SWITCH
ENERGY ALLIANCE

TEXAS
The University of Texas at Austin

Switch Energy Case Competition 2024
Egypt and Türkiye

Quwa Team No. 223

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Conclusion

- Comparison of Final & Current Energy mix for Egypt
- Executive Summary

Geographic & Demographic Overview – Egypt

Geography

Capital: Cairo

Country Size: 384,788 Sq Mi

Climate: hot, dry, desert

Location: Northern Africa, bordering the Mediterranean Sea, between Libya and the Gaza Strip, and the Red Sea north of Sudan, and includes the Asian Sinai Peninsula.

Economy

Natural resources: petroleum, natural gas, iron ore, phosphates, manganese, limestone, gypsum, talc, asbestos, lead, rare earth elements and zinc.

GDP : $1.912 trillion (2023 est.)

Exchange rate: 1 USD = 48.78 Egyptian pound (EGP)

Budget expenditures: $100.318 billion (2020 est.)

Budget revenues: $71.16 billion (2020 est.)

Population

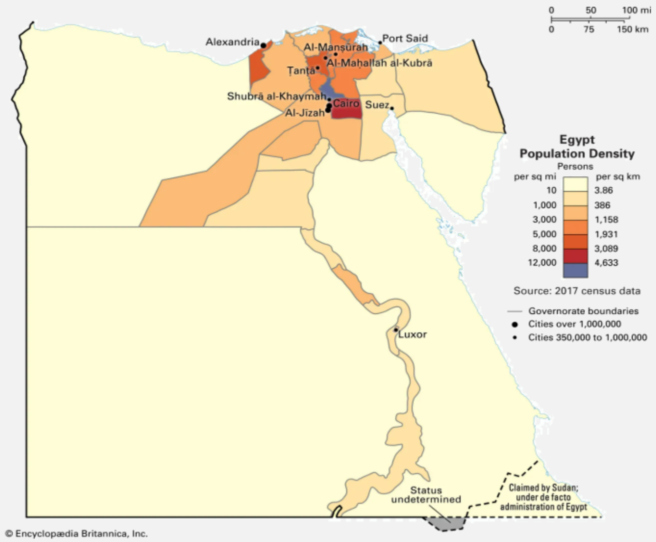
Population: 115 Million

Urban/Rural Population:
Urban: 43% Rural: 57%

Urban Population Density: 5000 persons per square mile.

HDI: 0.73

Official Language:
Arabic is the official language but English and French are spoken as well.



Population Density in Egypt

Geographic and Demographic Overview – Türkiye

Geography

Capital: Ankara

Country Size: 297,144 Sq Mi

Climate: Mediterranean, hot summers and mild winters.

Location: Southeastern Europe and Southwestern Asia, bordering the Black Sea, the Aegean Sea and Mediterranean Sea.

Economy

Natural resources: Coal, iron ore, copper, chromium, mercury, gold, barite, borate, celestite (strontium), feldspar, magnesite, rare minerals, clay, natural gas and hydropower.

GDP : $2.936 trillion (2023 est.)

Exchange rate: 1 USD = 32.392 Turkish lira

Budget expenditures: $249.3 billion (2020 est.)

Budget revenues: $210.5 billion (2020 est.)

Population

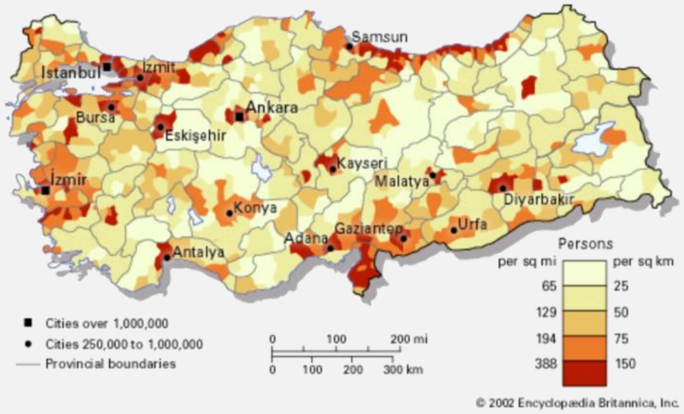
Population: 86 Million

Urban Population Density: 294 people per Sq Mi

Urban/Rural Population: Urban: 77.9% Rural: 22.1%

HDI: 0.855

Official Language: Turkish is the first language spoken by 90% of the population.



Population Density in Türkiye

Egypt’s Energy Poverty Assessment

Accessibility
100% of Egypt’s population has access to electricity since 2016, yet rural regions face issues with maintaining reliable energy supplies (MDPI).

Environmental Impact
Egypt’s dependence on fossil fuels contributes significantly to CO_2 emissions (MDPI). Rising temperatures threaten agriculture productivity (Carnegie Endowment).

Quality of Energy Services
Despite improvements in energy efficiency, grid reliability remains a challenge during periods of peak demand (EOMJ).

Reliability
Power outages continue to affect rural regions due to aging infrastructure and demand pressures (EOMJ).

Affordability
Electricity prices in Egypt have significantly increased since 2016, with recent increases to 50% in 2024 (Egyptian Streets) because of a deal with the IMF, creating significant strain on low-income households (Reuters).

Safety
Outdated energy infrastructure pose risks such as outages and electrical fires (EJOM). Gas pipeline explosions are frequent.

Security
Regional water conflicts impact energy security by hindering hydropower generation from the Nile (MDPI). Egypt’s energy security Is vulnerable to regional conflicts.

Potential for Roadblocks
Financial constraints and political instability present challenges to scaling renewable energy and infrastructure upgrades (MDPI).

Türkiye's Energy Poverty Assessment

Accessibility

Türkiye has a well-developed electricity infrastructure, but rural regions occasionally face challenges in reliability due to geographic barriers.

Environmental Impact

Türkiye is among the top 20 global emitters, with coal and gas making up 70% of the energy mix (IEA). Deforestation caused by segments of power transmission lines installed (ScienceDirect).

Quality of Energy Services

Investments in smart grid technology to improve efficiency and reliability. High consumption periods can present challenges in energy delivery (ScienceDirect).

Reliability

About 15% of Türkiye's energy comes from renewables – stabilizing the energy supply. Reliance on energy imports creates reliability challenges (IEA).

Affordability

In 2022, Turkish authorities increased electricity prices for households by about 20% and for industry by 50%. These substantial hikes were due to Turkey's reliance on energy imports (CyprusMail).

Safety

Seismic activities creates a vulnerable energy infrastructure system (ScienceDirect) Coal mining accidents are reported annually in the energy sector (IEA).

Security

Türkiye heavily relies on imports – the limited domestic energy sources makes it highly susceptible to regional conflicts, like the conflict in Ukraine (ScienceDirect).

Potential for Roadblocks

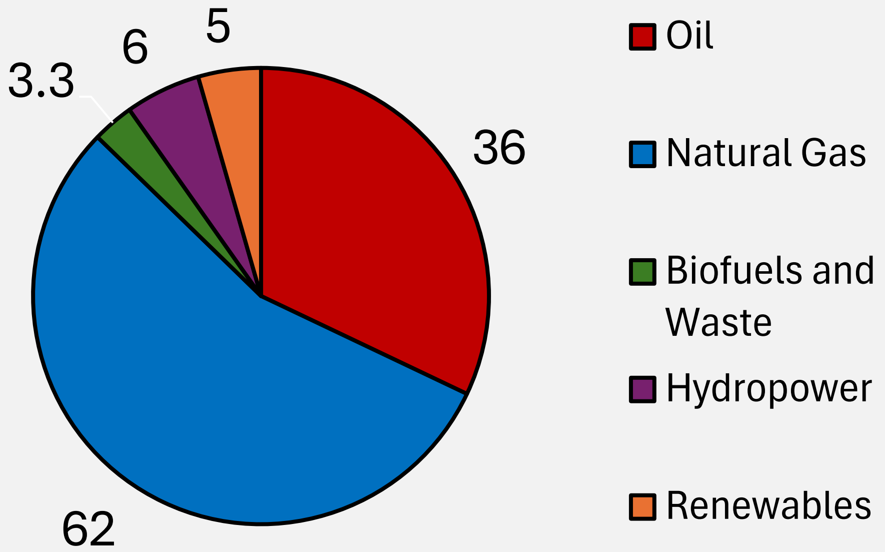
High inflation and fluctuating prices have led to reductions in energy investment. Renewable projects have regulatory approval delays which slows down projects.

Three Key Energy Poverty Challenges

	Affordability	Environmental Impact	Reliability
Egypt	In 2024, Egypt implemented significant increases in electricity prices, with hikes reaching up to 50%. These rising costs have created financial issues for low-income households (AfricaNews).	Increased reliance on fossil fuels to generate electricity continues to contribute to CO_2 emissions, impacting the environment and agricultural productivity (Egyptian Streets).	Frequent power outages in Egypt due to a combination of high demand and challenges with fuel imports (AfricaNews).
Türkiye	In 2022, electricity prices for households rose by about 20% and for industry by 50% due to reliance on imported energy and global market fluctuations (PWC).	The energy sector is heavily reliant on fossil fuels which contributes to greenhouse gas emissions, making Türkiye one of the highest-emitting countries.	Despite progress in renewable energy, the country remains vulnerable to external issues (Statista). The reliance on imports makes it susceptible to geopolitical risks.

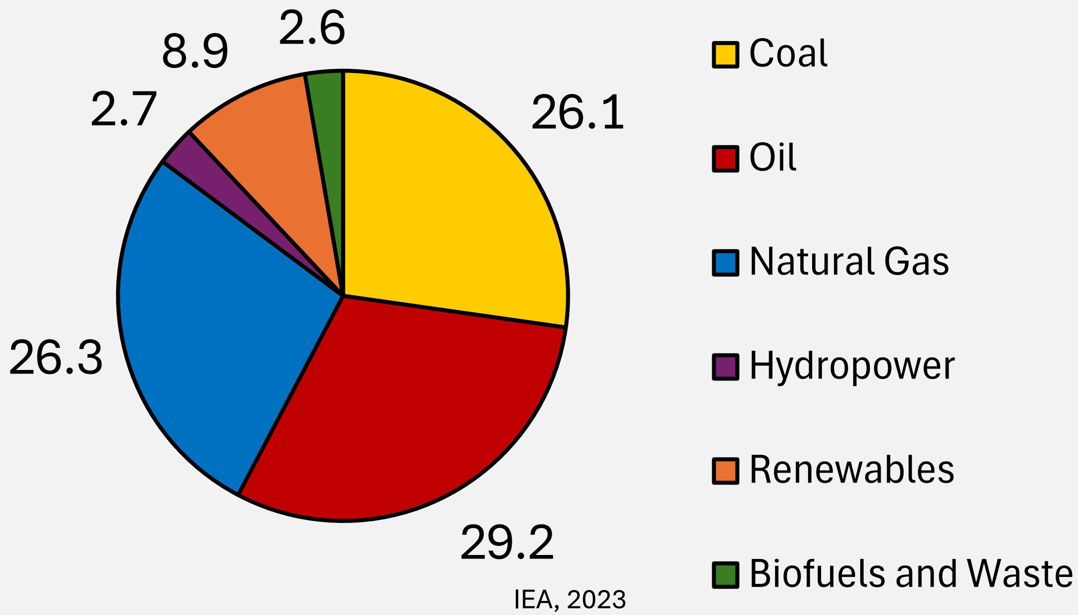
Energy Mix Assessment

Egypt's Energy Production (%)



US EIA, 2022

Türkiye's Energy Production (%)



IEA, 2023

Domestic Energy Production

34.4% of Egypt's Domestic Production is Crude Oil and 59.6% is Natural Gas. There is limited production in renewables including hydropower, wind and solar power.

37% of Türkiye's Domestic Energy Production comes from wind and solar power, and 32% of it is coal production. The natural gas production is limited in Türkiye.

