SWITCH ENERGY ALLIANCE

The University of Texas at Austin
Hildebrand Department of Petroleum and Geosystems Engineering
Cockrell School of Engineering

SEMPRA

GHANA

Switch Energy Case Competition

TEAM – URJA VRIDDHI

भारतीय प्रौद्योगिकी संस्थान
(भारतीय खनि विद्यापीठ), धनबाद
धनबाद -८२६००४, झारखण्ड, भारत
INDIAN INSTITUTE OF TECHNOLOGY
(INDIAN SCHOOL OF MINES), DHANBAD
DHANBAD - 826004, JHARKHAND, INDIA

Mentor- Andreas Matzakos

Ajay Kumar

Ranjan Kumar

Bhautik Agrawal

Raj Kumar

SWITCH ENERGY ALLIANCE

Case Study Outline

01

Overview of Ghana

A. Demographics
B. Trends of Ghanaian Power sector
C. Present Energy Mix
D. Energy Distribution

02

Challenges to Current Energy Mix

A. Understanding Dumsor
B. Overdependence on Hydropower
C. Unstable and weak Economy
D. Unskilled Local people
E. Impact of Covid-19

03

Solution: Ghana Energy Revolution 2050

A. Energy opportunities
B. Economic analysis
C. Impact on People of Ghana
D. Conclusion

SWITCH ENERGY ALLIANCE

Overview of Ghana

OVERVIEW OF GHANA

1 Demographics

2 Trends of Ghanaian Power Sector

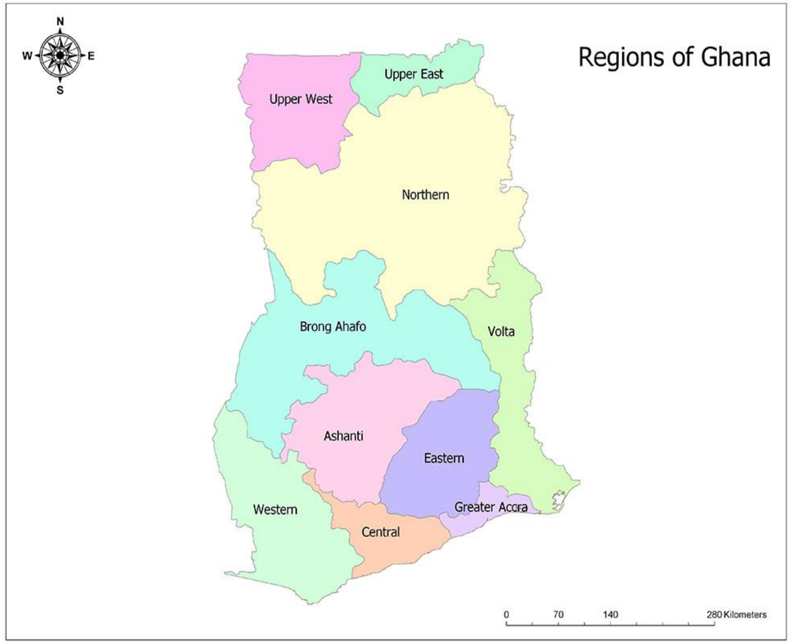
3 Present Energy Mix

4 Energy Distribution

Overview of Ghana

1. **Demographics** | 2. Trends of Ghanaian Power Sector | 3.Present Energy Mix | 4. Energy Distribution

Source: Natural History on Net



Source: Mappr.co

GDP per capita : $2445.29

Language : English(Official), Akan(Mostly Spoken)

Area : 238,530 km^2

Population : 31,732,128

Sex Ratio : 102.81 Males/100 Females

Currency : Ghanaian Cedi

Source: Statistics Times

SWITCH
ENERGY ALLIANCE

Overview of Ghana

1. Demographics | **2. Trends of Ghanaian Power Sector** | 3.Present Energy Mix | 4. Energy Distribution

1957

Ghana gets Independence

The Impetus to industrialization was embarked leading to the building of Dams, Roads and Factories for strengthening the power sector.

1961

Establishment of Volta River Authority

Under VRA the construction of Akosombo Dam was started

1972

Generating Unit added to Akosombo unit

3521.23 GWh of electricity generation capacity was added to meet the growing energy demands.

1978-1984

Economic Crisis

The domestic power consumption declined from 3529GWH in 1978 to 1151 GWH in 1984

1998

Energy Crisis

Caused due to low rainfall and decreased inflow to the Volta lake

2007

Oil Discovery

3 Billion bbl of oil reserves discovered

Source: energysustainsoc.com

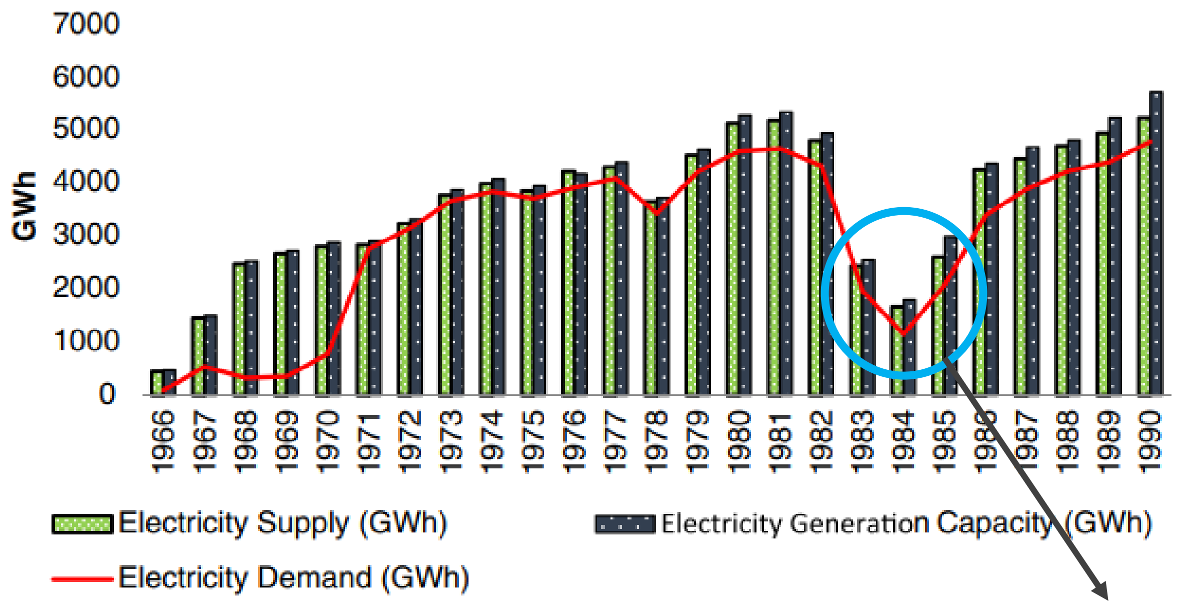
SWITCH ENERGY ALLIANCE

Overview of Ghana

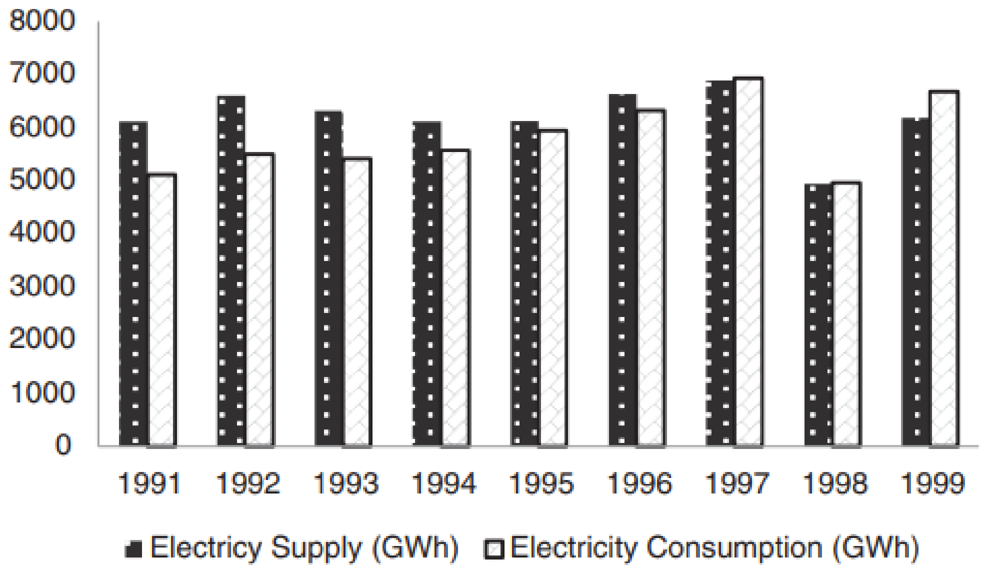
1. Demographics | **2. Trends of Ghanaian Power Sector** | 3.Present Energy Mix | 4. Energy Distribution

Trends in Electricity Sector: 20th Century

Trends in Electricity Demand, Supply and Generation Potential from 1996-1990



Trends in Electricity Supply and Consumption from 1996-1990



- Economic and Energy crisis due to a major drought in the Akosombo dam
- The inflow into the dam was less than 15% of the expected total.

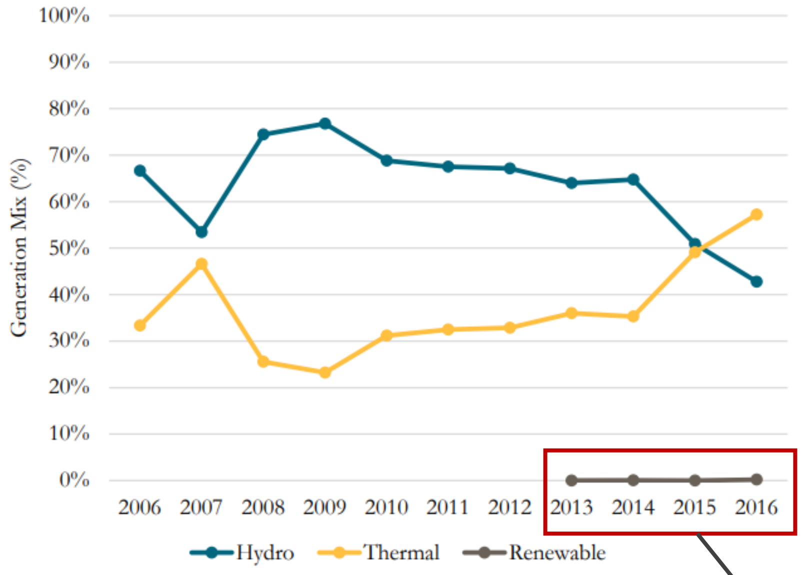
Source: Data from VRA Annual Report

Overview of Ghana

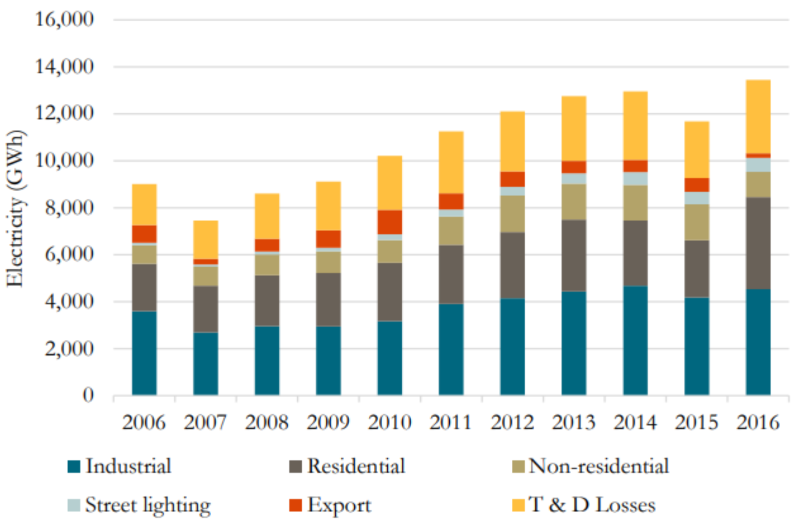
1. Demographics | **2. Trends of Ghanaian Power Sector** | 3.Present Energy Mix | 4. Energy Distribution

