected effects of rising temperatures and reduced rainfall, notably from the agriculture sector, which now consumes around 80% of all available freshwater resources. Water consumption will be influenced not just by rising temperatures, but also by the region's growing population, which is expected to reach almost a billion people by mid-century.

In the 2050s, the Upper Blue Nile River Basin is expected to become wetter and warmer (Link et al., 2012), which will have further climatic consequences on the Nile. Future dam developments, on the other hand, are unlikely to have a considerable impact on Egypt's and Sudan's water availability. Changes in rainfall and evaporation rate have an influence on surface water infiltration and groundwater recharge rates. Due to a lack of water storage capacity, the country's reliance on erratic rainfall patterns grows. Surface water infiltration and groundwater recharge are directly affected by variations in rainfall and evaporation. During droughts or lengthy dry seasons, this has the potential to significantly reduce the dependability of unimproved groundwater and surface water sources.

Increased demand on pumping mechanisms, which can lead to malfunctions if maintenance is neglected, as well as the risk of lowering water levels near wells or boreholes, especially in high-demand regions. Furthermore, even in the presence of increasing rainfall, rising temperatures have the potential to worsen soil moisture deficits.

## Adaptation Actions Towards Improving Water Resource Management

Because the Nile's source waters are located outside of Egypt's borders, diplomatic negotiations and agreements (water diplomacy) are necessary to improve and safeguard the long-term sustainable management of its water resources. Continued and intensified diplomatic consultations with all regional nations that rely on the Nile River: Ethiopia, Sudan, and Uganda are required for proper resource management. Egypt has already implemented national adaptation measures (The Egyptian Cabinet, 2011; UNDP, 2018) aimed at improving water resource management, such as water conservation measures for agriculture, industry, and municipal supplies, improving water quality and sanitation to reduce pollution, building new infrastructure for water collection in flash flood areas (e.g. Sinai, Red Sea, and Upper and Middle Egypt), increasing the use of renewable energy (solar and wind) for water desalination, increasing storage capacity and improving public awareness campaigns on water scarcity and water shortage. Egypt is dedicated to expanding its investment in modern irrigation systems (*Regional Center for Renewable Energy and Energy Efficiency*, 2017), adopting laws to encourage individuals to use water responsibly, and collaborating with Nile Basin countries to minimize evaporation and protect river flows.

## Recommendations

Egypt has made several steps towards climate mitigation and adaptation. This has been pursued through pioneering initiatives targeting the agricultural, irrigation, water resources, tourism and industry sectors in addition to other sectors, in which the adverse effects of climate change are felt. The implementation of targeted projects that address the root causes of climate change have been carried out by, e.g., boosting renewable energy projects. Egypt is determined to increasing the share of renewable energies in the country’s overall energy mix. More concretely, Egypt is raising its 2030 target for renewable energy in the energy mix to 60%, up from the current goal of 42% (Renewables Now 2024, AFEX 2023), by promoting locally suitable and more efficient technologies. This is intended to minimize its reliance on fossil fuels, and to improve the country's energy efficiency in order to boost its adaptive capacity to expected climate change consequences. These efforts could be enhanced through the following measures:

- Boost the knowledge of the main development risks and the effects of anticipated climate change trends in Egypt, as well as possible adaptation responses.
- Increase the participation of the public, scientific institutions, women, and local communities in planning and managing, in order to enable stakeholder involvement, in general, and to improve of gender equity, in particular.
- Strengthen environmental monitoring capabilities for more effective environmental management.

- Increase the understanding of climate change impacts on Egypt’s coastal zones, including an investment in risk assessments and adaptation options.
- Design and implement a Technology Needs Assessment to understand the needs of technology transfer, capacity building and local dissemination of the technology.
- Ensure that donors develop within sectoral and regional plans and in line with financial opportunities the integration of National Environmental Strategy goals.
- Warrant that basic information are available to the scientific community and policymakers on an institutional basis, e.g., through systematic measurements of sea surface temperatures, coastal land use, and sea level variations.
- Assist in the development of energy efficiency measures by improving financing possibilities and providing legal support for public-private partnerships (PPPs).
- Implement cross-sectoral climate-smart solutions for Egypt's agricultural and water management sectors at national and subnational levels.
- Take advantage of the outcomes of COP27, which was held in Egypt to accelerate the energy transition and the adaptation and mitigation projects, as well as the climate financing for Egypt and Africa.

## About the Author

Jauad El Kharraz is the Executive Director of the Regional Center for Renewable Energy & Energy Efficiency (RCREEE) since October 2021. He brings over 20 years of experience in various sustainable energy fields including energy policies, wind and solar technologies, and green hydrogen in addition to water management, desalination, water-energy-food-climate nexus, and environment. Prior to joining RCREEE, he held the position of Director of Research at the Middle East Desalination Research Center in Oman. Previously, he served as a senior expert, advisor, and evaluator for several international institutions (e.g. European Commission, EU-GCC Clean Energy Technology Network, KAS-REMENA, Ocean Oasis) and member of International Desalination Association, European Desalination Society and Oman Energy Majlis. His sustainable energy career officially started in 1998 as a researcher at the Global Change Unit at the University of Valencia. He carried out projects for international donors such as GIZ, SIDA, IsDB, and USAID.

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