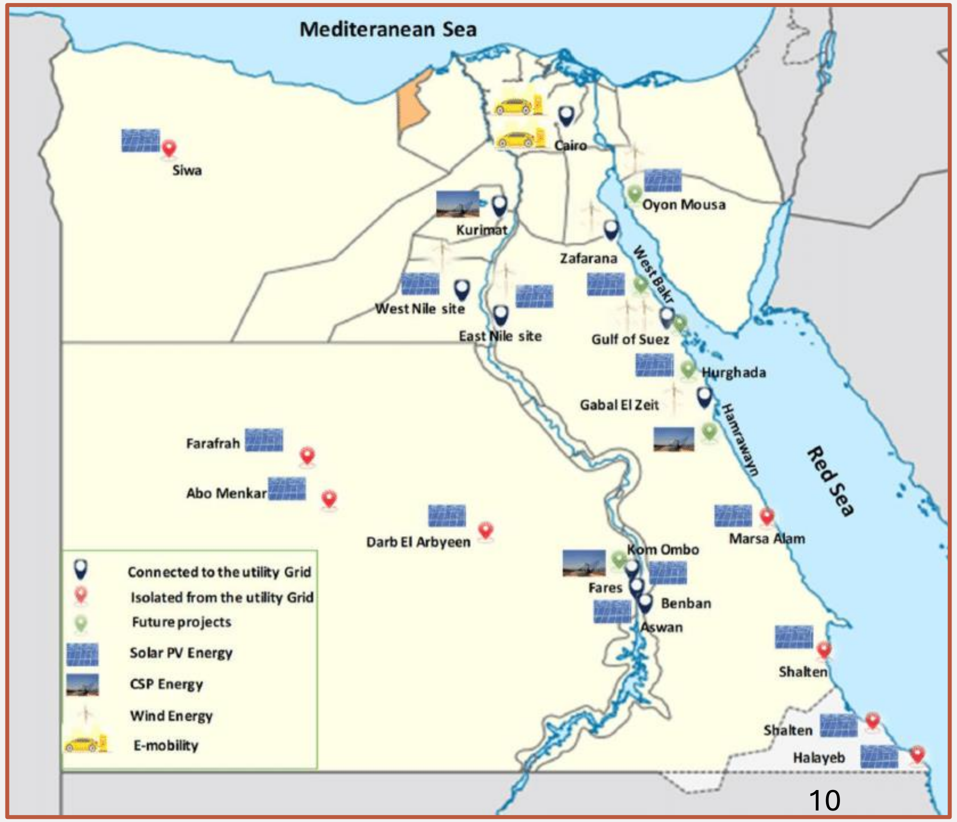
Background on Egypt’s Current Energy

Viability of Utilizing Renewables in Egypt

The case for integrating renewables:

- **Renewable Potential**:
  Egypt has abundant solar and wind resources, making it ideal for expanding its renewable energy capacity.
- **Stabilizing Energy Supply**:
  Integrating renewables can reduce dependency on fossil fuels, improve grid reliability, and decrease the risk of energy shortages during peak demand periods (MDPI).
- **Reducing Environmental Impact**:
  Transitioning to solar and wind power will lower greenhouse gas emissions and help mitigate climate risks, supporting Egypt's commitments to international climate agreements (Carnegie Endowment).

The present and future sites of renewable energy sources projects in Egypt



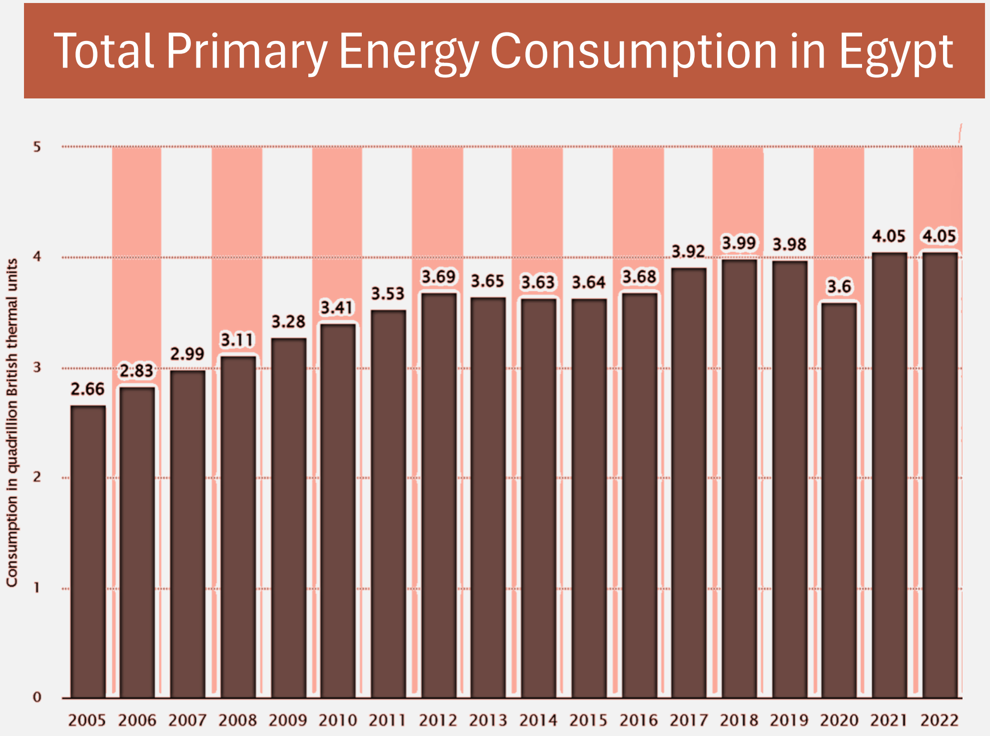
Quwa Team's Goals: Aligning with Egypt's Vision 2030

Vision 2030 Goals:

- This aligns with COP27 commitments to address climate change, positioning Egypt as a leader in regional energy transitions (ICIEC).
- **Expanding Renewables**:
  - Egypt aims to produce 13.7 GW of renewable energy by 2030, targeting 42% of its energy mix from wind and solar initiatives (Ahram).

Quwa Team's Goals:

- **Supporting Renewable Energy Integration**: Initiatives that increase Egypt's renewable energy capacity. This aligns with the goal of achieving 42% renewable energy in the energy mix by 2030.
- **Enhancing Energy Efficiency and Modernization**: Our team is involved in implementing advanced technologies like smart grids and battery storage systems to optimize energy use, helping to meet the rising demands of a growing population while reducing energy waste.



Suggested Solutions
Automation and Upgrade of Egypt’s Energy National Grid and Increase in Grid Capacity

1. Automation of National Grid

2. Natural Gas Power Plants

3. Solar Power

4. Wind Power

5. Nuclear Power

6. Battery Storage

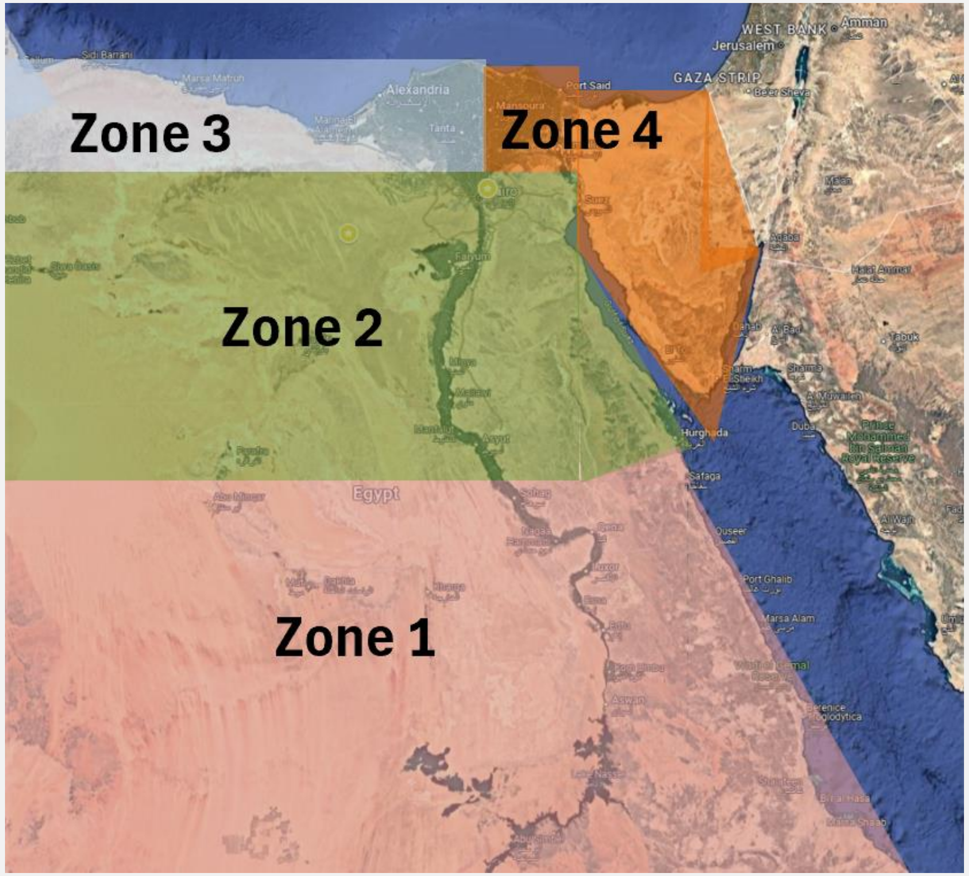
7. Carbon Storage Hub

Proposed Energy Gridlines

1. Automated Grid:

- ➢ **Dividing Egypt into four main regions considering current administrative system which will facilitates failure detection and automated solutions:**
  - Upper Egypt (Zone 1)
  - Middle Egypt and Cairo (Zone 2)
  - West Delta and Alexandria (Zone 3)
  - East Delta and Sinai (Zone 4)
- ➢ Smart Failure detection system:
  - Low-cost line monitoring sensors: 3,000-5,000-line sensors to cover 50,000 km, sensors installed every 10-15 km.
  - Phasor measurements units: provide real-time data on power flow, voltage and stability at critical stations, 150-175 PMUs to cover 60-70% of substations.
  - Io T communication models: provide connectivity for data transmissions from sensors, PMUs and smart meters, 3-5 million modules.
  - SCADA lite real-time monitoring systems: real-time data monitoring and control functions in control centers.
  - Smart meters: Egypt started installing smart meters, extra 3-4.5 million smart meters installation is suggested.

Gridline Placements for Zones in Egypt



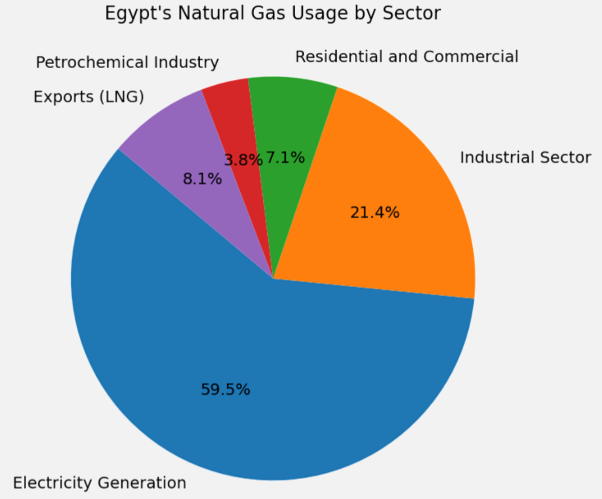
Gas Power Plants

2. Gas Power Plants:

The plan is divided into two main parts explained below:

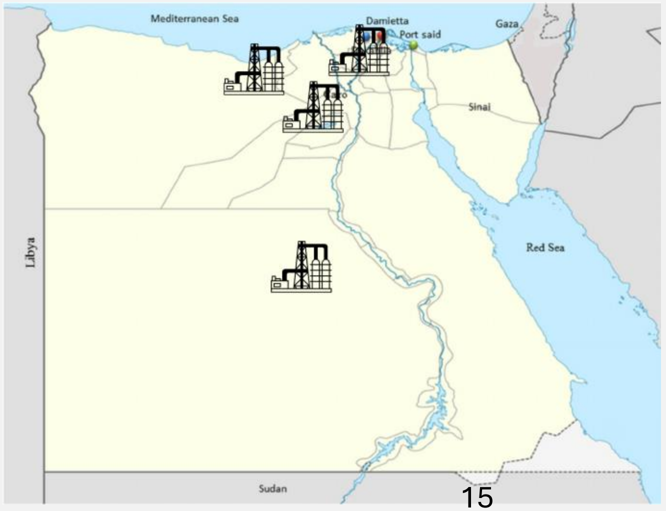
- **Upgrading Existing Single Cycle Power Plants:**
    - Convert the existing single cycle power plants to combined cycles power plants.
    - This will increase the capacity of each plant from 35% to 50-60%.
    - Increase the generated power from (50-500 MW) to (1.5-5 GW).
    - Egypt has 20 operational single cycle gas plant.
    - The plan involve the conversion of all running single cycle power plants to combined cycle power plant.
- **Build Four New Combined Cycle Power Plants:**
    - Build one new power plant per zone.
    - The total capacity of each plant of 2 GW.