Trends in Electricity Generation: 21st Century

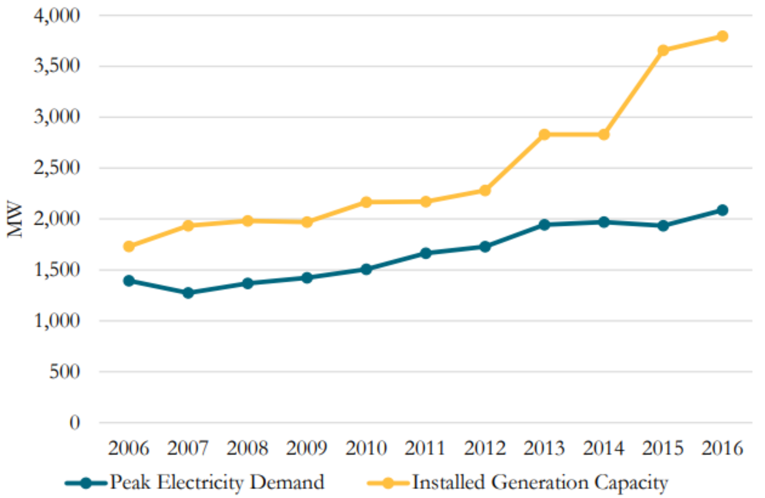
Historic Electricity generation mix



Electricity consumption pattern for Ghana



Peak electricity demand versus installed generation capacity



There is a huge potential in Ghana with respect to Renewables to contribute in Electricity generation

Source: Energy Commission of Ghana, 2016a,2017; VRA 2015

Overview of Ghana

1. Demographics
2. Trends of Ghanaian Power Sector
3.Present Energy Mix
4. Energy Distribution

GENERATION CAPACITY

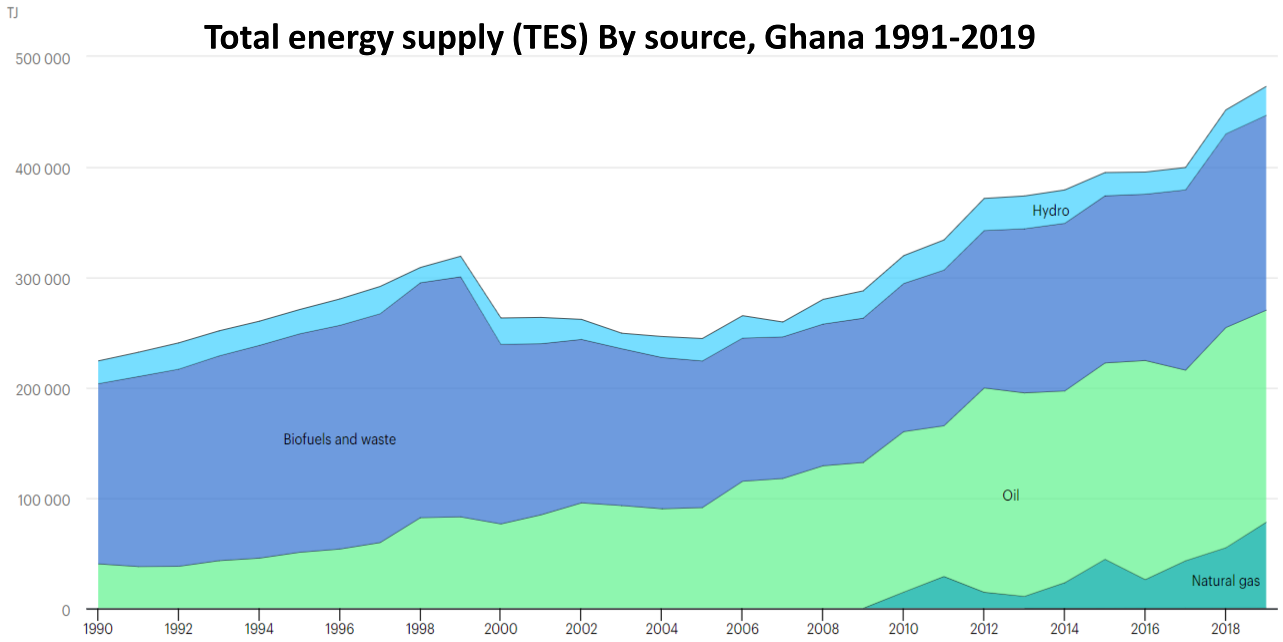
- Total Installed Capacity (2): 5,326 MW
  - Hydro: 1,580 MW
  - Natural Gas, other: 2,070 MW
  - Liquid Gas: 69 MW
  - Solar: 63 MW
  - Bio: 6.4 MW
  - Diesel: 335 MW
  - Crude Oil: 700 MW
  - HFO: 400 MW

Power Africa new MW to date at financial close: 550 MW

CONNECTIONS

- Current Access Rate (3): 84%
  - Urban: 93%
  - Rural: 73%
- Power Africa new connections: 170,619

Total energy supply (TES) By source, Ghana 1991-2019



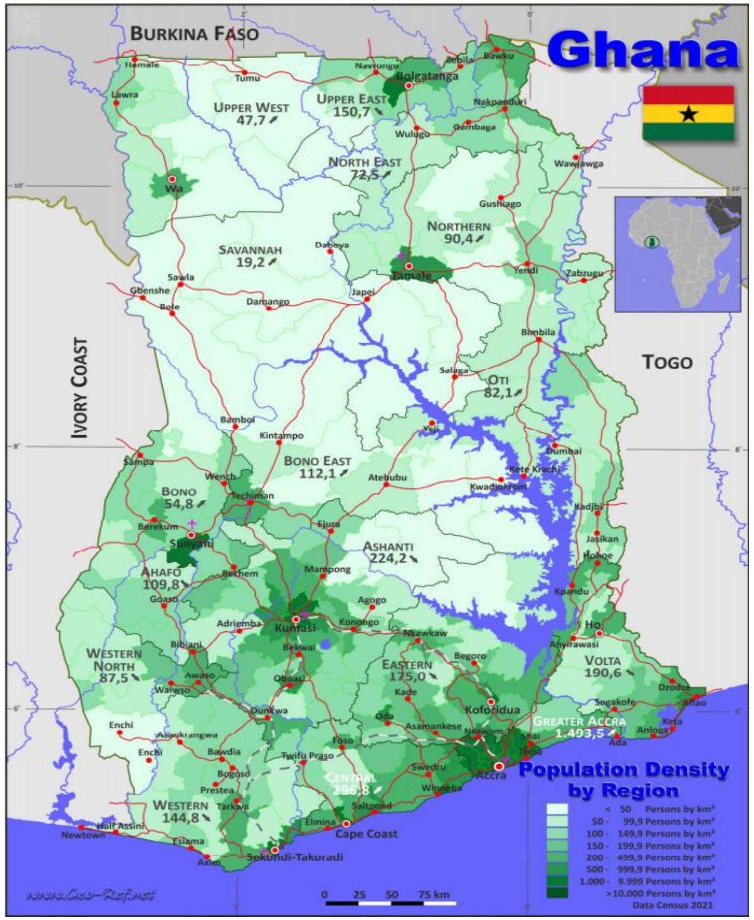
Source: usaid.gov;iea.org

SWITCH ENERGY ALLIANCE

Overview of Ghana

1. Demographics | 2. Trends of Ghanaian Power Sector | 3.Present Energy Mix | **4. Energy Distribution**

Population density by Region



Transmission Grid Map

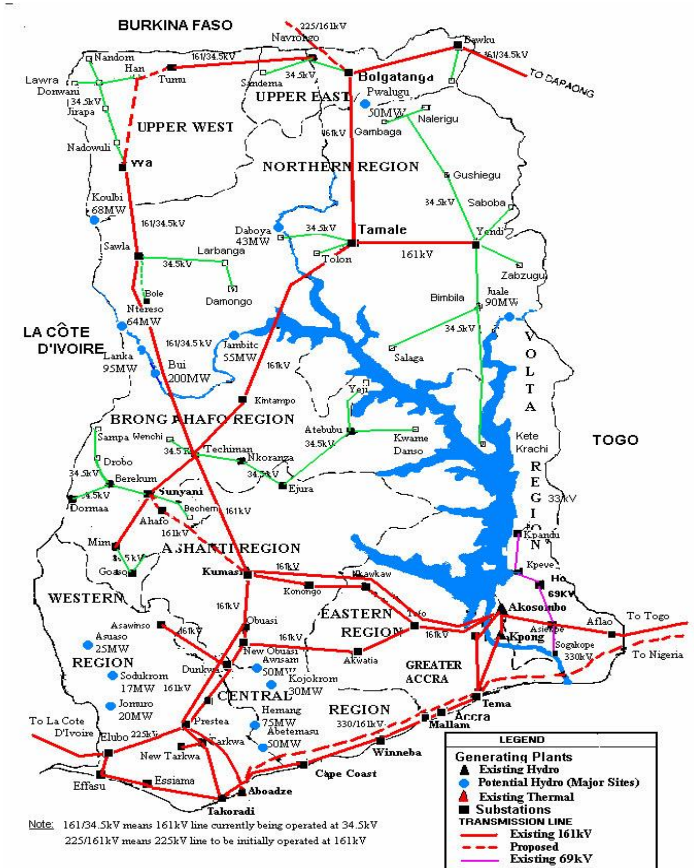


Figure 1: Map of Ghana showing Transmission Grid

KEY POINTERS:

- Establishment of more substations across country to account for the transmission losses
- Energy opportunities in the Northern Ghana should be explored
- Major energy generation in the southern part only

Source: geo-ref.net; ECG

SWITCH ENERGY ALLIANCE

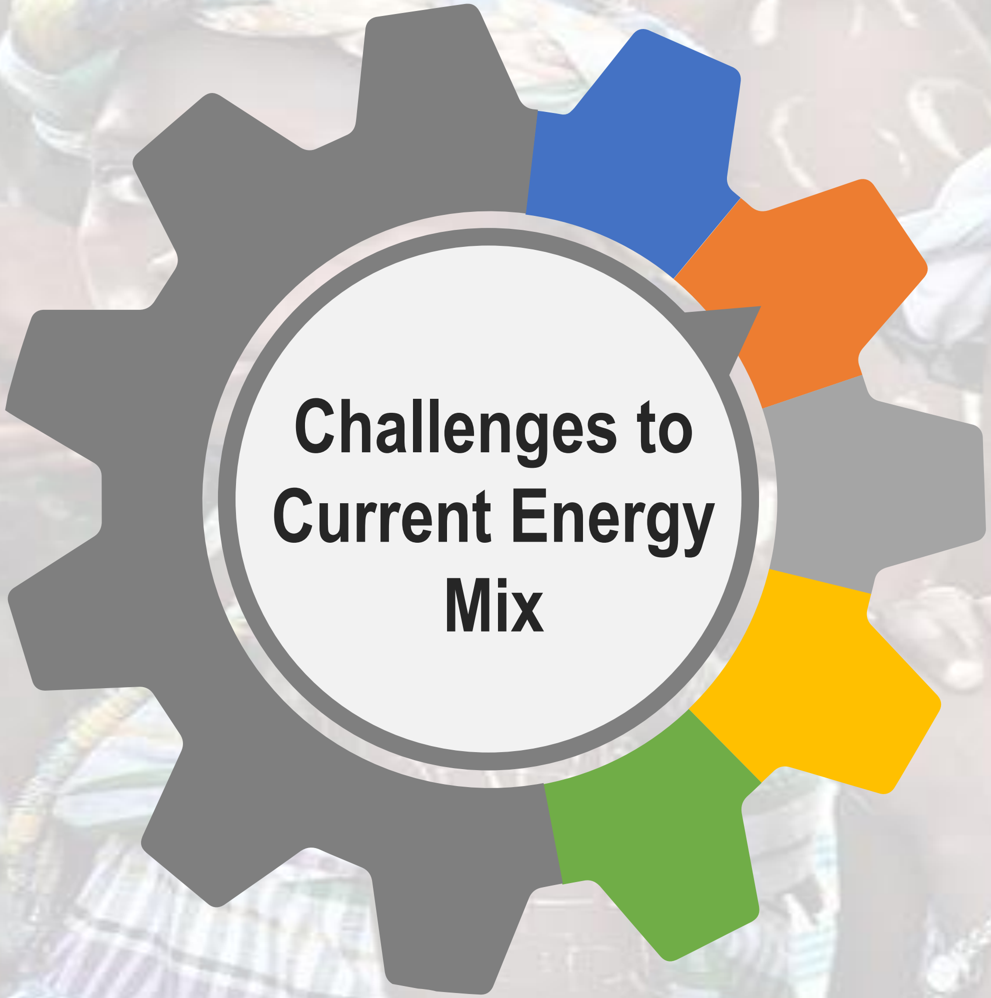
Problem Statement

Dependency on biomass fuels leading to huge air pollution. Expensive power and high poverty levels leading to energy insufficiency

Scarcity of financial capitals for the alternative cleaner & economically feasible energy resources such as wind and solar

Lack of technical skills and knowledge in the domestic population to develop and utilize these resources

Challenges to current Energy Mix



1. Understanding Dumsor
2. Overdependence on Hydropower
3. Unstable and Weak Economy
4. Unskilled Local people
5. Impact of Covid-19

Challenges to current Energy Mix

1. **Understanding Dumsor**
2. Overdependence on Hydropower
3. Unstable and weak economy
4. Unskilled local people
5. Impact of Covid-19

Dumsor: Root Cause Analysis

Frequent nationwide power outages and load shedding are indicative of the supply-demand mismatch

The overloaded transformer sub-stations, transmission and distribution losses, and transmission bottlenecks are contributory factors to the frequent power outages

At the beginning of 2015, the Dumsor schedule went from 24 hours with light and 12 without to 12 hours with light and 24 without.

Transmission losses account for 3.9 %. While the distribution and commercial losses by the Electricity Company of Ghana account for as much as 16.2 % of the gross electricity supply

Dumsor can also be accounted taking into the consideration the Ghanaian generating capacity which was 400-600 megawatts, less than what Ghana needed in 2015

Source: Jamie Senoy Lighting Africa

Source: Energy Commission of Ghana,2016a, 2017

SWITCH ENERGY ALLIANCE

Challenges to current Energy Mix

1. Understanding Dumsor | 2. Overdependence on Hydropower | 3.Unstable and weak economy | 4. Unskilled local people | 5.Impact of Covid-19

CAUSES OF Dumsor

- Poor Credit Risk of ECG
- Gas and fuel Supply Challenges
- Distorted Tariff Regime
- Poor Infrastructure Planning
- Low water level at Akosombo and Bui

IMPACT OF 'DUMSOR' ON THE ECONOMY

ECONOMY OF GHANA

ECONOMIC GROWTH

The decrease in economic growth from **7.3 %** in 2013 to **4.2%** in 2014 is broadly attributed the energy supply deficit.

COST OF DOING BUSINESS

Inadequate and unreliable power supply increases cost of doing business. A lot of SMESare forced to use expensive alternatives such as buying diesel and petrol

LOST OF JOBS

In order to manage redundancy, companies are laying off workers

HOW TO STOP 'DUMSOR'

SHORT TERM MEASURES

Ongoing maintenance and upgrade at the thermal plants should be completed immediately

Imcomplete works, financial and other problems impeding atuabo gas project should be resolved urgently

ECG must collect payment of bills from big customers

Power barges and emergency generators which were brought during 2007 should be refurbished and used to augment power supply.

Energy conservation and demand side load management: everybody must be actively involved in conserving energy

MEDIUM TERM MEASURES

Construction of new gas pipelines to connect offshore fields to onshore gas processing plants.

Government has to settle its indebtedness to ECG to enable the company. The distorted tarrif regime has to be revised.

Government has to settle its indebtedness to ECG to enable the company. The distorted tarrif regime has to be revised.

Source: codeforghana.org

Challenges to current Energy Mix

1. Understanding Dumsor | **2. Overdependence on Hydropower** | 3.Unstable and weak economy | 4. Unskilled local people | 5.Impact of Covid-19

History of origin of Hydropower

Developed under the "Hydro-Dam Scheme" initiated under Colonial regime that primarily enhanced the reliable power supply to the countries Aluminium industries.

Lack of Energy Diversification

Akosombo powered Ghana's most energy demand and this continued overdependence on one source is an insecurity to the country. Continued energy demand led to construction of Bui and Kpong dam which again was a hydropower source.

Uneven Energy Distribution

Energy sources are not equally distributed across the country and a major part is lost into transmission to northern part

1965 – Construction of Akosombo Dam

1982 – Construction of Kpong dam to aid power supply

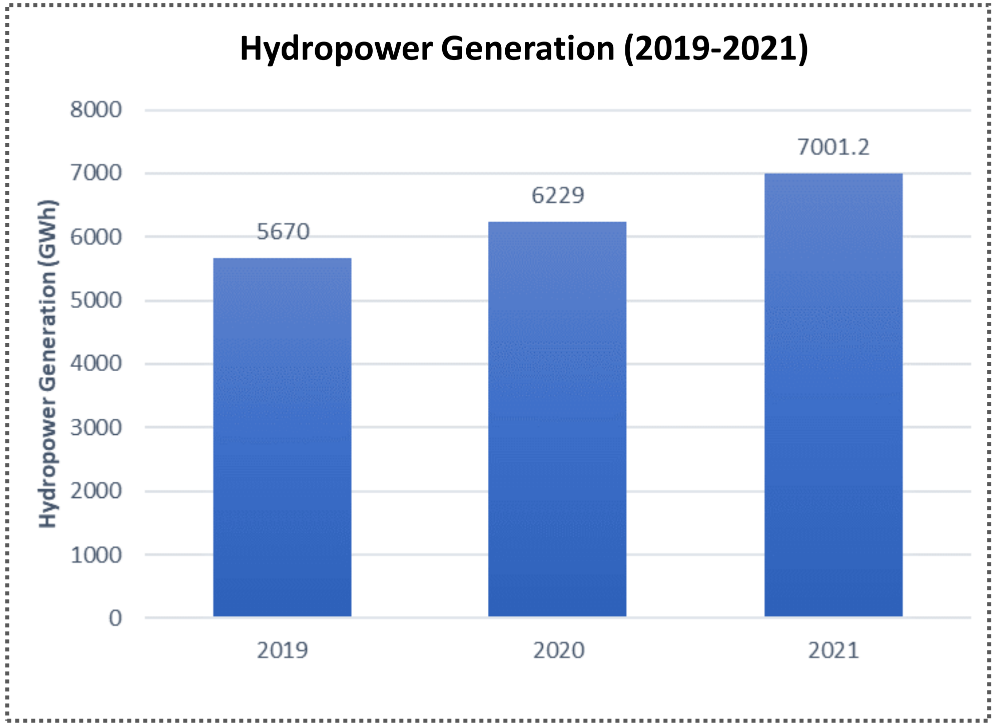
2013 – Bui Dam built to account for increased energy demand

Challenges to current Energy Mix

1. Understanding Dumsor
2. Overdependence on Hydropower
3.Unstable and weak economy
4. Unskilled local people
5.Impact of Covid-19

Hydropower Dominance & Shortfall

1. Akosombo, Kpong and Bui Dams powering major energy Demands of Ghana
2. Incapability of Hydropower to supply electricity due to poor rainfall. At the end of 2011, Ghana's electricity generation mix stood at 67% hydro sources against 33% thermal.
3. Customers were provided with an average of 12.5 hours of electricity every three days. Ghana experienced about 159 days of blackout in 2014 alone.
4. Ghana lost about 1.8% of its gross domestic product due to the 2007-2008 power crisis.
5. Total grid electricity generation in 2018 was 14,069 GWh of which 4,991 GWh (39.2 %) was from hydropower

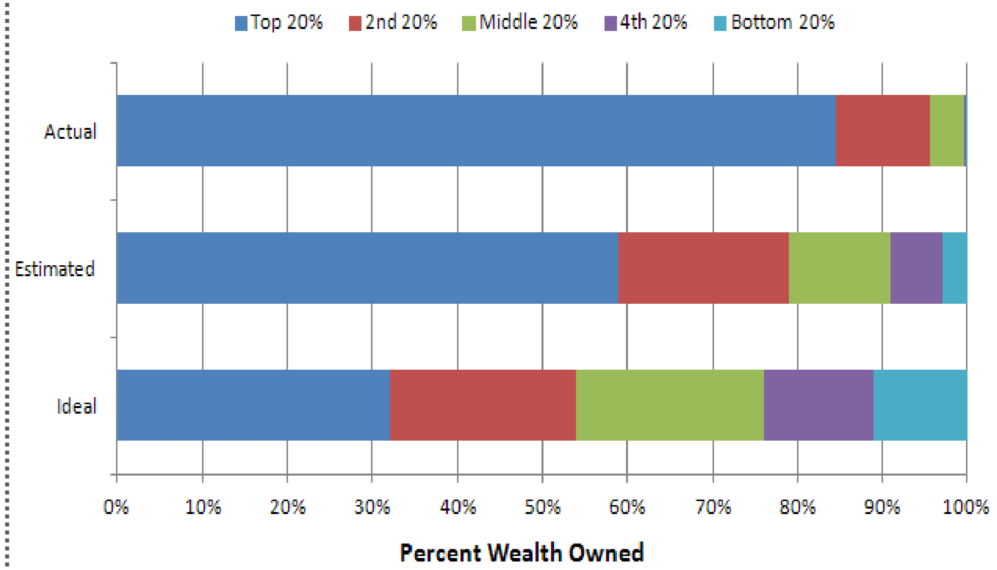


Source: Statista

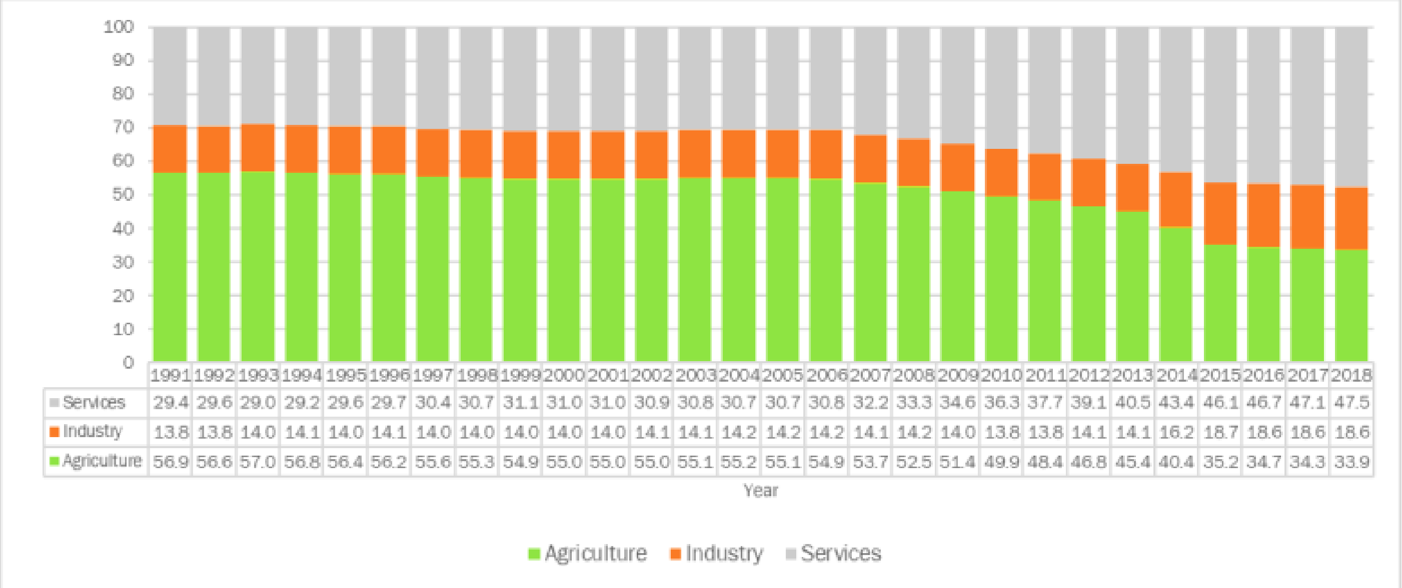
Challenges to current Energy Mix

1. Understanding Dumsor
2. Overdependence on Hydropower
3. **3.Unstable and weak economy**
4. Unskilled local people
5. 5.Impact of Covid-19

Wealth distribution in Ghana



Distribution of Agriculture, Industries and Services in Ghana



	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Services	29.4	29.6	29.0	29.2	29.6	29.7	30.4	30.7	31.1	31.0	31.0	30.9	30.8	30.7
Industry	13.8	13.8	14.0	14.1	14.0	14.1	14.0	14.0	14.0	14.0	14.0	14.1	14.1	14.2
Agriculture	56.9	56.6	57.0	56.8	56.4	56.2	55.6	55.3	54.9	55.0	55.0	55.0	55.1	55.2

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Services	30.7	30.8	32.2	33.3	34.6	36.3	37.7	39.1	40.5	43.4	46.1	46.7	47.1	47.5
Industry	14.2	14.2	14.1	14.2	14.0	13.8	13.8	14.1	14.1	16.2	18.7	18.6	18.6	18.6
Agriculture	55.1	54.9	53.7	52.5	51.4	49.9	48.4	46.8	45.4	40.4	35.2	34.7	34.3	33.9

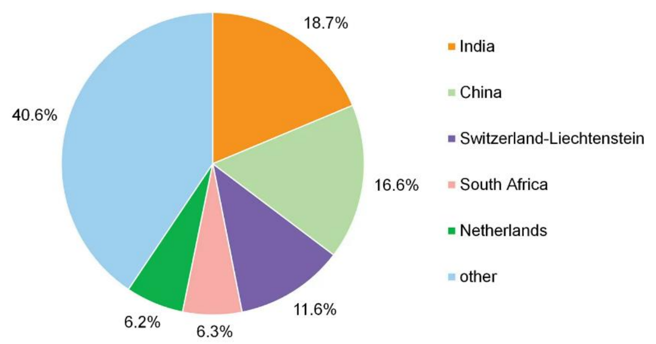
- There is non-uniform wealth distribution among the Ghanaians which is not healthy for the economy.
- The share of Agriculture has been decreasing overtime