Egypt's Natural Gas Usage by Sector



Damietta Liquid Natural Gas Liquification Plant

The Plan's Gas Power Plant Sites



Data from reports from:

- Egyptian Ministry of Petroleum and Mineral Resources
- Egyptian Electricity Holding Company
- Energy Information Administration (EIA) Energy Balance Sheets
- BP Statistical Review of World Energies of Petroleum and Electricity

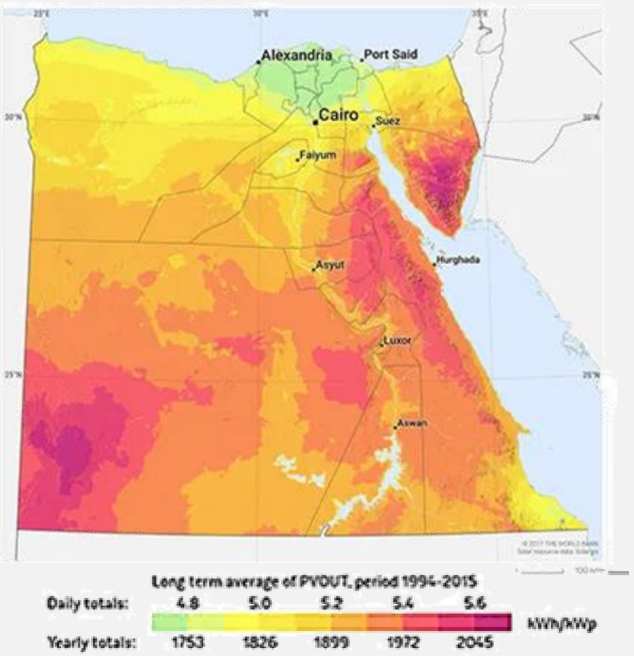
Solar Power

3. Solar Power:

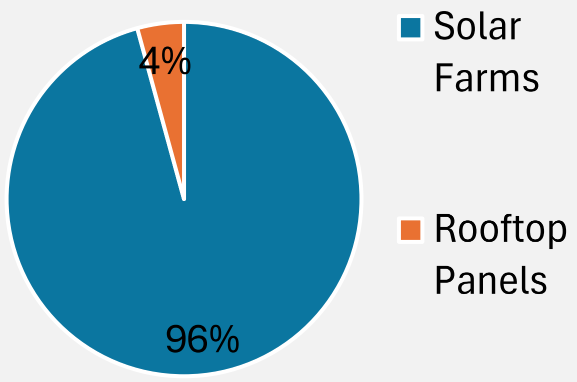
The plan is divided into two main parts as shown in the chart and explained below:

- **Solar Panel Farms:**
  - Build new 4 solar farms with capacity of 2.25 GW
  - Supports up to ~ 4.25 million household
  - High-efficiency PV panels
  - Inverters to convert DC to AC power
  - Transformers to increase voltage for transmission
  - Land Preparation and Fen
  - Operation and Maintenance
- **Rooftop Solar Panel:**
  - For residential and industrial facilities
  - Focused on cities such as New Administrative Capital City
  - Governmental and commercial buildings

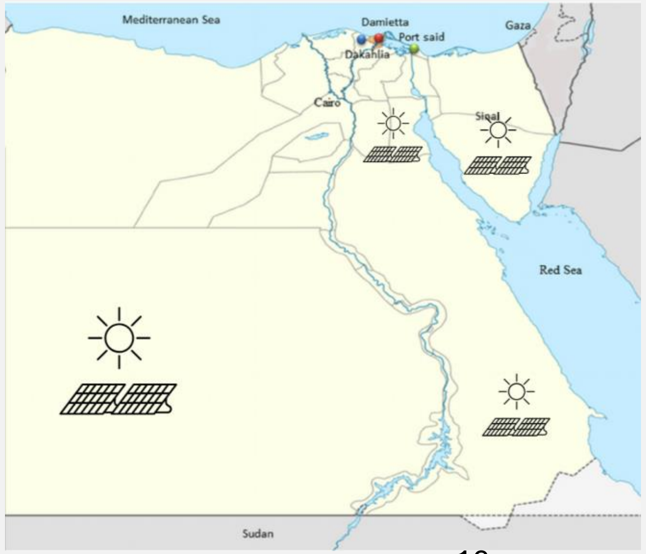
Egypt Map of High Photovoltaic Power Potential



Distribution of Panels in the Plan



The Plan's Solar Power Sites



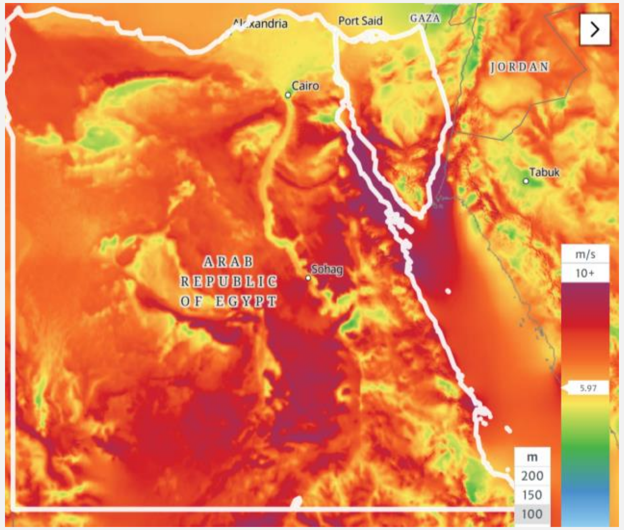
Wind Power

4. Wind Power:

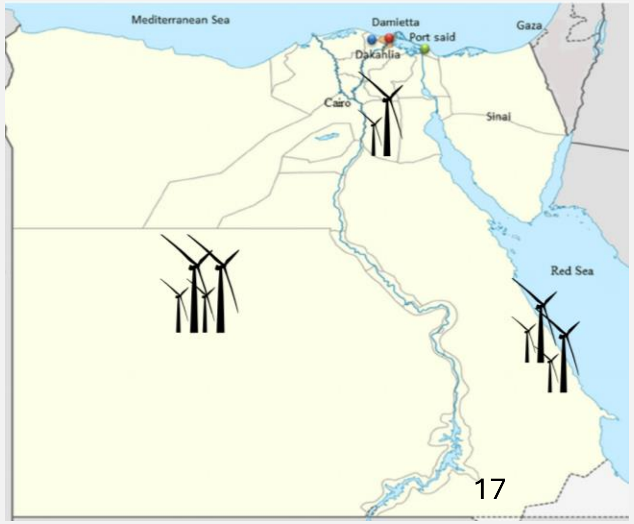
The plan is divided into three main parts as shown in the chart and explained below:

- **Identify and Prioritize Key Locations:**
  - Current wind atlas shows a mean power density of 663 W/m2 at height of 100 m (Source: Global Wind Atlas)
  - Conduct detailed wind speed assessments using advanced meteorological tools
  - Evaluate environmental and social impacts, especially for areas along migration routes (e.g., Gulf of El Zayt) to ensure minimal disturbance to wildlife
- **Expand Existing Wind Farms:**
  - Expand Gulf of El Zayt and Gabal El Zayt: Increase capacity by 300 MW at these sites using new, larger-capacity turbines
  - Upgrade Existing Infrastructure: Retrofitting existing wind farms with modern, high-capacity turbines, which could increase output by 20-30% without expanding land use
- **Develop New Wind Farms:**
  - Develop three new wind farms in Red Sea Coast, Western Desert and Gulf of Suez.
  - New wind farms with capacity ~ 1 GW

Egypt Wind Atlas



The Plan's Wind Power Sites



Nuclear Power

5. Nuclear Power:

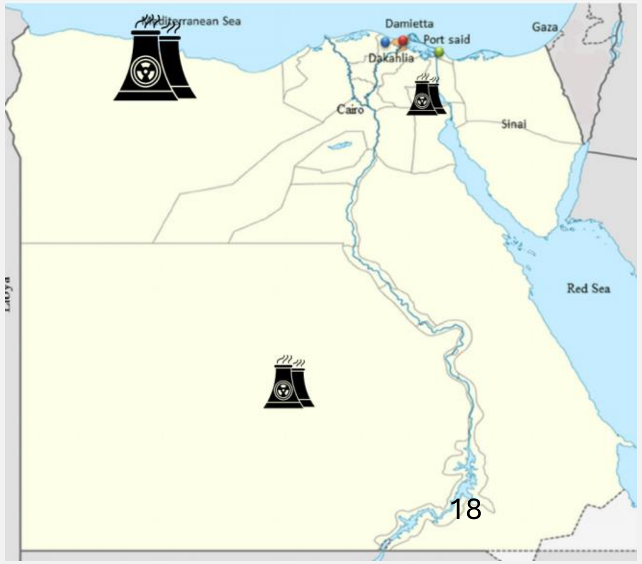
The plan is divided into two main parts explained below:

- **Operationalize El-Dabaa Nuclear Power Plant:**
  - Construction monitoring to keep the project on schedule
  - Strengthen training programs in collaboration between International Atomi Energy Agency (IAEA), Egyptian Atomic Energy Authority and international entities such as Rosatom, NuScale and Rolls-Royce SMR
  - Enhance grid infrastructure around El-Dabaa project to manage the large influx of stable
  - Project Capacity 4.8 GW
  - Add storage batteries near El-Dabaa Power plant to store the excess power
  - Develop a long-term waste management and recycling plan, in addition to licensing and safety protocols
- **Build two small Modular Reactors (SMR):**
  - The two new reactors will be as support in case of failure and to achieve energy stability
  - The total capacity of the two reactors is 600 MW (300 MW each)
  - Locations of the reactors will be one near Suez and the second in upper Egypt zone

El Dabaa Nuclear Power Plant Computer Generated Image

* Korea JoongAng Daily – Image by ASE

The Plan's Nuclear Power Sites



Storage Batteries

6. Storage Batteries:

The plan involves the following:

- **Installing Hybrid-system, which combines lithium-ion and flow batteries**
- This will ensure both fast response (lithium-ion) and longer duration (flow batteries)
- The plan involves three storage locations
- Target capacity minimum of 2 GW with 4 hours storage
- Suggested locations focus will be near renewable farms and urban centers with high energy demand
- Develop recycling and disposal plan giving specifically the projected life-span of lithium-ion batteries
- The objectives of this storage batteries includes:
    - Store excess energy to use when generation is low and in grid failure incidents
    - Provide frequency regulation and voltage control that will stabilize the grid during fluctuations
    - Reduce reliance on natural gas Peaker plants during peak times by supplying stored power during peak hours

Lithium-ion Battery System

* Windpower Engineering & Development

1 MW, 4 MWH Energy Storage in Pullman, Washington

* LNGPrime – Image by KBR

Carbon Storage Hub

7. Carbon Storage Hub:

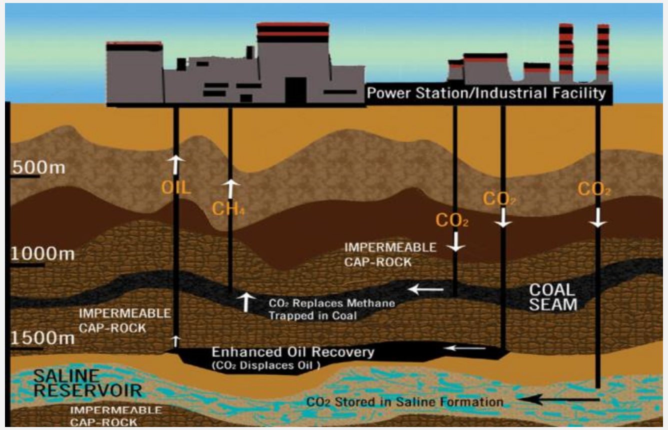
The plan involves the following:

- **Establishing foundational infrastructure for large scale carbon storage sites.**
- Continue with El-Meleiha field pilot and start 3 new pilots to get detailed geological assessment and operational requirements.
- Establish economic policy incentives.
- Create agreements with EU and MENA countries for CO_2 transport to Egypt, offering competitive rates and/or in exchange with services.

Sleipner Carbon Storage Project

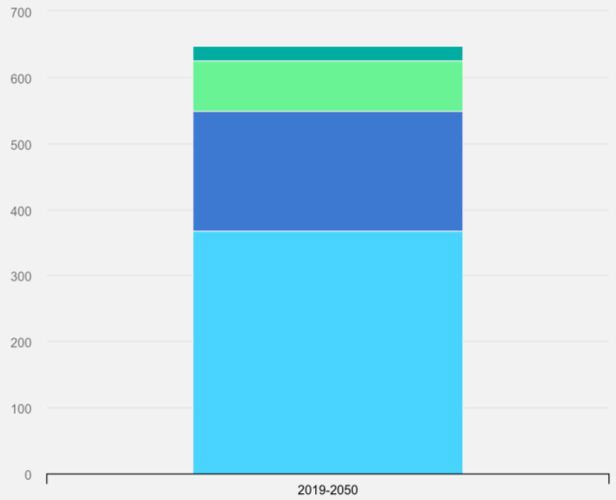
* Equinor

Carbon Capture & Sequestration Flow Chart



* World Resources Institute

Cumulative World Energy Sector CO_2 Emissions Predictions



* IEA CCUS Report 2020

Implementation in Ten-Year Plan: Years 1-2

Years 1-2	Grid Automation	Natural Gas Power Plants	Nuclear Power
Objectives	Essential infrastructure upgrades in high-risk areas and pilot installations	Retrofit Aging Natural Gas Plants	Feasibility and planning
Zone	**All Zones**	**All Zones**	**Zone 1 and Zone 2**
Processes	Install 500-1,000 sensors in critical transmission corridors Install PMUs at 25% of key substations, around 40-50 units Deploy smart meters for 1 million connections in high-demand areas Install initial SCADA systems in Cairo and Alexandria	Replace or retrofit aging gas turbines with newer, more efficient models for 3 single cycle plants in high-risk areas Begin implementing predictive maintenance techniques and carbon capture systems in power plants, especially in large plants near industrial areas Invest in training for plant operators to improve fuel management, reduce waste, and optimize plant performance	Conduct environmental , geotechnical, seismic and infrastructure assessment studies for proposed locations for the new two SMR power plants Choose SMR technology that is suitable for Egypt's needs from proven models such as NuScale (USA), Rolls-Royce SMR (UK) or other internationally certified vendor Develop licensing pathways

Implementation in Ten-Year Plan: Years 1-2

Years 1-2	Solar and Wind Power	Storage Batteries	Carbon Storage Hub
Objectives	Land acquisition, budget allocation and community engagement. Increase capacity of existing wind plants	Site preparation, permitting and technology selection	Establish foundational infrastructure and assess large-scale feasibility
Zone	**Zone 1 , Zone 2 and Zone 4**	**All Zones**	**Zone 1, Zone 3 and Zone 4**
Processes	Obtain land and secure permits for new solar projects in addition to expansion of the existing solar project in Western Desert and new hybrid solar-wind project in Eastern desert in Zone 1. Select site and secure approvals for solar project in South Sinai in Zone 4 Promote rooftop solar adoption, prepare infrastructure and increase public awareness Workforce training regarding rooftop solar power, wind power and solar power plants Increase capacity of Gulf of El Zayt and Gabal El Zayt by 300 MW using larger capacity turbines	Identify target locations near high demand areas and secure environmental and regulatory permits Evaluate hybrid battery options with flow batteries for continuous energy supply and fast response	Continue with the current Meleiha field and add pilot sites in the Nile Delta and Mediterranean industrial zones Acquire detailed data on geological suitability, CO_2 storage potential, and operational requirements.

Implementation in Ten-Year Plan: Years 3-4

Years 3-4	Grid Automation	Natural Gas Power Plants	Nuclear Power
Objectives	Scale up monitoring and control across other critical regions	Retrofit Aging Natural Gas Plants	Design and Engineering
Zone	**All Zones**	**All Zones**	**Zone 1 and Zone 2**
Processes	Expand with an additional 1,000 sensors in transmission and distribution lines Add 50-60 PMUs across more substations Deploy Io T modules for early-stage monitoring devices Increase penetration by adding another 500,000 smart meters	Replace or retrofit aging gas turbines with newer, more efficient models for additional 7 single cycle plants in high-risk areas (total of 10 plants)	Complete the detailed design of the SMR facilities, including reactor buildings, cooling systems, containment structures, and safety systems Coordinate with local manufacturing partners to produce certain components in Egypt, reducing import costs Assess grid requirements and plan necessary upgrades Design cooling system to utilize seawater for Suez site and closed-loop system for Zone 1 site

Implementation in Ten-Year Plan: Years 3-4

Years 3-4	Solar and Wind Power	Storage Batteries	Carbon Storage Hub
Objectives	Upgrade existing wind projects, start new plant and begin physical construction and installations for the new solar projects	Grid integration, construction and start energy storage	Build core infrastructure to facilitate CO_2 capture, transport, and storage; establish policies to attract foreign investment
Zone	**Zone 1 and Zone 2**	**Zone 2**	**Zone 1, Zone 3 and Zone 4**
Processes	Retrofitting existing wind farms with modern and high-capacity turbines Begin land acquisition and construction for new wind farm near Suez in zone 2 Begin construction and installation of initial PV capacity in addition to grid reinforcement in the new solar project in Western Desert and the hybrid solar-wind project in Zone 1 and the South Sinai project in Zone4 Rooftop PV installation, battery setup and net metering	Start installation of battery modules, inverters, and transformers in first site in Zone 2 near Cairo with initial capacity of 700 MW capacity with 2,800 MWh energy storage Test system for reliability and integration with grid	Construct pipelines from major industrial centers and/or plan contract and secure CO_2 transportation Expand onshore facilities and offshore CCS sites in Mediterranean reservoirs Implement carbon credits or a carbon pricing mechanism and create a tax-exempt framework for foreign investments to attract international investment

Implementation in Ten-Year Plan: Years 5-6

Years 5-6	Grid Automation	Natural Gas Power Plants	Nuclear Power
Objectives	Widen the network coverage with energy storage systems to support renewables	Retrofit aging natural gas plants and planning and site selection for the new plants	Construction and proper training of staff
Zone	All Zones	All Zones	Zone 1 and Zone 2
Processes	Install an additional 1,000 sensors Reach 60-70% substation coverage, adding 40-50 units Increase total to 2 million smart meter unit across more cities Deploy additional Io T modules to support data from storage and new monitoring systems	Replace or retrofit aging gas turbines with newer, more efficient models for additional 6 single cycle plants in high-risk areas (total of 16 plants) Identify optimal sites in each zone near high demand and/or renewable site and battery storage sites Select high-efficiency combined cycle gas turbine and finalize contracts with supplier Conduct environmental impact assessment and secure construction permits	Land preparation and establish necessary infrastructure. Construct the reactor containment building, cooling tower, control rooms and administrative building. Manufacture reactor modules and key components off-site to speed up assembly Train engineers, operators and maintenance staff in partnership with SMR vendor for module specialized training

Implementation in Ten-Year Plan: Years 5-6

Years 5-6	Solar and Wind Power	Storage Batteries	Carbon Storage Hub
Objectives	Complete major construction activities for the new solar projects, start Suez solar project and Western Desert Wind plant	Installing second storage site and maintenance for first site	Position Egypt as a profitable carbon storage hub
Zone	**Zone 1 and Zone 2**	**Zone 2 and Zone 3**	**Zone 1, Zone 3 and Zone 4**
Processes	Finalize PV installations and establish full grid connectivity for the new solar project in Western Desert and the hybrid solar-wind project in Eastern desert Zone 1 and the South Sinai project in Zone4 Start wind turbines installation in the hybrid project and Suez wind plant. Secure land for Suez solar plant and continue rooftop PV installation in addition to maintenance setup and system monitoring Land acquisition for the new wind plant in Western Desert Zone 1 Start grid integration for the finalized projects	Start installation of battery modules, inverters, and transformers in second site in Zone 3 near Alexandria with initial capacity of 500 MW capacity with 2,000 MWh energy storage Test system for reliability and integration with grid Preventative maintenance for the first site in Zone 2	Establish additional offshore storage sites in deep-sea reservoirs in the Mediterranean, with potential to store large quantities of CO_2 Initial review of the project integrity and updated potential storage capacities

Implementation in Ten-Year Plan: Years 7-8

Years 7-8	Grid Automation	Natural Gas Power Plants	Nuclear Power
Objectives	Enhance data transmission and power stability with HVDC lines and remaining monitoring systems	Continue retrofitting aging natural gas plants and begin the construction of the new plants	Reactor modular assembly and star operation in El-Dabaa nuclear power plant
Zone	**All Zones**	**All Zones**	**Zone 1, Zone 2, Zone 3**
Processes	Begin installation of 2 HVDC lines Complete coverage with remaining line monitoring sensors Finalize with remaining 30-40 PMUs Add 1 million smart meters to reach 3 million in critical regions	Finalize replacing gas turbines with newer, more efficient models for all single cycle gas plants (total of 20 plants) Begin construction of and transport gas turbine, steam turbines, HRSGs and transformers to plant locations Set-up high voltage transmission lines and begin substations and essential grid infrastructure Conduct regular site inspections and implement rigorous safety standards for construction and operation	Ensure proper training for El-Dabaa plant staff, perform safety inspection and perform initial testing to ensure operational integrity. Then start operation Implement robust physical security measures in El-Dabaa and new plants Transport and install the modules on-site and connect the modular to the cooling system, power lines and control systems Install radiation monitoring systems and establish emergency response plans

Implementation in Ten-Year Plan: Years 7-8

Years 7-8	Solar and Wind Power	Storage Batteries	Carbon Storage Hub
Objectives	Initial testing and initial production for the new solar projects, Construction of Suez solar project and Western Desert Wind plant	Installing third storage site and maintenance for other two sites	Offering services to neighboring countries and industries
Zone	Zone 1 and Zone 2	Zone 1, Zone 2 and Zone 3	Zone 1, Zone 3 and Zone 4
Processes	Initial testing and start operations in solar project in Western Desert and the hybrid solar-wind project in Eastern desert Zone 1 and the South Sinai project in Zone4 Finish wind turbines installation in the hybrid project and Suez wind plant and Initial testing Start PV installation in Suez solar plant and maintenance setup and system monitoring for rooftop solar panels Start wind turbines installation in the new wind plant in Western Desert Zone 1	Start installation of battery modules, inverters, and transformers in the third site in Zone 1 near solar, wind and nuclear power plants location with initial capacity of 800 MW capacity with 3,200 MWh energy storage Test system for reliability and integration with grid Preventative maintenance for the other two sites in Zone 2 and 3	Create agreements with EU and MENA countries for CO_2 transport to Egypt, offering storage services at competitive rate (for example, approximately \$20-30 per ton of CO_2 stored, potentially generating annual revenues of \$500 million-\$1 billion as storage capacity expands) Apply for carbon credit incentives through the UN and other global bodies to fund expansions and innovations and review for current projects