Source: Government of Ghana National Survey of Ghana

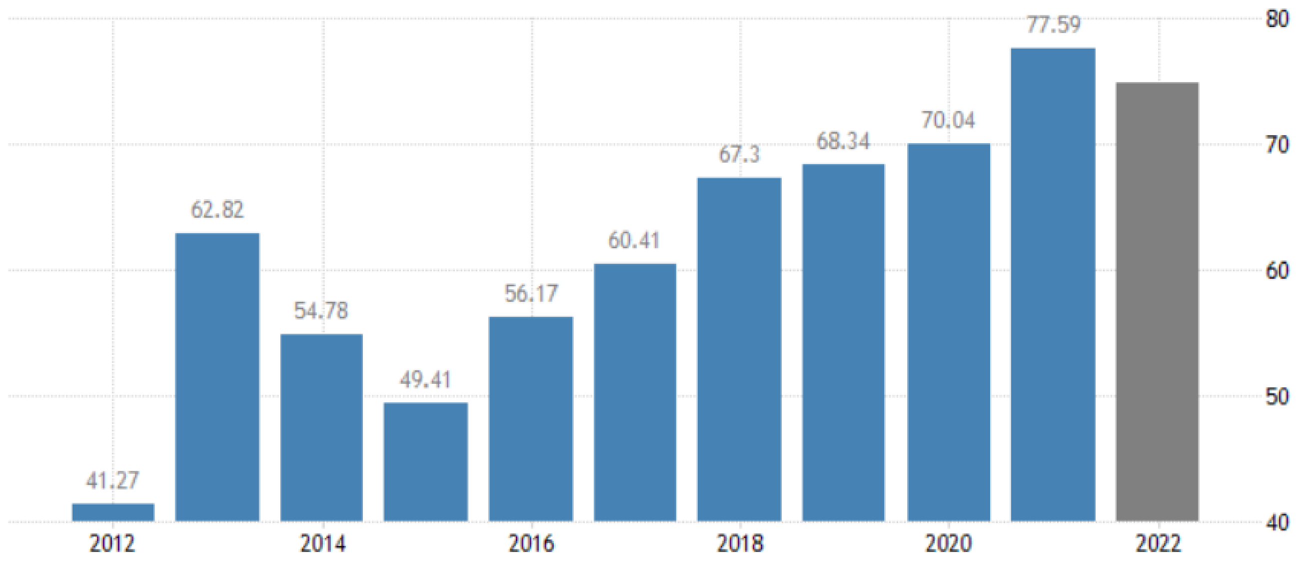
Challenges to current Energy Mix

1. Understanding Dumsor
2. Overdependence on Hydropower
3. **3.Unstable and weak economy**
4. Unskilled local people
5. Impact of Covid-19

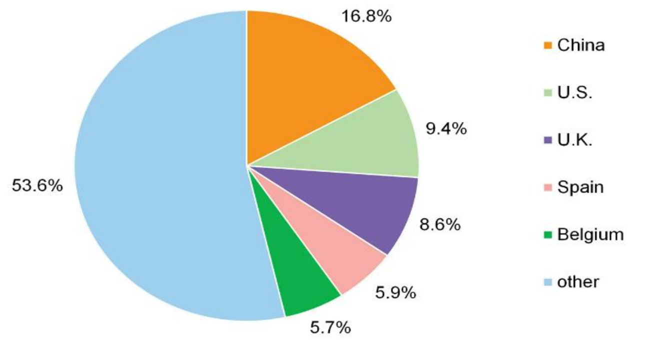
Major Export destinations (2017)



GDP of Ghana(USD Billion)



Major Import sources (2017)



- Inflation rose from 13.9% in January to 37.2% in September.
- Petrol and diesel prices have jumped by 88.6% and 128.6% respectively.
- Most public transport fares have increased by over 100% since January.

Source: Encyclopedia Britannica,inc,trading economics.com

Challenges to current Energy Mix

1. Understanding Dumsor | 2. Overdependence on Hydropower | 3.Unstable and weak economy | **4. Unskilled local people** | 5.Impact of Covid-19

Gender based Labor force distribution

Category	% of labor force						
	GLSS 3	GLSS 4	GLSS 5	GLSS 6	GLSS 7	Population census	Population census
	1992	1999	2006	2013	2017	2000	2010
Total unemployment	2.3	2.7	3.1	5.2	5.1	10.4	5.8
Male unemployment	2.2	3.4	3.2	4.8	4.5	10.1	5.4
Female unemployment	2.4	2.2	3.0	5.5	5.7	10.7	6.3
Urban unemployment	6.7	5.8	6.1	6.5	7.8	12.8	8.0
Rural unemployment	0.5	1.2	1.3	3.9	3.5	8.6	3.5
Youth unemployment (15-24)	5.2	5.0	6.6	10.9	7.1	16.7	12.9
Adult unemployment (25+)	1.4	2.1	1.9	3.4	4.1	8.6	4.0

Source: Calculations from Source: GLSS 3, 4, 5, 6 & 7 and Population & Housing Census 2000 & 2010.

Industry wise Labor force distribution

Industry	GLSS1 (1993)	GLSS4 (1998)	Census (2000)	GLSS5 (2004/5)	Census (2010)	GLSS6 (2013)	GLSS7 (2017)
Agriculture, fishing, and forestry	64.6	55.8	51.2	55.7	40.1	46.4	38.6
Manufacturing	8.0	11.0	11.2	11	12.7	9.2	11.6
Construction	1.4	1.7	3.2	1.9	2.9	3.3	4.3
Mining, electricity, water and gas	0.9	1.0	1.8	1.0	2.3	1.7	1.6
Services	25.1	30.6	32.7	30.5	42.1	39.5	44.0
Total	100.0	100.0	100.0	100	100.0	100	100

Source: Calculations from Household and Population Census data by the Ghana Statistical Service

Government Policies to curb Unemployment

- Youth Employment Agency (YEA)
- National Youth Employment Programme (NYEP)
- National Employment Policy (NEP)
- National Employment Coordinating Council (NECC)

Challenges to current Energy Mix

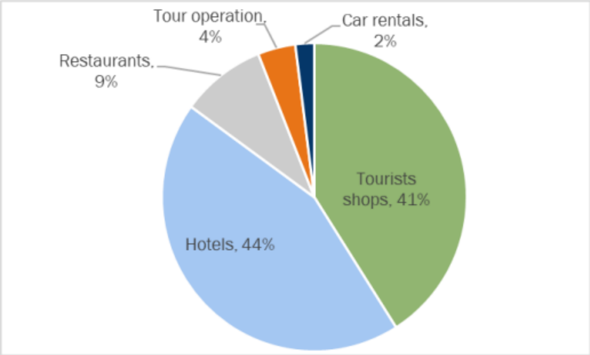
1. Understanding Dumsor
2. Overdependence on Hydropower
3. Unstable and weak economy
4. **Unskilled local people**
5. Impact of Covid-19

Gender based Labor force distribution

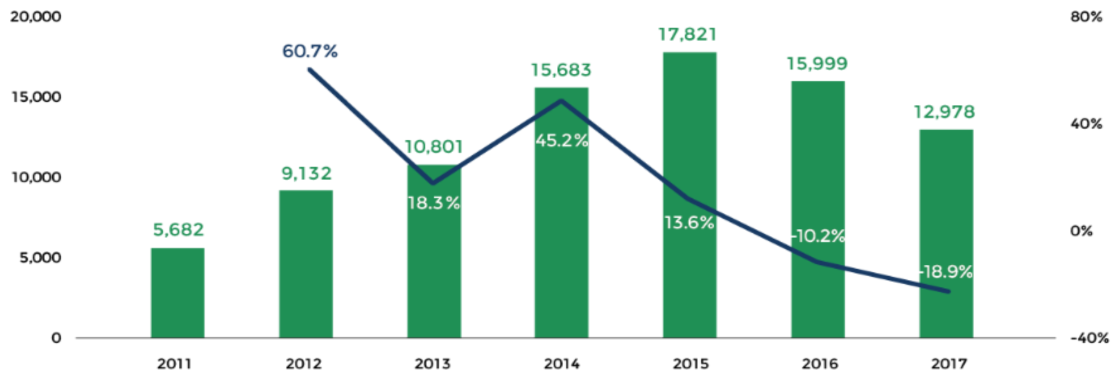
Demographic group	2012/13	2016/17
Gender		
Male	48.9	37.9
Female	51.0	62.1
Age		
15-24	36.0	40.7
25-34	29.8	30.0
35-65	34.1	29.3
Education		
Less than secondary	76.8	62.1
Secondary	17.1	28.6
Post-secondary	6.1	9.3

Sources: GLSS 6 and 7.

Business Establishment Survey (2017)



Source: GSS (2017); Integrated Business Establishment Surveys, 2017.



Source: UNESCO Institutes for statistic

SWITCH ENERGY ALLIANCE

Challenges to current Energy Mix

1. Understanding Dumsor
2. Overdependence on Hydropower
3. Unstable and weak economy
4. Unskilled local people
5. **Impact of Covid-19**

Estimated impact on petroleum receipts

Shortfall in the Ghana Stabilisation Fund

↓ GH¢1,058m

Shortfall in the Ghana Heritage Fund

↓ GH¢453m

Shortfall in Annual Budget Funding Amount (ABFA)

↓ GH¢3,526m

Shortfall in transfers to GNPC

↓ GH¢642m

Estimated impact on tax revenue

Shortfall in import duties

GH¢808m

Shortfall in other non-oil tax revenues

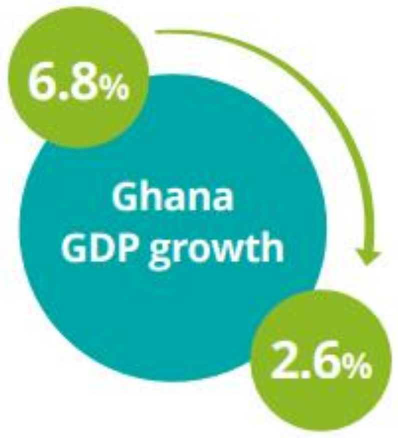
GH¢1,446m

Total shortfall in non-oil tax revenue

GH¢2,254m

Impact on GDP Growth

Ghana's estimated GDP growth is set to plummet from a target of 6.8% to about 2.6% in 2020



Initial cost of preparedness and response plan

Total amount dedicated by Government of Ghana (GoG) towards fight against Covid-19

GH¢572m

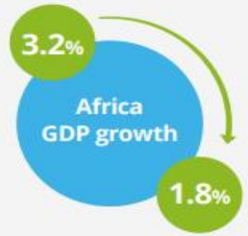
Total fiscal impact from revenue shortfall and cost of preparedness and response plan

GH¢9,505m

Impact on the Global and Africa economy

Global GDP growth of 3.3% for 2020 to slow to less than 2.9% due to Covid-19.