Implementation in Ten-Year Plan: Years 9-10

Years 9-10	**Grid Automation**	**Natural Gas Power Plants**	**Nuclear Power**
Objectives	Complete the deployment with full HVDC coverage and final equipment installations	Final installation, testing, and commissioning of the new natural gas plants and stat operations	Construction and Modular Assembly
Zone	**All Zones**	**All Zones**	**Zone 1, Zone 2, Zone 3**
Processes	Complete remaining 2-3 HVDC lines Install final SCADA Lite units in remaining regions Deploy final Io T modules for comprehensive system coverage Complete the deployment with full HVDC coverage and final equipment installations	Complete the installation of all turbines and equipment and ensure that plants are fully connected to the national grid Conduct testing on plant system to ensure efficiency standards (>60%) and capacity output goals are met Gradually bring plants online, allowing for seamless integration with the existing grid Ensure proper training for engineers, operators and maintenance staff Conduct post-construction review	El-Dabaa plant is fully operational Initial testing for the new two SMR plants (both cold and hot testing) to verify performance and safety Integrate with national grid and gradually ramp up power production to full capacity Monitor performance and safety measures For all three plants schedule routine inspections and long-term waste management plans

Implementation in Ten-Year Plan: Years 9-10

Years 9-10	Solar and Wind Power	Storage Batteries	Carbon Storage Hub
Objectives	Maintenance, review and finalizing all solar and wind projects	Preventative maintenance and post construction review	Maximize storage capacity and establish Egypt as a primary carbon storage provider in Africa and the Mediterranean
Zone	**Zone 1 and Zone 2**	**All Zones**	**Zone 1, Zone 3 and Zone 4**
Processes	Solar project in Western Desert and the hybrid solar-wind project in Eastern desert Zone 1 and the South Sinai project in Zone 4 are fully function and connected to the grids Suez wind plant is fully operational and Suez solar plant initial testing and start operation Initial review of wind and solar projects Preventive maintenance for solar, wind projects and government rooftop panels Maintenance programs for residential rooftop solar panels	Post construction review for all storage sites Preventative maintenance for all three storage sites Monitor system integration with the grid and failure prevention	Implement state-of-the-art monitoring for CO_2 containment and security Explore digital innovations like AI-based monitoring to reduce operational costs and enhance safety Aim, plan and execute an ultimate storage capacity of 20-30 million tons per year, like major CCS hubs in the North Sea.

Implementation in Ten-Year Plan

Financial Discussion

(World-Energy, 2023)
(International Renewable Energy Agency [IRENA], 2023)
(World Nuclear News, 2023)
(Energy Storage News, 2023)

Financial Plan

Total Budget: $32.4 billion

Government Bonds & Loans:

- **50% ($16.2 billion)**

50% is allocated to bonds because they provide long-term, stable financing with relatively low interest. This allows Egypt to fund massive infrastructure projects without losing control, especially since green bonds have proven attractive to investors.

International Grants & Partnerships:

- **30% ($9.72 billion)**

30% through grants and partnerships to reduce debt reliance while benefiting from international climate commitments, where developed nations like Germany provide funding for renewable energy in exchange for carbon credits.

Private Investments & Public-Private Partnerships:

- **20% ($6.48 billion)**

20% PI&PPP as Egypt engages private sector capital for innovation and efficiency in energy projects, while keeping essential infrastructure under public control. This model is supported by successful frameworks like the GCF-EBRD Renewable Energy Financing.

Cost of Grid Automation

Component	Quantity	Cost Range (USD)
Line Monitoring Sensors	3,000 - 5,000	$900,000 - $2,500,000
Phasor Measurement Units	150 - 175	$3,000,000 - $5,250,000
Smart Meters	3 - 4.5 million	$150,000,000 - $450,000,000
IoT Communication Modules	3 - 5 million	$30,000,000 - $100,000,000
SCADA Lite Systems	5 - 6	$2,500,000 - $6,000,000
Energy Storage Systems	15 - 20	$15,000,000 - $60,000,000
HVDC Transmission Lines	4 - 5	$1,200,000,000 - $2,500,000,000

Total Cost Estimate:

$1.4 billion - $3.1 billion

Cost of Energy Resources: Renewables

Solar Energy			
Location	**Project Size**	**Estimated Cost ($M)**	**Potential Output**
Western Desert	1 GW	$600 - $800	2 million households
Eastern Desert (Red Sea)	500 MW (Hybrid)	$400 - $550	750,000 households
South Sinai	250 MW	$150 - $200	500,000 households
Upper Egypt (Luxor, Qena)	500 MW	$300 - $400	1 million households
New Administrative Capital	100 MW (Rooftop)	$80 - $100	Local urban buildings

Total Estimated Cost: $1.53 billion – $2.05 billion

Wind Energy	
Project / Initiative	**Estimated Cost (USD)**
Expansion of Existing Wind Sites	$500 million
New Wind Farms (1.5 GW)	$1.5 billion
Workforce Development and Local Incentives	$100 million

Total Estimated Cost: $2.1 billion

Cost of Energy Resources: Non-Renewables

Nuclear Power		
Phase	**Cost per Facility**	**Total Cost for Two Facilities (USD)**
Feasibility and Planning	$50M - $100M	$100M - $200M
Design and Engineering	$100M - $150M	$200M - $300M
Construction and Assembly	$1.5B - $1.8B	$3B - $3.6B
Testing and Commissioning	$200M - $300M	$400M - $600M
Operations (Annual)	$20M - $30M	$40M - $60M (ongoing)

Total Estimated Cost: $4 billion - $4.8 billion

Natural Gas Power Plants		
Option	**Cost per 300 MW Plant**	**Total Cost for 20 Plants (300 MW each)**
Conversion	$250M - $450M	$5B - $9B
Two New 2 GW Power Plant	$1.6 billion to $3 billion	$3.2 billion to $6 billion

Total Estimated Cost: $8.2 billion - $15 billion

Cost of Energy Storage

Phase	Capacity (MW)	Duration (hours)	Energy (MWh)	Estimated Cost	Details
Phase 1 (Years 1-3)	500 MW	4 hours	2,000 MWh	$300M - $500M	Install near Benban Solar Park and Gulf of Suez wind farms.
Phase 2 (Years 4-6)	700 MW	4 hours	2,800 MWh	$400M - $600M	Expand storage near major urban centers (e.g., Cairo, Alexandria).
Phase 3 (Years 7-10)	800 MW	4 hours	3,200 MWh	$500M - $700M	Scale up near renewable sites and add distributed storage.

Total Estimated Cost for 2 GW (8 GWh): $1.2 billion - $1.8 billion

Cost and Revenue of Carbon Storage

Phase	Cost (USD)
Phase 1: Pilot and Feasibility Studies	40-50 million
Phase 1: Geological and Environmental Assessments	20 million
Phase 2: Develop CCUS Infrastructure	500-800 million
Phase 2: Establish Economic Policies and Incentives	10-15 million
Phase 2: Public-Private Partnerships and Funding	100 million
Phase 3: Expand CCS Capacity and Storage Sites	1-1.5 billion
Phase 3: Regional Agreements and Incentives	50 million
Phase 4: Optimize Storage and Monitoring	200 million
Phase 4: Scale for High Volume Storage	2-3 billion
Phase 4: Establish a Carbon Storage Economic Zone	50 million

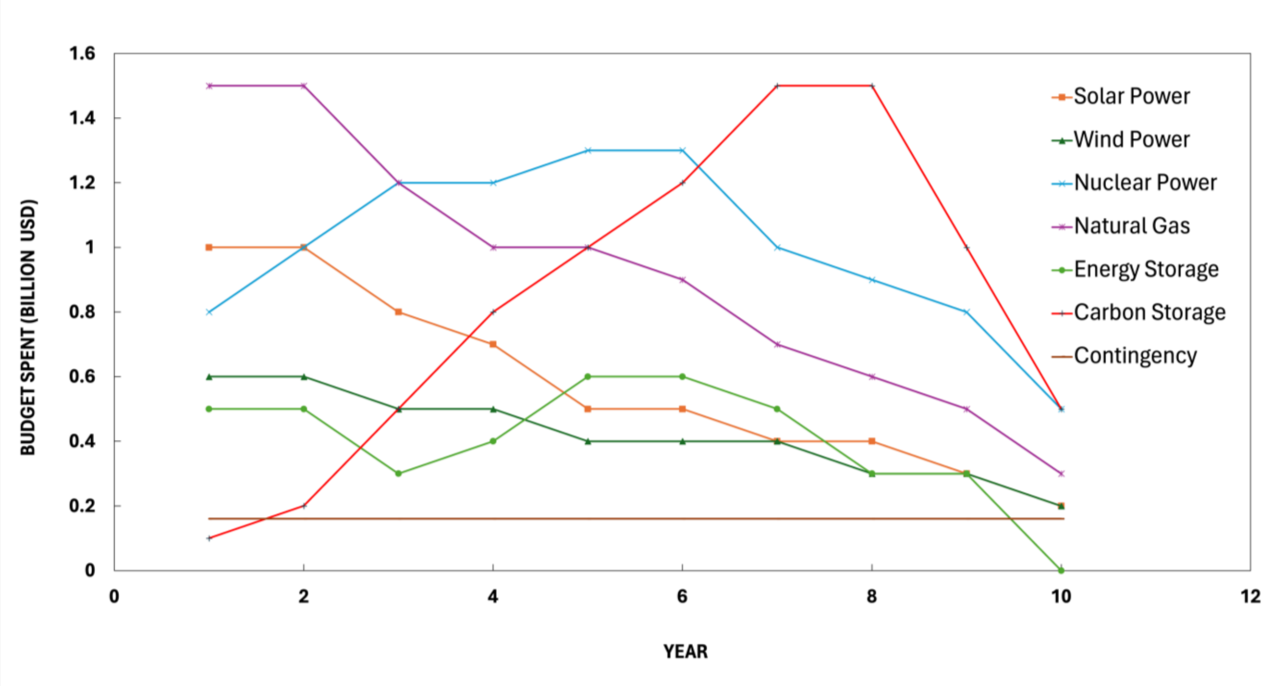
Total Estimated Costs:

$4-6 billion (over 10+ years)

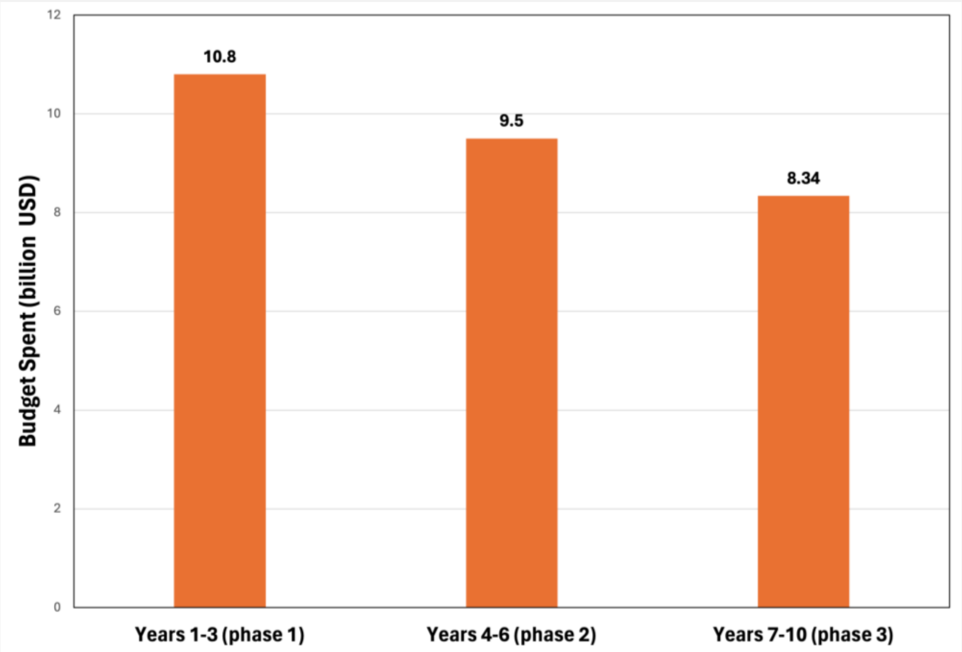
Projected Revenue
Short-Term: Modest income from regional partnerships and pilot services. **Long-Term:** $500 million-$1 billion annually through international storage services, carbon credits, and storage fees.