Africa's projected GDP growth of 3.2% for 2020 is now expected to slow to about 1.8%



Source: IMF; UNECA;GoG & Deloitte Analysis

SWITCH
ENERGY ALLIANCE

Solution: Ghanaian Energy Revolution 2050

Solution: Energy Revolution 2050

1. Energy Opportunities
2. Economic Analysis
3. Impact on people of Ghana
4. Conclusion

SWITCH ENERGY ALLIANCE

Solution: Ghanaian Energy Revolution 2050

1. Energy Opportunities → 2. Economic Analysis → 3.Impact on people of Ghana → 4. Conclusion

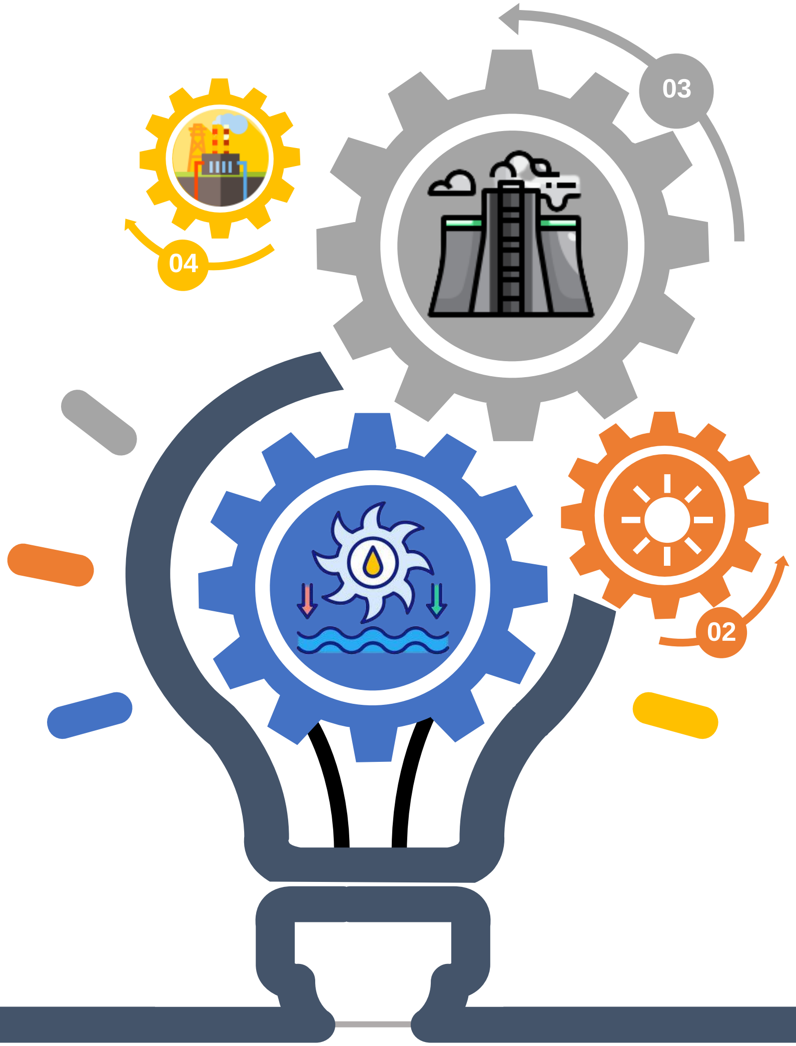
ENERGY OPPORTUNITIES

01 Hydropower
Akosombo, Kpong and Bui dams power 47.4% of Ghana’s Energy requirements.

02 Solar Power
With increasing energy demands, the share of solar have to grow from its current share of 6.26%

03 Thermal
Thermals power nearly 47.50 % of energy demands and its share in future energy mix should be decided based on sustainability and demands.

04 Geothermal
The exploration in the Geothermal domain can be carried out to exploit its potential if any



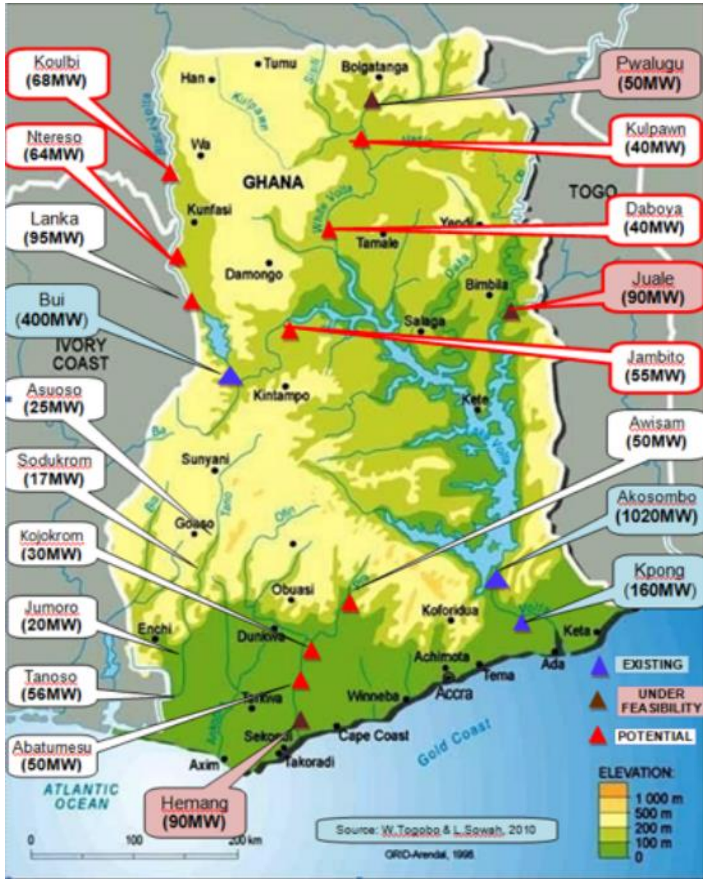
Solution: Ghanaian Energy Revolution 2050

SWITCH ENERGY ALLIANCE

Solution: Ghanaian Energy Revolution 2050

1. Energy Opportunities | 2. Economic Analysis | 3.Impact on people of Ghana | 4. Conclusion

Prospective locations for Hydropower projects



Current Hydropower Stations in Ghana

Hydroelectric station	Community	Coordinates	Type	Capacity (MW)	Year completed	Name of reservoir	River
Akosombo Hydroelectric Power Station	Ajena	6.299722°N 0.059444°E	Reservoir	1,038	1965	Lake Volta	River Volta
Bui Hydroelectric Power Station	Bui Gorge	8.278602°N 2.236935°W	Reservoir	400	2013		Black Volta River
Kpong Hydroelectric Power Station	Akuse	6.119989°N 0.125000°E	Reservoir	160	1982		River Volta

Source: ECG

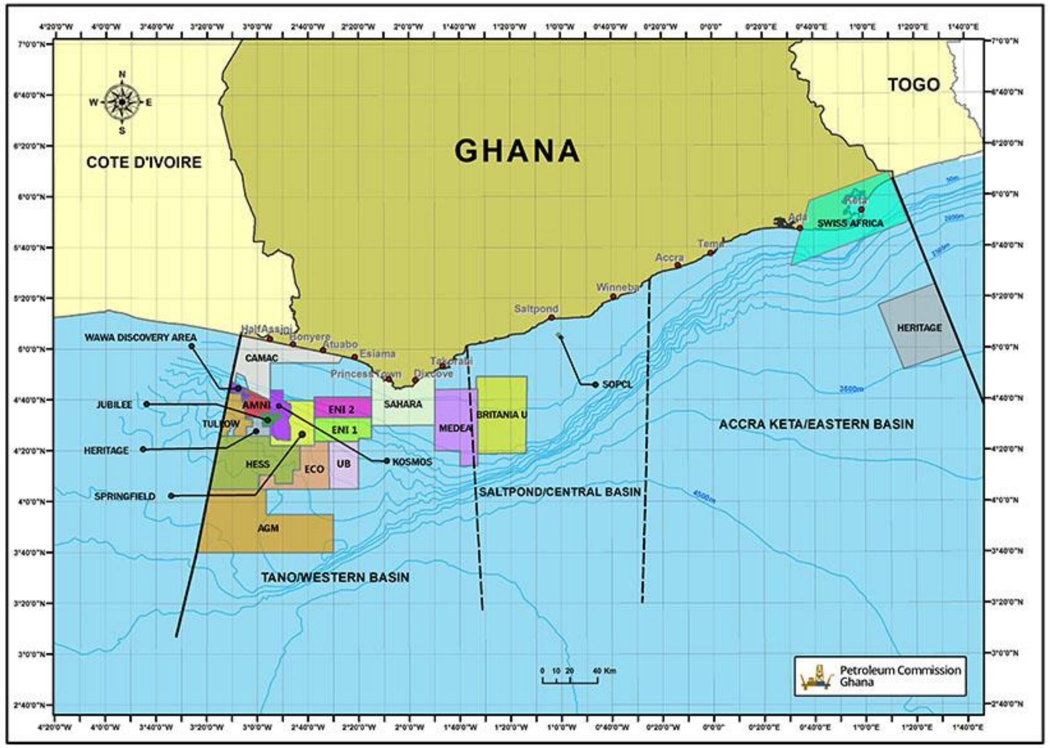
Solution: Ghanaian Energy Revolution 2050

THERMAL ENERGY

Solution: Ghanaian Energy Revolution 2050

SWITCH ENERGY ALLIANCE

1. Energy Opportunities | 2. Economic Analysis | 3.Impact on people of Ghana | 4. Conclusion



Offshore oil and gas fields in Ghana

THERMAL ENERGY

- Up to 89% of installed thermal plants depend on natural gas as the primary fuel source.
- The sources of supply include the associated gas fields (Jubilee and TEN) and the non-associated gas field (Sankofa) in the western offshore of Ghana, as well as imports from Nigeria through the West African Pipeline (WAGP)
- Thermal power plants contribute around 1556 MWh which turns out to be 46.25% of total share in energy mix.

Source: epaoilandgas.org

Solution: Ghanaian Energy Revolution 2050

Thermal Power stations

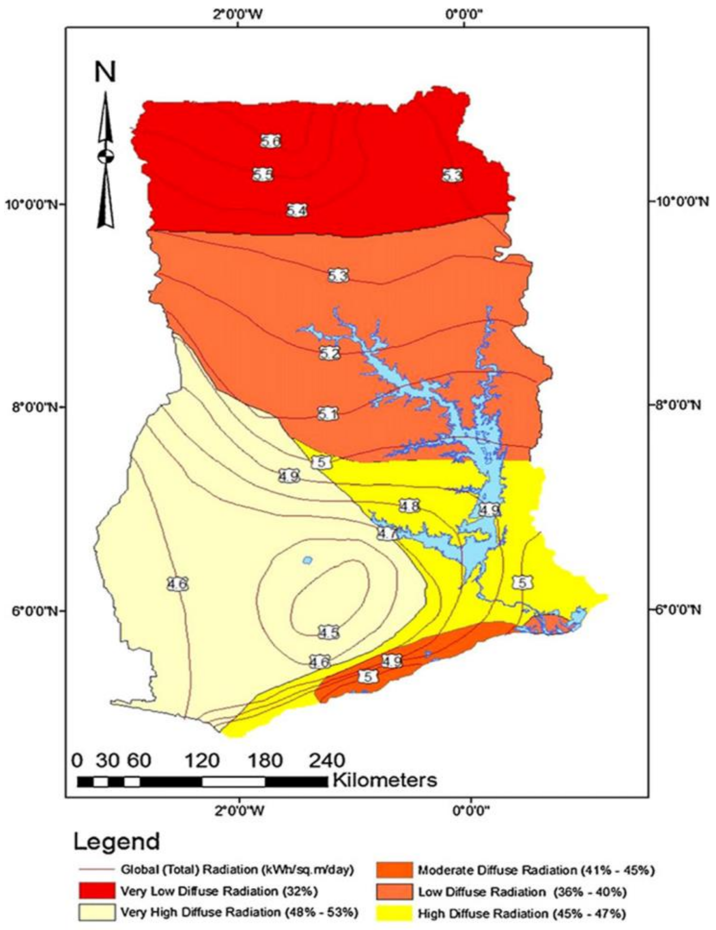
Power station	Community	Coordinates	Type	Capacity (MW)	Year completed	Additional description
Takoradi Thermal Power Station	Takoradi	4.971667°N 1.657228°W	Light crude oil or Natural gas	550	2000	A total of 550 MW is generated; four gas turbines and a steam turbine
Kpone Thermal Power Station II	Kpone	5.673900°N 0.037500°E	Natural gas or Diesel fuel or Crude oil	340	2017 (Expected)	Biggest independent power plant in Africa to date.
Kpone Thermal Power Station I	Kpone	5.734998°N 0.010548°E	Natural gas and Diesel fuel	230	2016 (Expected)	Owned by Volta River Authority
Tema Thermal Power Station	Tema	5.677362°N 0.015828°E	Diesel fuel	236	2008	54 Caterpillar 3516B diesel power generators
Sonon Asogli Thermal Power Station	Kpone	5.68029°N 0.047368°E	Natural gas	200	2010	Maximum installed capacity of 200MW. Often output is less than maximum

Solution: Ghanaian Energy Revolution 2050

SWITCH
ENERGY ALLIANCE

Solution: Ghanaian Energy Revolution 2050

1. Energy Opportunities | 2. Economic Analysis | 3.Impact on people of Ghana | 4. Conclusion



Solar intensity distribution map

SOLAR ENERGY

- Solar resource is abundant in all parts of Ghana with very high potential for grid and off-grid electricity generation. It is estimated that 35 EJ of solar potential exists in the country
- This if harnessed efficiently would provide about 100 times the current power needs of the country estimated at 53,000 MWh a year
- The monthly average solar radiation in the country is 4.4–5.6 kWh/m2/day and that for Northern, Upper East, Upper West, and the northern parts of Volta and Brong-Ahafo regions of Ghana is 4.0 – 6.5 kWh/m2/day, which makes it capable for solar energy generation
- Ghana’s average annual daily solar radiation is between 4.0 – 6.0 kWh/m2
- Solar PV electricity generation is one of the promising renewable energies to improve the country’s electricity supply security.

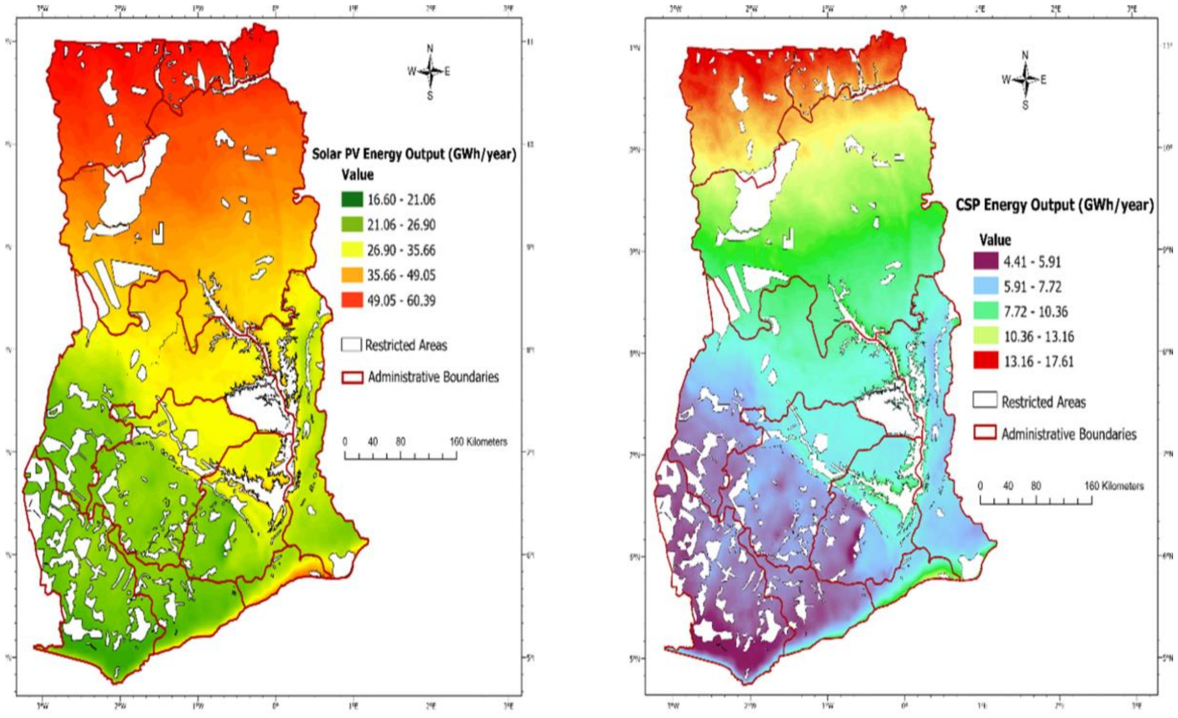
Source: Ministry of Energy,2006

SWITCH ENERGY ALLIANCE

Solution: Ghanaian Energy Revolution 2050

1. Energy Opportunities | 2. Economic Analysis | 3.Impact on people of Ghana | 4. Conclusion

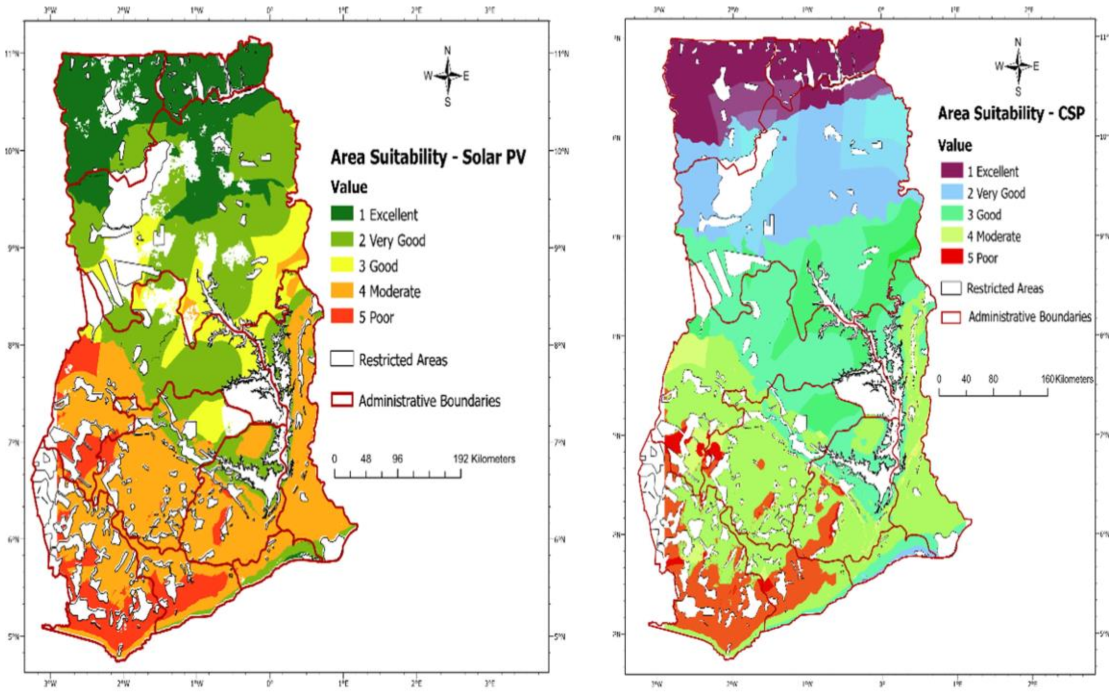
Area suitability Maps for solar implementation



(a) (b)

(a) Area suitability for solar PV deployment, (b) Area suitability for CSP deployment.

Maps showing maximum energy generation capacity per year per grid cell (GWh/year).



(a) (b)

(a) Utility-scale solar PV energy output, (b) CSP energy output.

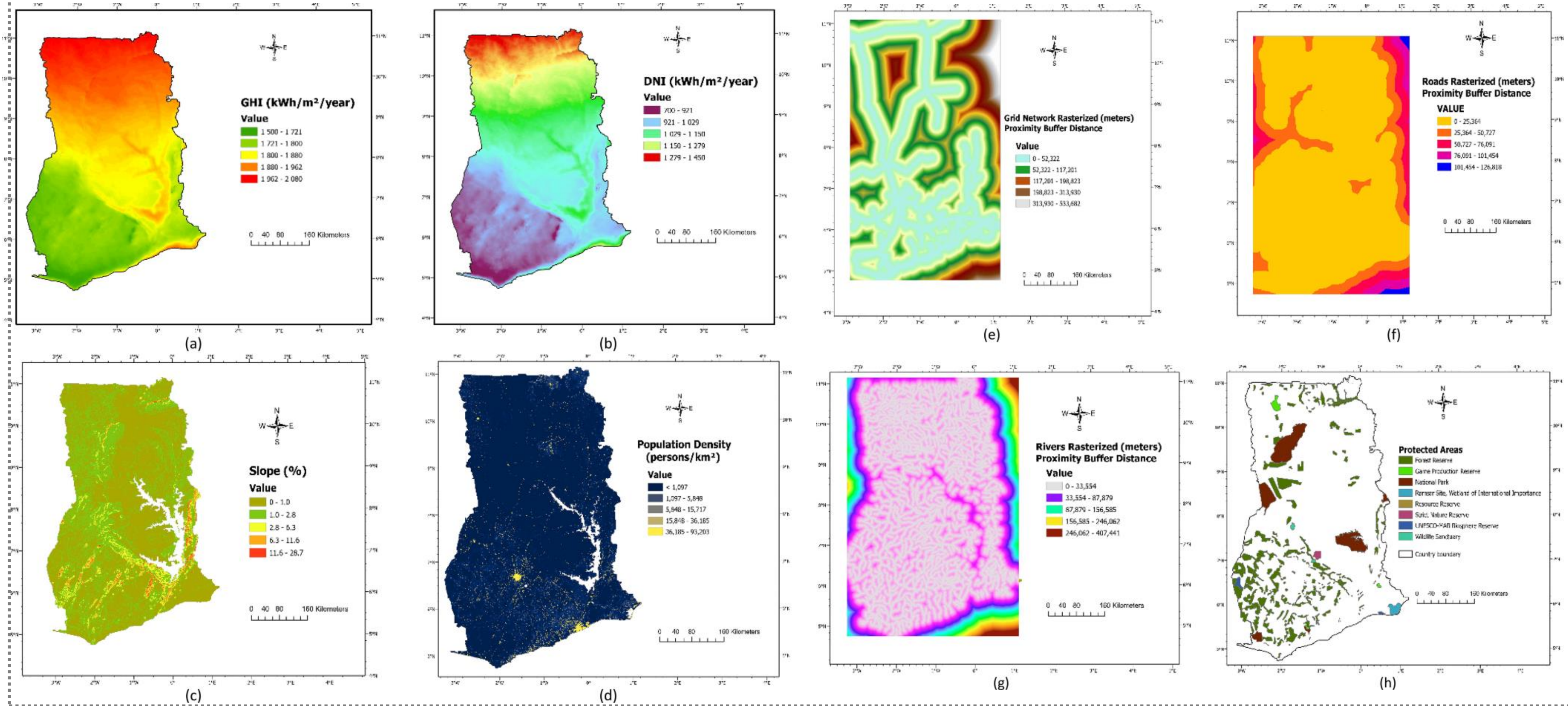
Source: ECG

SWITCH ENERGY ALLIANCE

Solution: Ghanaian Energy Revolution 2050

1. Energy Opportunities | 2. Economic Analysis | 3.Impact on people of Ghana | 4. Conclusion

Input raster data for computing geographical potential



Legend

(a): Global Horizontal Irradiance
(b): Direct Normal Irradiance
(c): Slope
(d): Population Density
(e): Grid Network
(f): Roads
(g): Rivers
(h): Area restriction mask

Source: ECG

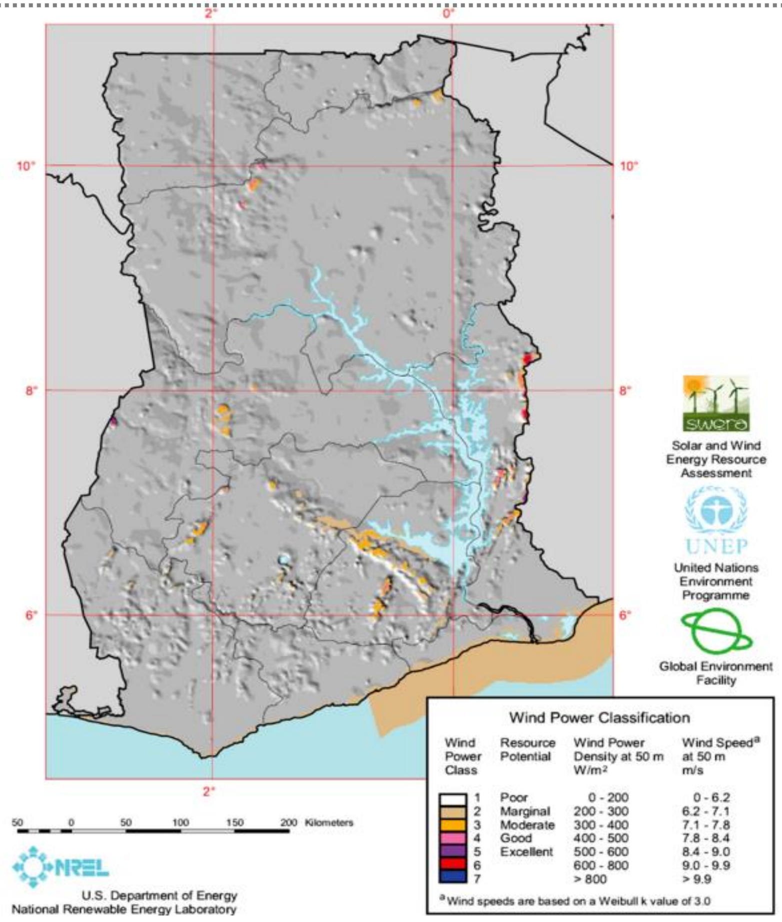
Solution: Ghanaian Energy Revolution 2050

Current Solar Power Stations in Ghana

Solar power station	Community	Coordinates	Capacity (megawatts)	Year completed	Name of Owner	Notes
Nzema Solar Power Station	Aiwiaso Village	6.155567°N 2.419711°W	155	2022-2023 (Expected)	Blue Energy Plc.[9]	Seeking EPC proposals
BXC Solar Power Station	Onyandze, Gomoa West District, Central Region, Ghana	5.372778°N 0.693333°W	20	2016[11]	Beijing Xiaocheng Company	Operational
Gomoa Onyaadze Solar Power Station	Onyandze, Gomoa West District, Central Region, Ghana	5.346111°N 0.703333°W	20	2018[13]	Meinergy Ghana Limited	Operational
Navrongo Solar Power Station	Navrongo	10.880000°N 1.102778°W	2.5	2013	Volta River Authority	Operational
Kaleo Solar Power Station	Kaleo	10.174167°N 2.533611°W	13	2022	Volta River Authority	Operational