Spending Timeline

10-year spending timeline



Total Spending per Phase



Total spending overall (using average of range values): $28.64 billion => Contingency fund of: $3.76 billion (11.6%)

Summary of Financials

- **Total Budget: ($32.4 billion)**
  - **Grid Automation:**
    - $1.4 - $3.1 billion
  - **Renewables:**
    - Solar Power: $1.53 - $2.05 billion
    - Wind Power: $2.1 billion
  - **Non-Renewables:**
    - Nuclear Power: $4 - $4.8 billion
    - Natural Gas: $8.2 - $15 billion
  - **Energy Storage:**
    - $1.2 - $1.8 billion
  - **Carbon Storage:**
    - $4 - $6 billion

Impact and Carbon Footprint Analysis

Environmental Impact Analysis

➢ **Land:**

- **Desert Utilization:** Solar and wind projects utilize Egypt’s deserts, reducing the impact on arable land.
- **Land Conservation:** This approach preserves fertile land for agriculture, supporting food security and biodiversity.
- **Ecosystem Protection:** Minimal disruption in designated areas helps maintain local ecosystems, reducing habitat loss.

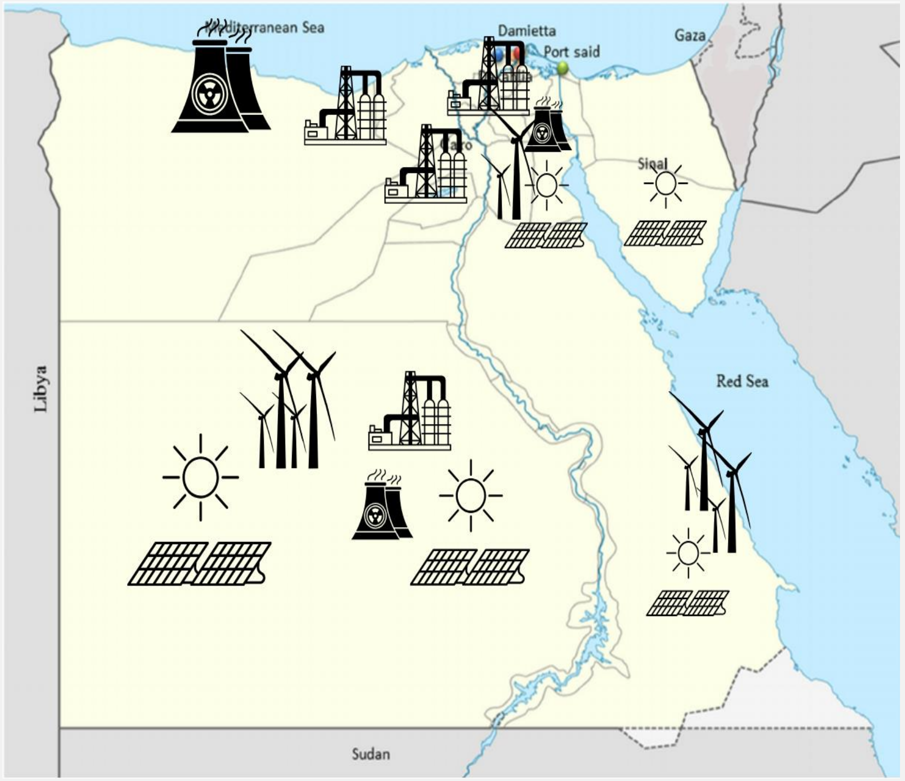
➢ **Water:**

- **Significantly Lower Water Usage:** Renewable energy requires **80% less** water than fossil fuels, essential for Egypt’s water-scarce regions.
- **Resource Conservation:** Less water demand eases pressure on vital freshwater resources like the Nile.
- **Sustainable Operation:** Reduced reliance on water supports steady energy generation, even during droughts or low water availability.

➢ **Atmosphere:**

- **Lower Emissions:** Nuclear and renewable projects reduce greenhouse gas emissions, improving air quality and public health.
- **Carbon Storage Initiative:** Egypt’s CCS projects enable CO_2 sequestration, establishing it as a regional leader in climate mitigation.
- **Climate Change Resilience:** Reduced fossil fuel reliance aligns with Vision 2030 goals for a resilient, low-carbon economy.

Egypt's Renewable Energy Sites based on the Ten-Year Plan



Social Impact Analysis

➢ Job Creation:

- **50,000 Jobs**: Solar, wind, and nuclear projects will generate 50,000 new jobs.
- **Focus on Underdeveloped Regions**: Jobs will prioritize areas with high unemployment, boosting local economies.
- **Employment Sectors**:

Construction: Building energy infrastructure.
Operations & Maintenance: Long-term management of facilities.
Logistics & Support: Supporting supply chain and transportation needs.

➢ Quality of Life:

- **Healthier Living Conditions**: Access to clean energy reduces reliance on fossil fuels, leading to better air quality and reducing respiratory issues.
- **Cleaner Cooking Alternatives**: Increased renewable energy access provides safer, cleaner options for cooking, improving indoor air quality and reducing health risks.
- **Air Pollution Reduction**: Renewable projects reduce emissions, leading to lower air pollution levels and enhancing overall community health.

➢ Rural Electrification:

- **Energy Accessibility for All**: Goal of achieving **100% electricity reliability** in rural areas, positively impacting **57% of Egypt's population**.
- **Support for Rural Development**: Reliable electricity enables improvements in healthcare, education, and agricultural productivity in rural areas.
- **Community Empowerment**: Rural electrification fosters social and economic growth, empowering residents with better access to technology and resources.

Financial Impact Analysis

➢ **GDP Growth:**

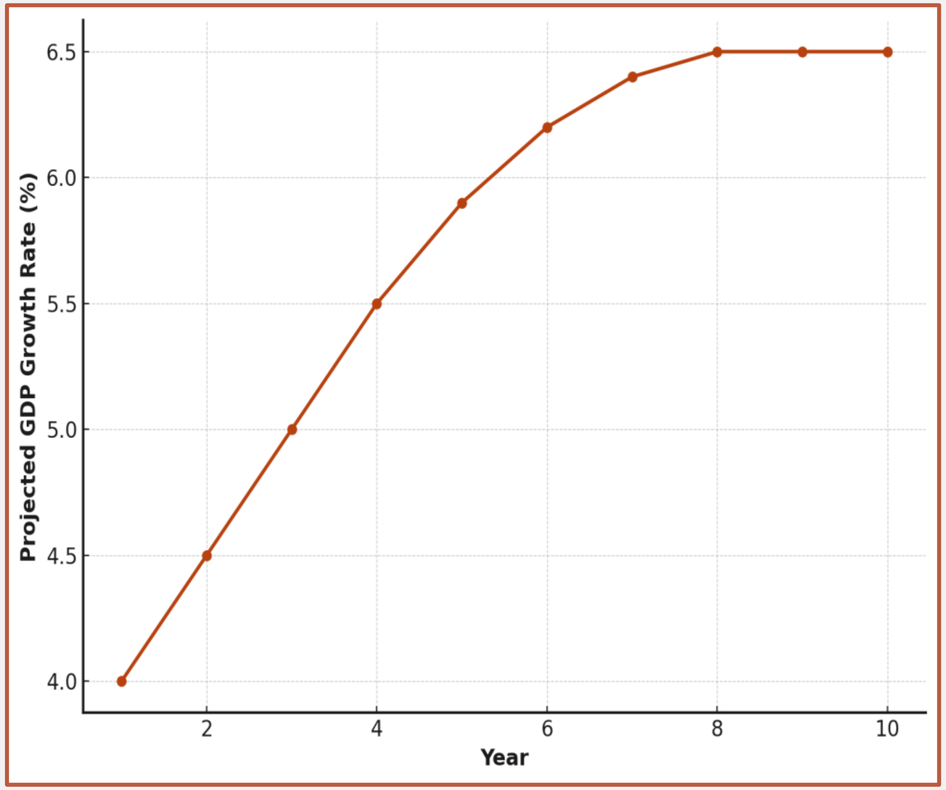
- **Annual Contribution:** Expansion of the energy sector, including **renewables and LNG**, is projected to add **3% to Egypt's GD**P annually.
- **Economic Diversification:** Developing renewable energy reduces reliance on traditional industries, promoting a more balanced economy.
- **Long-Term Growth**: Sustained investment in energy infrastructure supports consistent GDP growth over the next decade.

➢ **Trade & Exports:**

- **Regional Energy Hub:** Egypt’s position as an LNG export leader strengthens its trade balance and enhances its status in the global energy market.
- **Reduced Import Dependency:** Increased domestic production in renewables reduces energy import needs, boosting Egypt’s trade balance.
- **Export Revenue Growth:** Renewable and LNG exports contribute to foreign exchange earnings, benefiting the national economy.

➢ **Economic Stability:**

- **Cost Reduction**: Domestic energy production cuts down import costs, providing stability against global energy price volatility.
- **Energy Export & Import Balance**: Maintaining an export surplus of **20-30 GW** stabilizes energy availability and economic resilience.
- **Shock Resistance**: Reducing dependency on imports shields Egypt from external market fluctuations, strengthening economic stability.



Based on Egypt's 2030 Vision Strategy released by the UNDP, the GDP growth is projected to be 5 – 6% annual growth rate

Political Impact Analysis

- **International Partnership:**

  Strategic Agreements: Collaborations with various countries secure advanced technology for Egypt's energy transition.

  Key Partnerships:

  - **EU & Egypt MoU**: Agreement for renewable hydrogen and clean energy support.
  - **COP28 Green Energy Projects**: Three major green energy initiatives for fuel, ammonia, and solar energy.
  - **Egypt-Denmark**: Renewable energy cooperation focusing on sustainable tech exchange.
  - **Egypt-Greece**: Natural gas and energy transport collaboration.
  - **Egypt-Turkey**: Joint efforts in natural gas and nuclear energy development.

- **Global Influence:**
  - **Carbon Storage Leadership**: Egypt's carbon capture initiatives enhance its position in climate talks, increasing diplomatic influence.
  - **Regional Exporter**: Egypt exports electricity to neighboring countries, including Sudan, Jordan, and Libya, reinforcing its role in regional energy security.
  - **Climate Commitments**: Active participation in carbon reduction and renewable energy aligns with international climate goals, boosting Egypt's global reputation.

- **Policy Alignment:**
  - **Compliance with Climate Standards**: Egypt's policies align with agreements like the Paris Climate Accord and COP28 commitments, establishing it as a reliable partner in climate action.
  - **Investment Attraction**: Policies like the Renewable Energy Law (2014) and Feed-in Tariff Program attract foreign investments, particularly in solar and wind energy projects.
  - **Technology Exchange**: Examples include partnerships with Siemens for wind turbine technology and Orascomfor solar development, which advance Egypt's clean energy capabilities and infrastructure.

Carbon Footprint Analysis

1) Natural Gas:

Natural Gas Power Plant Summary

- Expand Existing Plants:
  - Capacity: 6,000 MW (6 GW)
  - Annual Output: 10,512,000 MWh/year
  - CO_2 Emissions: 500 g CO_2/kWh
  - Total Emissions: 5,256,000 metric tons of CO_2/year
- Build New Plants:
  - Capacity: 8,000 MW (8 GW)
  - Annual Output: 14,016,000 MWh/year
  - CO_2 Emissions: 500 g CO_2/kWh
  - Total Emissions: 7,008,000 metric tons of CO_2/year

2) Solar Power:

- Utility-Scale Solar PV with Battery Storage:
  - Mean Lifecycle Emissions: 123.8 g CO_2 eq/kWh
  - Annual Emissions for 4 Solar Farms: ~1.95 million metric tons of CO_2 per year
  - Key Emission Contributors: Battery manufacturing (54%) and PV panel production/assembly (53% of energy use).

- (*WNN | What Is Capacity Factor and How Do Solar and Wind Energy Compare?*, n.d.)
- (*How Wind Can Help Us Breathe Easier*, n.d.)

Carbon Footprint Analysis

3) Wind Power:

- Expand Existing Farms:
  - Capacity: 300 MW
  - Annual Output: 919,800 MWh/year
  - CO_2 Emissions: 11 g CO_2/kWh
  - Total Emissions: 10,117.8 metric tons of CO_2/year

- Upgrade Existing Infrastructure:
  - Additional Capacity: 60-90 MW (20-30% increase)
  - Annual Output Increase: 183,960 - 275,940 MWh/year
  - CO_2 Emissions: 11 g CO_2/kWh
  - Total Additional Emissions: 2,023.6 - 3,035.3 metric tons of CO_2/year

- Develop New Farms:
  - Capacity: 1,000 MW
  - Annual Output: 3,066,000 MWh/year
  - CO_2 Emissions: 11 g CO_2/kWh
  - Total Emissions: 33,726 metric tons of CO_2/year

- (*WNN | What Is Capacity Factor and How Do Solar and Wind Energy Compare?*, n.d.)
- (*How Wind Can Help Us Breathe Easier*, n.d.)