Solution: Ghanaian Energy Revolution 2050

Solution: Ghanaian Energy Revolution 2050



Wind source map

WIND ENERGY

- The Solar and Wind Energy Resource Assessment (SWERA) project implemented in collaboration with the US National Renewable Energy Laboratory (NREL), UNEP and Global Environment Facility identified certain spots along the coastline of Ghana in 2004 that could support wind power generation

- The bulk of wind resources in Ghana are classified as moderate and are available in few areas in Greater Accra, Central, Eastern, Western, Volta, Brong Ahafo, Ashanti and Northern region

- The annual average wind speed of 8 m/s is available with a few excellent sites of wind speeds between 8.4 and 9.9 m/s

- Wind speeds between 9 and 9.9 m/s exist along the coastline of Ghana which could be harnessed to produce about 2000 MW of electricity

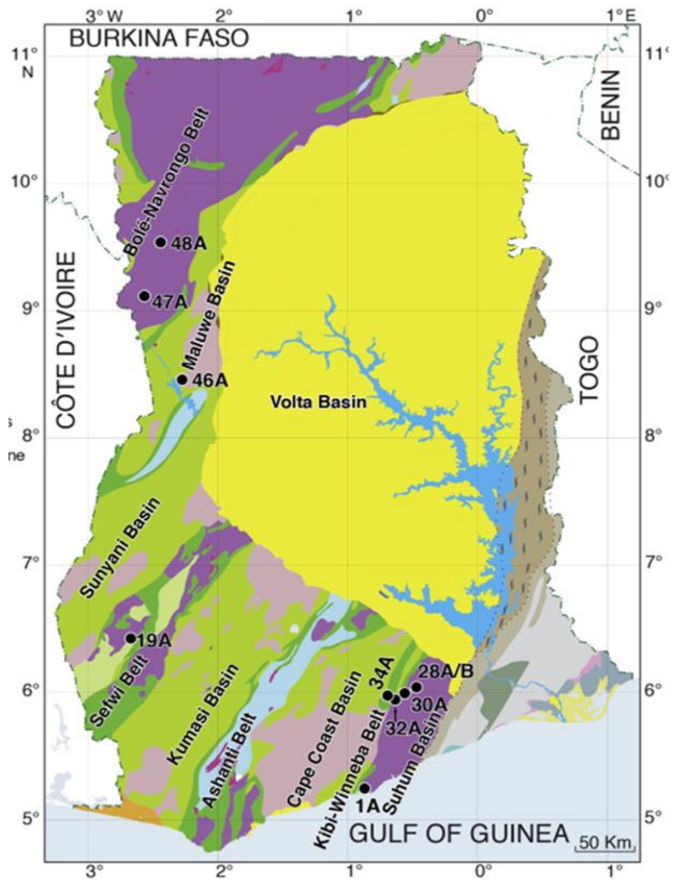
- Near the coasts of the country, excellent sites for wind power generation have also been identified and mapped

Source: US Department of Energy ,National Renewable Energy Laboratory

SWITCH ENERGY ALLIANCE

Solution: Ghanaian Energy Revolution 2050

Solution: Ghanaian Energy Revolution 2050



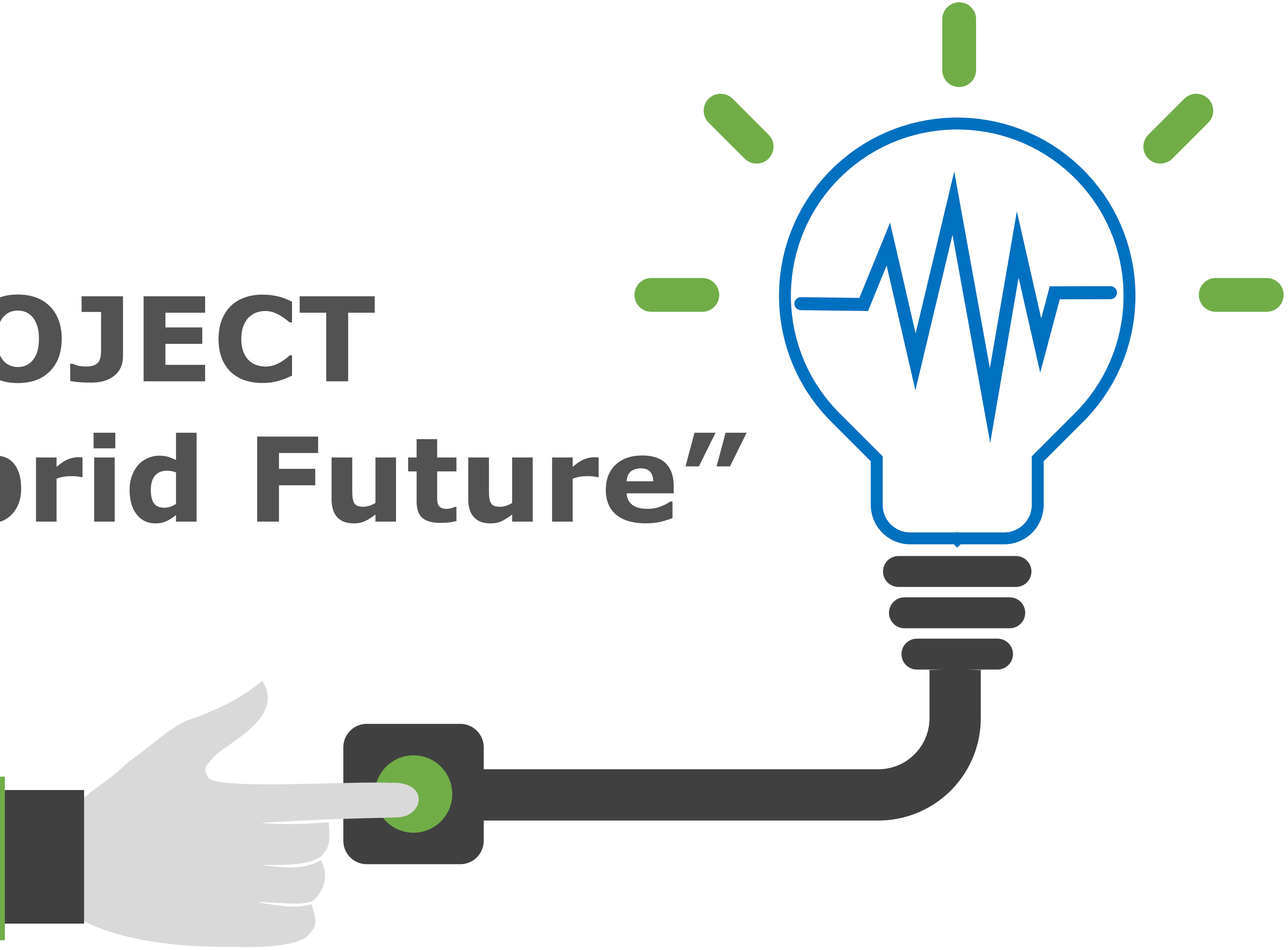
Geothermal potential map

GEOTHERMAL ENERGY

- Ghana has very complex geology dominated by Paleoproterozoic Birimian rocks consisting of five evenly spaced volcanic belts trending northeast-southwest
- Faults, fractures network zones were depositional sites for hydrothermal fluids, facilitating geothermal fluid flow by providing channels of high permeability
- Magmatic and granitoid intrusions with elevated thermal heat flux exist in abundance
- As the hydrothermal fluids moved through faults between formations, affected by shear zones, hydrothermal reservoirs were created
- The transition zone between the volcanic belts and the sedimentary basins has been found to be the site of gold mineralization in Ghana

Source: stellaeenergy.com/geothermal-energy-in -ghana

PROJECT
“The Hybrid Future”



Re-energizing Ghana

Solution: Ghanaian Energy Revolution 2050

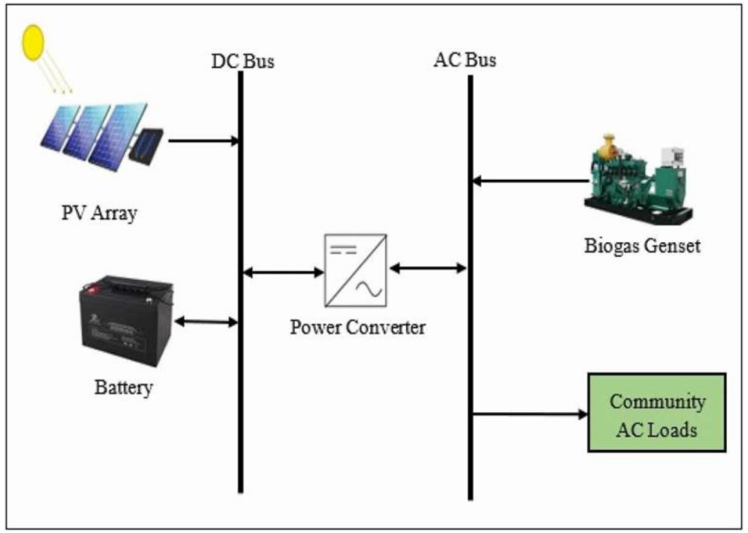
SWITCH ENERGY ALLIANCE

1. Energy Opportunities | **2. Economic Analysis** | 3.Impact on people of Ghana | 4. Conclusion

Hybrid Energy System

Hybrid renewable energy system (HRES) comprises more than one power generation technology, either renewable or conventional fuel units, that work in a standalone or grid-connected mode

Arrangement of Hybrid System Components



ADVANTAGES OF HYBRID ENERGY

- Increased capacity factor in the access point of the hybrid plant thanks to the complementarity of the load curves of both technologies.
- Switching between sources when one is inactive reduces the unpredictability inherent in renewable energy and improves the stability of the electricity supplied. Thus, the power on the supply point is ensured.
- Optimization on the use of electric infrastructures, involving synergies on O&M and CAPEX.
- Speeding up connection times and the commissioning of new renewable generation plants if there is no need to apply for a new access point

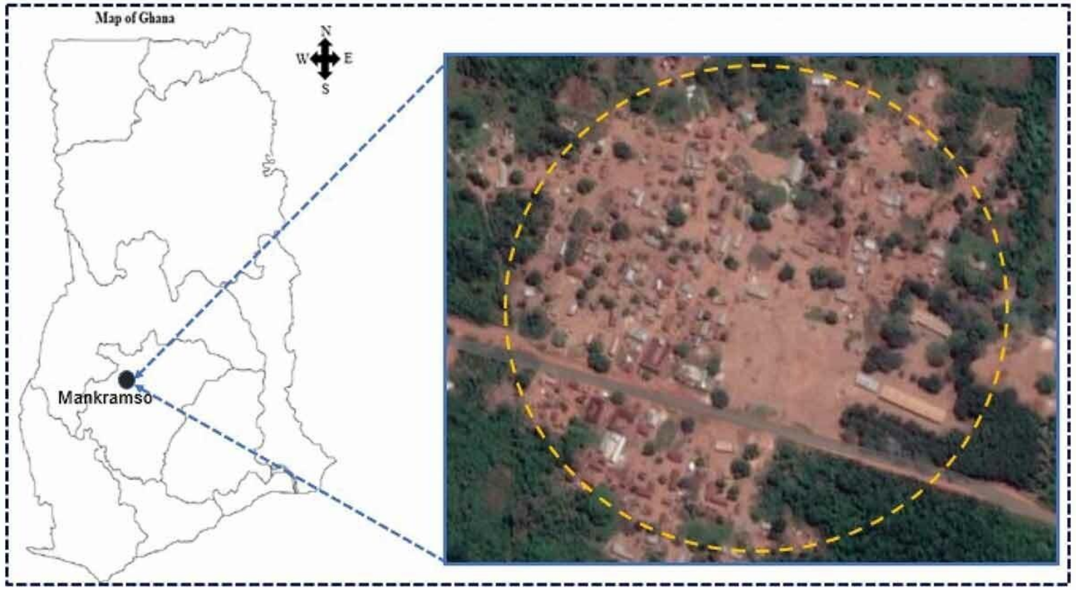
Source: stellaeenergy.com/geothermal-energy-in -ghana

Solution: Ghanaian Energy Revolution 2050

SWITCH ENERGY ALLIANCE

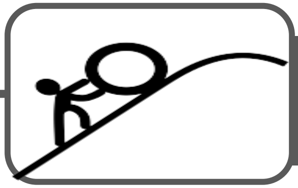
1. Energy Opportunities | **2. Economic Analysis** | 3.Impact on people of Ghana | 4. Conclusion

MANKRAMSO: PILOT TEST



North District of the Ashanti Region

Population :1892



CHALLENGES

1. The community is about 7.0 km away from the national grid
2. The community mainly relies on firewood, charcoal, kerosene lamps, solar lanterns for lighting and other energy activities.
3. Hindrance to quality education, human well-being, and community business activities

REASON

1. Insufficient power production to meet existing power demand
2. Some remote areas' geographical locations may preclude grid extension

Source: https://doi.org/10.1080/23311916.2022.2034376

Solution: Ghanaian Energy Revolution 2050

1. Energy Opportunities | **2. Economic Analysis** | 3.Impact on people of Ghana | 4. Conclusion

Electrical load estimation for Mankramso community

ASSUMPTIONS

In this study, an average of 3 rooms per household, a household size of 5 people, and a total of 400 households were considered for analysis.