Carbon Footprint Analysis

4) Nuclear Power:

- El-Dabaa Nuclear Power Plant
  - **Total Capacity:** 4,800 MW (4.8 GW)
  - **Annual Output:** 37,804,800 MWh/year
  - **Lifecycle CO_2 Emissions:** 6.1 g CO_2/kWh
  - **Total Annual Emissions:** 230,609.3 metric tons of CO_2/year

- Small Modular Reactors (SMRs)
  - **Total Capacity:** 600 MW (300 MW each)
  - **Annual Output:** 4,730,400 MWh/year
  - **Lifecycle CO_2 Emissions:** 6.1 g CO_2/kWh
  - **Total Annual Emissions:** 28,855.4 metric tons of CO_2/year

5) Carbon Capture and Storage Capacity in Hubs:

- Estimated Carbon Reduction from El-Meliha Project Initiatives:
  - Large-Scale Carbon Storage Sites: 25,000 - 30,000 tons of CO_2 reduction per year

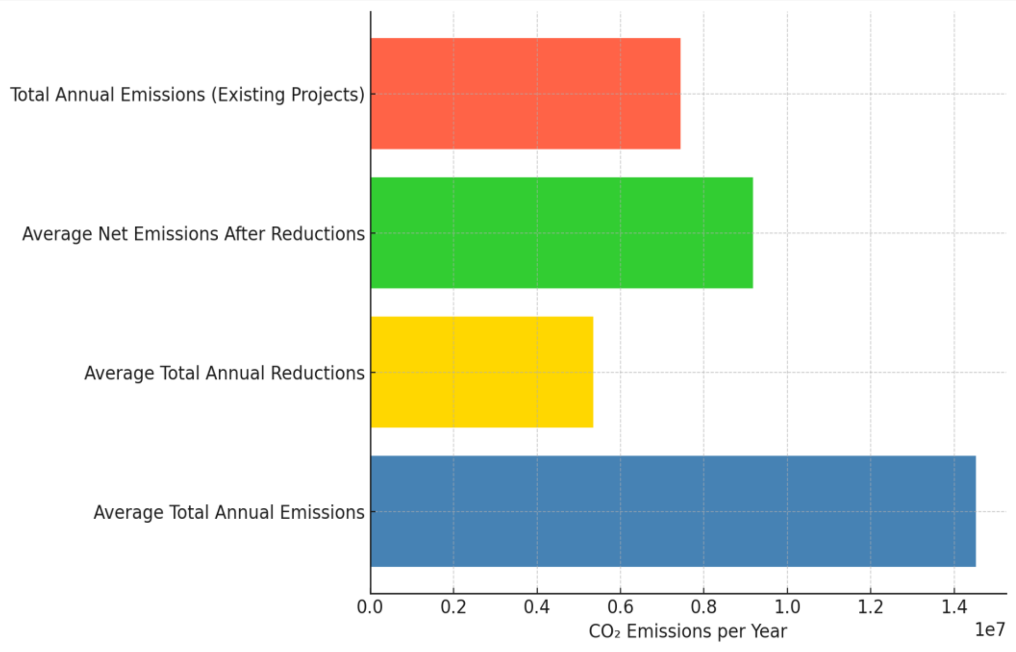
  These capacities and reductions will also be applied to the 3 new pilots.

- Estimated Carbon Reduction from Total Initiatives:
  - Large-Scale Carbon Storage Sites: 100,000 - 120,000 tons of CO_2 reduction per year

- Gibon and Menacho (2023)
- *What Is Generation Capacity?*

Carbon Footprint Analysis

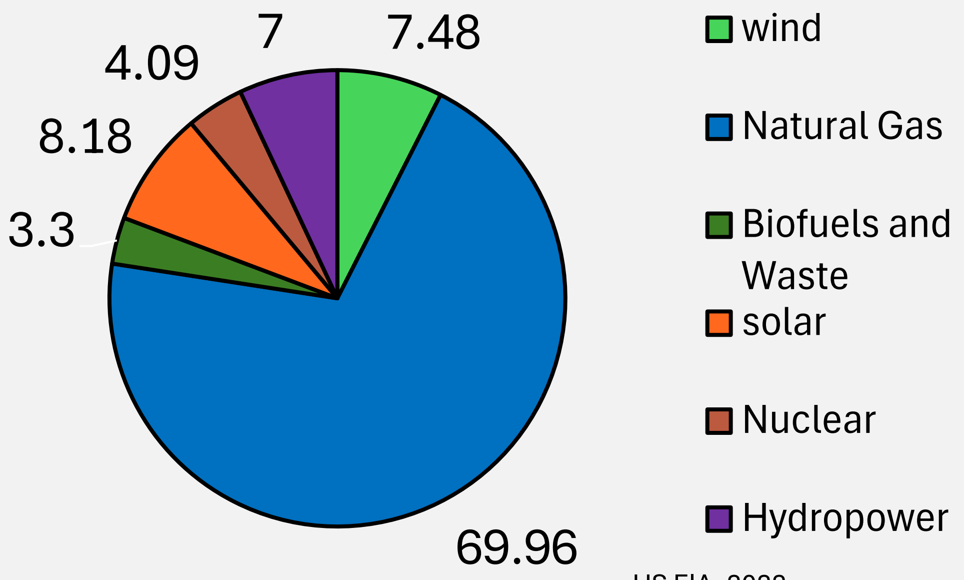
- **Total Annual Emissions (Solar, Wind, Nuclear, and Natural Gas):**
  - Minimum Scenario: 14,519,332.1 metric tons of CO_2/year
  - Maximum Scenario: 14,520,343.8 metric tons of CO_2/year
- **Total Annual Reductions:**
  - Minimum Scenario: 5,332,000 metric tons of CO_2/year
  - Maximum Scenario: 5,352,000 metric tons of CO_2/year
- **Net Emissions After Reductions:**
  - Minimum Scenario: **9,187,332.1 metric tons of CO_2/year**
    - After Normalization (118.48 GW): **77,543.3 metric tons of CO_2 per GW per year**
  - Maximum Scenario: **9,168,343.8 metric tons of CO_2/year**
    - After Normalization (118.48 GW): **77,383.1 metric tons of CO_2 per GW per year**
- **Total Annual Emissions (Existing Projects Only, 60 GW Total Capacity):**
  - Existing Projects: 7,446,727.1 metric tons of CO_2 per year
    - After Normalization (60 GW): **124,112.118 metric tons of CO_2 per GW per year**



Total Carbon Emissions vs Net Emissions after Reductions

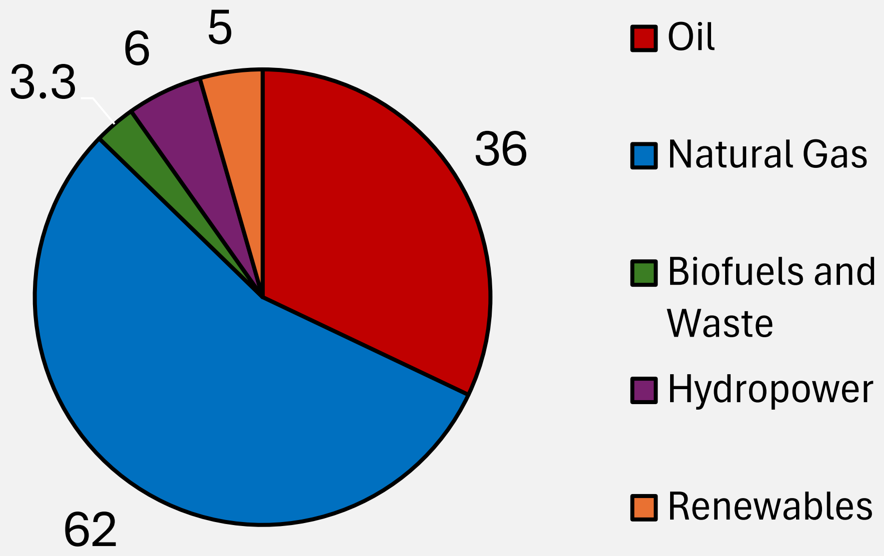
Energy Mix Analysis

Egypt's Energy Mix Updated to the Plan



US EIA, 2022

Egypt's Current Energy Production (%)



Feasibility of Transferring the Solution to Türkiye

Assessing the Success of Egypt's Energy Plan in Turkey

- **Potential for Success:**
  - Turkey’s growing interest in renewables (especially wind and solar) aligns with the objectives of Egypt’s plan.
  - Turkey has a wind energy potential estimated at 48GW, particularly in the Aegean and Marmara regions, which complements Egypt's solar-heavy strategy.

Wind Energy Produce Areas in Turkey

- **Challenges:**
  - **Geographic Differences:** Egypt’s high solar irradiance supports large solar farms, while Turkey’s northern regions may have less favorable solar conditions .
  - **Economic Stability:** Turkey’s recent inflation rates of **over 20%** could pose financial challenges for renewable investments, making it harder to secure long-term funding compared to Egypt.

Assessing the Potential of Egypt's Energy Plan to Turkiye

Advantages

1. **Energy Mix:** Turkey relies heavily on coal and gas, with renewables only about 15% of its energy mix. Integrating renewables and other domestic production sources will reduce emissions, increase independence and address Türkiye's high import dependency.
2. **Economic Viability:** Introducing cost-effective renewable technologies can reduce import reliance, lower costs, and provide price stability.
3. **Social Impacts:** Transitioning to renewables would mitigate Türkiye's environmental footprint as it ranks among the top 20 global emitters.

Energy Poverty Factors Addressed:

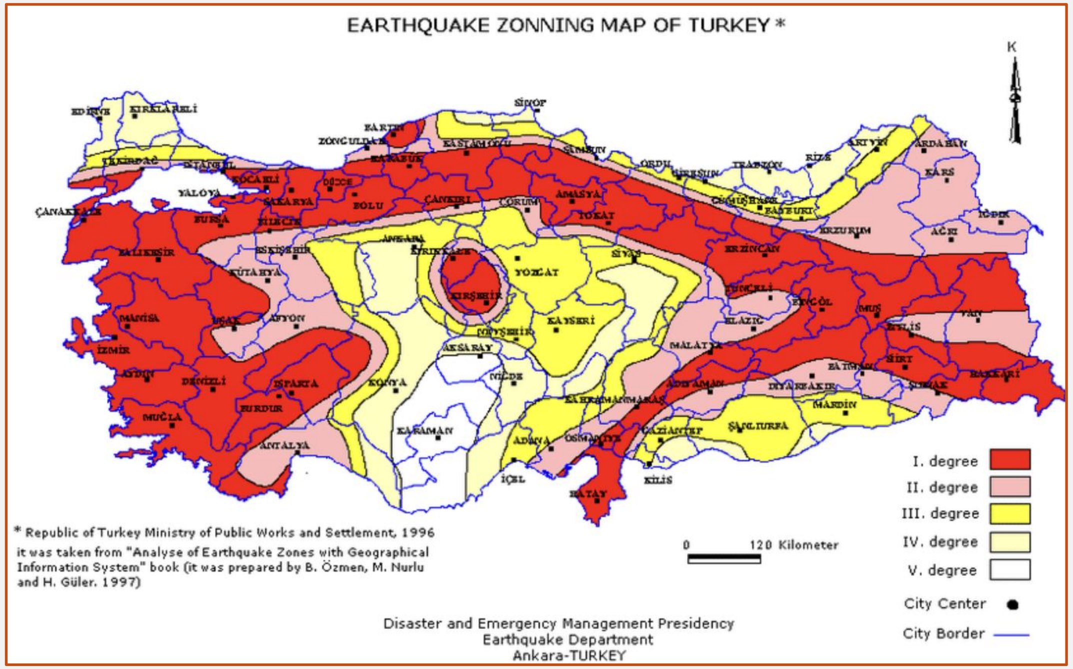
- **Security and Reliability**: With the plan implemented, Türkiye will become less reliant on imported fossil fuels, which makes it less susceptible to the volatility of the energy market (Stability).
- **Affordability**: Increasing the energy mix lower Turkey's energy costs by reducing reliance on expensive fuel imports, providing stable, affordable energy.
- **Environmental Impact:** Expanding the energy mix cuts emissions, improves air quality, and supports Turkey's climate goals for a cleaner environment.

In sum, with targeted adjustments and a tailored approach, implementing a modified 10-year plan in Turkey is feasible.

Challenges in Adapting Egypt’s Solutions for Turkey

Risks

1. **Regulatory Environment:** Turkey's regulatory framework impacts renewable projects and causes delays – this furthermore affects investment stability, and might be costly on the country itself.
2. **Infrastructure Resilience:** Türkiye faces risks from seismic activities, which disrupt energy infrastructure. Transition plans that require wide, flat, arid land might only be feasible in limited parts of the country. In addition, the instability caused by seismic activity can be a larger risk for certain energy sources like nuclear.
3. **Social Stigma:** Public concerns over the safety, environmental impact, and historical accidents (like Chernobyl) with nuclear energy causes a delay in implementing nuclear energy.



Earthquake Zoning Map of Turkiye

Finding a Global Pathway to Combat Energy Poverty

No Single Solution

Addressing energy poverty requires tailored approaches. Egypt, with solar potential of 73 GW, and Turkey, with 48 GW of wind potential, each must leverage their respective strengths.

Hybrid Approach

Integrating renewable sources with energy storage could support both countries’ needs. For instance, Egypt's goal to achieve 42% renewable energy by 2035 and Turkey's aim for 50% by 2030 underline the need for an adaptable, hybrid approach.

Localized Solutions

Egypt’s high solar potential and Turkey’s abundant wind resources highlight the importance of regional strengths. Adapting each country’s energy mix to local resources can more effectively address energy poverty and reduce dependency on fossil fuels.

Executive Summary

Problem Overview	• Energy infrastructure is outdated in Egypt and Türkiye. • Power supply in rural areas of both countries is unreliable, especially during peak demand. • Rising electricity costs and environmental challenges due to high fossil fuel usage.
Grid Enhancement Solution	• Smart grid upgrades, including the installation of sensors, phasor measurement units (PMUs), and millions of smart meters to improve real-time data monitoring and reduce outages. • Expansion of solar energy, including four new solar farms with a capacity of 9 GW and rooftop solar panels for residential and industrial use. • Wind energy expansion through the development of new wind farms and upgrading existing ones to boost capacity and efficiency.
Ten Year Solution	• Solar power projects aim to supply up to 9 GW of renewable energy, reducing Egypt's reliance on fossil fuels and ensuring energy availability during peak demand. • Wind energy projects will increase capacity through new developments and upgrades to existing infrastructure, contributing to the energy mix. • Nuclear power expansion, including the operationalization of the El-Dabaa nuclear plant, and storage batteries for energy stability during grid fluctuations.
Financing	• The total project budget is projected at $32.4 billion, with 50% funded through green bonds, 30% through grants and international partnerships, and 20% through private and public investments. • The financing plan is designed to ensure long-term sustainability with minimal debt burden.
Impact	• Solar and wind energy projects will provide clean energy to millions of homes, with the goal of achieving 100% electricity reliability in rural areas by 2030. • The combined efforts will reduce carbon emissions by up to 5 million tons annually.

Thank you

to the Switch Energy Alliance, the judges, and our mentor Judy Roper!

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Appendix

1) Natural Gas:

- New Natural Gas Plants
- Number of New Plants: 4
- Capacity per Plant: 2,000 MW (2 GW)
- Total Capacity: 8,000 MW (8 GW)
- Annual Output:8 GW×0.20×8,760 hours/year=14,016,000 MWh/year
- CO_2 Emissions per kWh: 500 g CO_2
- Total Annual Emissions:

14,016,000 MWh/year×1,000 kWh/MWh×500 g CO_2/kWh=7,008,000,000,000 g CO_2/year

- Converting to metric tons:

=7,008,000 metric tons of CO_2/year

Existing Natural Gas Plants in Egypt

- Number of Plants: 20
- Average Capacity per Plant: 300 MW
- Total Capacity: 6,000 MW (6 GW)
- Annual Output:6 GW×0.20×8,760 hours/year=10,512,000 MWh/year
- CO_2 Emissions per kWh: 500 g CO_2
- Total Annual Emissions:

10,512,000 MWh/year×1,000 kWh/MWh×500 g CO_2/kWh=5,256,000,000,000 g CO_2/year

- Converting to metric tons:

= 5,256,000 metric tons of CO_2/year

Appendix

2) Solar Power:

- Project Specifications (Using Mean Emissions)
  - Total Solar Farm Capacity: 4 solar farms, each at 2.25 GW
    - Total Capacity: 4×2.25 GW=9 GW4×2.25GW=9GW
  - Capacity Factor: 20%
    - Typical for utility-scale solar installations considering solar availability and efficiency.
  - Annual Hours: 8,760 hours per year
  - Mean Emissions Value: 123.8 g CO_2 eq/kWh

1.Calculate Annual Energy Production

Using the total capacity of 9 GW and a 20% capacity factor:

Annual Energy Production=9 GW×0.20×8,760 hours/year   Annual Energy Production=15,768,000MWh/year

2. Calculate Total Annual Carbon Emissions

Using the mean emissions value of 123.8 g CO_2 eq/kWh:

Total Annual Emissions=15,768,000MWh/year×1,000kWh/MWh×123.8g CO_2 eq/kWh

Total Annual Emissions=1,951,118,400,000 g CO_2 eq/year

Converting to metric tons:

Total Annual Emissions=1,951,118,400,000/1,000,000=1,951,118.4 metric tons of CO_2 eq per year

Appendix

3) Wind Power:

Expand Existing Wind Farms (300 MW Additional Capacity)

- Calculate Annual Energy Production:

Capacity Factor for Onshore Wind: Onshore wind typically has a capacity factor of 35%.

- Annual Energy Output:

Energy (MWh)=Capacity (MW)×Capacity Factor×Hours per Year

Energy=300 MW×0.35×8,760 hours/year=919,800 MWh/year

- Calculate Annual Carbon Emissions:

Lifecycle CO_2 Emissions for Wind Energy: 11 g CO_2 per kWh.

Total CO_2 Emissions (g)=Energy (kWh)×CO_2 Emissions per kWh

Total CO_2 Emissions=919,800,000kWh/year×11g CO_2/kWh=10,117,800,000g CO_2/year

- Convert to Metric Tons:
- Total CO_2 Emissions (metric tons)=10,117,800,0001,000,000=10,117.8 metric tons of CO_2/year

Appendix

Expand Existing Wind Farms (300 MW Additional Capacity)

Upgrade Existing Infrastructure (20-30% Increase in Output)

- Calculate Additional Annual Energy Output (20-30% Increase):

  Existing Capacity: 300 MW

  Additional Capacity: 20-30% increase yields 60-90 MW extra.

  Additional Energy (MWh)=Increased Capacity (MW)×Capacity Factor×Hours per Year

  Additional Energy=(60−90) MW×0.35×8,760 hours/year=183,960−275,940 MWh/year

- Calculate Additional CO_2 Emissions:

Total CO_2 Emissions (g)=Additional Energy (kWh)×CO_2 Emissions per kWh

Total CO_2 Emissions=(183,960,000−275,940,000) kWh/year×11 g CO_2/kWh =2,023,560,000−3,035,340,000 g CO_2/year

- Convert to Metric Tons:

Total CO_2 Emissions (metric tons)=(2,023,560,000−3,035,340,000)/1,000,000=2,023.6−3,035.3 metric tons of CO_2/year

Appendix

Expand Existing Wind Farms (300 MW Additional Capacity):

Develop New Wind Farms (1 GW Total Capacity)

- Calculate Annual Energy Production for 1 GW:

Energy (MWh)=1,000 MW×0.35×8,760 hours/year=3,066,000 MWh/year

- Calculate Annual CO_2 Emissions:

Total CO_2 Emissions (g)=3,066,000,000 kWh/year×11 g CO_2/kWh=33,726,000,000 g CO_2/year

- Convert to Metric Tons:

Total CO_2 Emissions (metric tons)=33,726,000,0001,000,000=33,726 metric tons of CO_2/year

Appendix

4) Nuclear Power:

- Calculate Annual Energy Production:

Capacity Factor for Nuclear: Nuclear reactors generally have a high capacity factor, around 90%.

Total Capacity: 600 MW (300 MW each)

Annual Energy Output for 600 MW:

Energy (MWh)=Capacity (MW)×Capacity Factor×Hours per Year

Energy=600 MW×0.90×8,760 hours/year=4,730,400 MWh/year

- Calculate Annual Carbon Emissions:

Lifecycle CO_2 Emissions for Nuclear Power: 6.1 g CO_2 per kWh.

Total CO_2 Emissions (g)=Energy (kWh)×CO_2 Emissions per kWh

Total CO_2 Emissions=4,730,400,000 kWh/year×6.1 g CO_2/kWh=28,855,440,000 g CO_2/year

- Convert to Metric Tons:

Total CO_2 Emissions (metric tons)=28,855,440,000/1,000,000=28,855.4 metric tons of CO_2 per year

Appendix

4) Nuclear Power:

- Existing Project: El-Dabaa Nuclear Power Plant
    - Total Capacity: 4,800 MW (4.8 GW)
    - Capacity Factor: 90% (typical for nuclear reactors)
    - Annual Energy Production:

  Energy=Capacity×Capacity Factor×Hours per Year

  =4,800 MW×0.90×8,760 hours/year=37,804,800 MWh/year

  Calculate Annual Carbon Emissions for El-Dabaa

    - Lifecycle CO_2 Emissions for Nuclear: 6.1 g CO_2 per kWh
    - Total CO_2 Emissions (g):

  =Energy (kWh)×CO_2 Emissions per kWh

  = 37,804,800,000 kWh/year×6.1 g CO_2/kWh=230,609,280,000 g CO_2/year

  Convert to Metric Tons:Total CO_2 Emissions=230,609,280,000/1,000,000=230,609.3 metric tons of CO_2/year

Appendix

4) Nuclear Power:

- Build Two Small Modular Reactors (SMRs)
    - Total Capacity of SMRs: 600 MW (300 MW each)
    - Capacity Factor: 90%
    - Annual Energy Production:

    Energy=600 MW×0.90×8,760 hours/year=4,730,400 MWh/year

    Calculate Annual Carbon Emissions for SMRs

    - Lifecycle CO_2 Emissions for Nuclear: 6.1 g CO_2 per kWh
    - Total CO_2 Emissions (g):

    =4,730,400,000 kWh/year×6.1 g CO_2/kWh=28,855,440,000 g CO_2/year

    Convert to Metric Tons:=28,855,440,000/1,000,000=28,855.4 metric tons of CO_2/year

Appendix

4) Carbon Storage Capacity in Hubs:

- CO_2 reduction for four pilot projects:

Biofuel Production Plant: 1.2 million tons/year×4=4.8 million tons of CO_2 reduction per year

Plastic-to-Oil Plant: 63,000 tons/year×4=252,000 tons of CO_2 reduction per year

Biodegradable Plastic Plant: 45,000 tons/year×4=180,000 tons of CO_2 reduction per year

Large-Scale Carbon Storage Sites: 25,000−30,000 tons/year×4=100,000−120,000 tons of CO_2 reduction per year

Total Emissions Summary (Including Natural Gas, Solar, Wind, and Nuclear)
Total Emissions (Min)=1,950,000+45,867.4+259,464.7+12,264,000=14,519,332.1 metric tons CO_2/year
Total Emissions (Max)=1,950,000+46,879.1+259,464.7+12,264,000=14,520,343.8 metric tons CO_2/year

Total Emissions Before New Projects

Now, let's add up the emissions from the existing projects only:
Total Emissions=5,256,000+1,950,000+10,117.8+230,609.3=7,446,727.1 metric tons of CO_2/year