The electrical appliance power ratings are classified into Tier 1 (very low), Tier 2 (low), Tier 3 (medium), Tier 4 (high), and Tier 5 (very high) based on the multi-tier approach

The derating factor is taken to be 85%. Also, a ground reflectance of 20% is considered.

The study adopted the World Bank's new multi-tier framework (MTF) energy access index (household use, productive use, and community use) to categorize the community's electricity demand

The PV array lifetime is assumed to be 30 years

Load estimation of different categories

Energy Access Index	AC loads (KWh/d)
Household use	136.8
Community use	33.36
Productive use	92.64
Total	**262.8**

Source: https://doi.org/10.1080/23311916.2022.2034376

Solution: Ghanaian Energy Revolution 2050

1. Energy Opportunities | **2. Economic Analysis** | 3.Impact on people of Ghana | 4. Conclusion

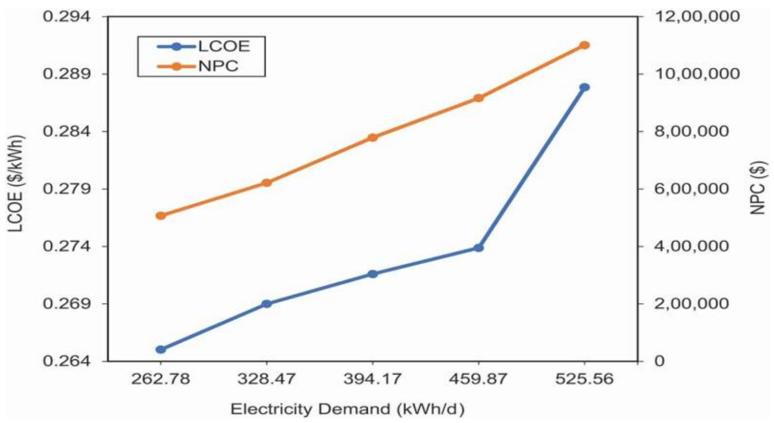
Distribution of annual electricity demand

Index	Electricity Demand (MWh/yr)	Electricity Demand %
Households use	50	52
Productive use	34	35
Commercial use	12	13
Total	**96**	

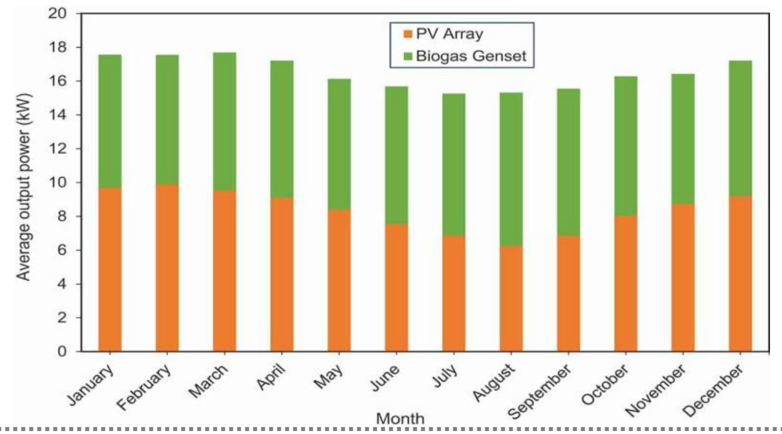
Hybrid energy systems' technical performance

Variable	Unit	PV/biogas /battery	PV/diesel /battery	Diesel only
PV capacity	kW	50	48	-
Biogas genset capacity	kW	20	-	-
Diesel genset capacity	kW	-	54	54
Battery capacity	kWh	237	230	-
Converter capacity	kW	42.1	13.6875	-
Capacity shortage	%	0.09	0	0
Electricity production	MWh/yr	144.573	117.954	155.512

Impact increasing in electricity demand on NPC and LCOE



Monthly average electricity production.



Source: https://doi.org/10.1080/23311916.2022.2034376

SWITCH ENERGY ALLIANCE

Solution: Ghanaian Energy Revolution 2050

1. Energy Opportunities | **2. Economic Analysis** | 3.Impact on people of Ghana | 4. Conclusion

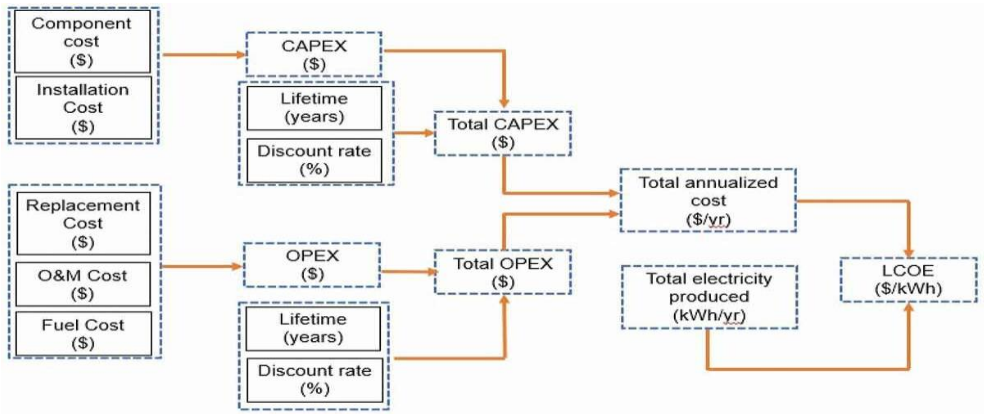
Hybrid energy system economic performance

Variable	Unit	PV/Biogas	PV/Diesel	Diesel only
LCOE	$/kWh	0.265	0.450	0.980
NPC	$	506,629	861,099.50	1,875,373
Operating cost	$/yr	14,303.94	32,522.27	88,128.66
Initial capital	$	221,322.50	212,388.4	117,500
Fuel cost	$/yr	342.78	18,860.82	66,974.57

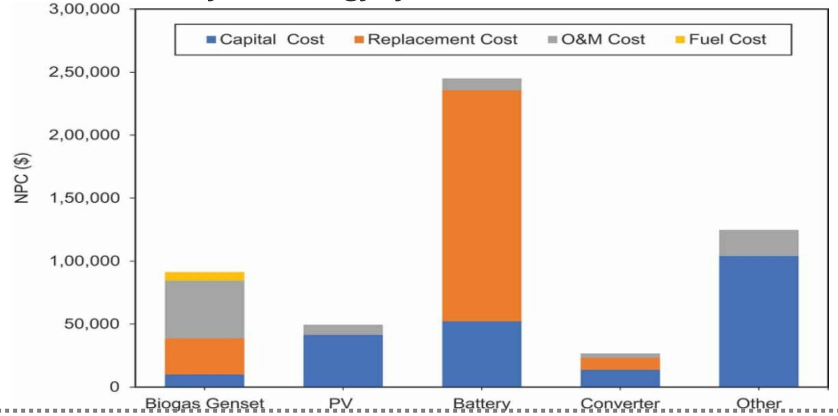
Hybrid energy systems emissions

Hybrid energy system	Renewable fraction %	Carbon dioxide emissions (kg/yr)
PV/biogas/battery	100	313.68
PV/diesel/battery	50.3	41,487.70
Diesel only	0	147,322.40

Flow chart for calculating the Levelized cost of energy



Hybrid energy system cost breakdown.



Source: https://doi.org/10.1080/23311916.2022.2034376

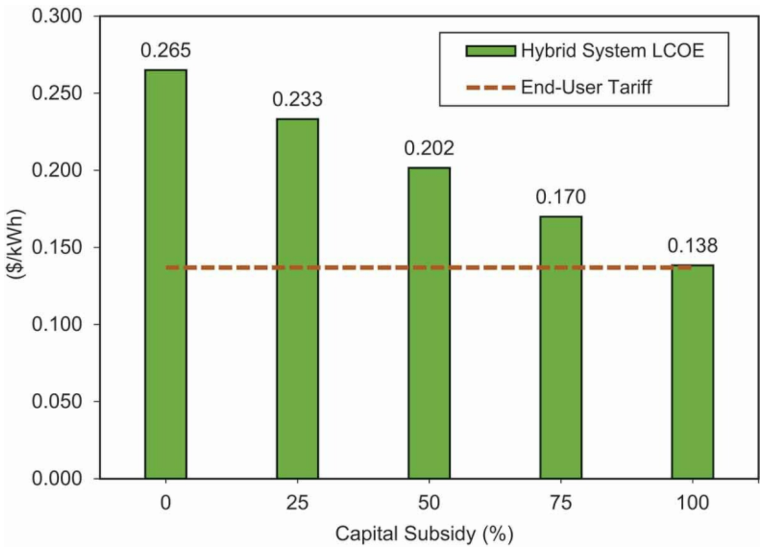
SWITCH
ENERGY ALLIANCE

Solution: Ghanaian Energy Revolution 2050

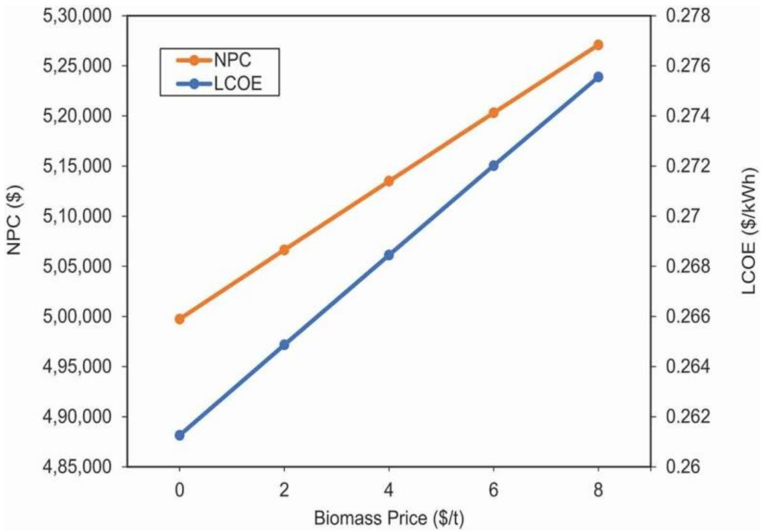
1. Energy Opportunities | **2. Economic Analysis** | 3.Impact on people of Ghana | 4. Conclusion

Sensitivity Analysis

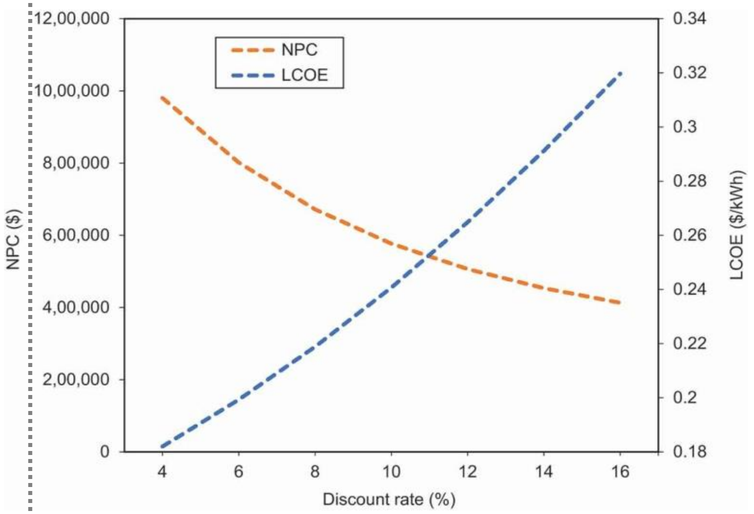
Effect of capital subsidy on the hybrid system LCOE



Impact of biomass price on LCOE and NPC



Effect of discount rate on hybrid system NPC & LCOE



Source: https://doi.org/10.1080/23311916.2022.2034376

Solution: Ghanaian Energy Revolution 2050

SWITCH ENERGY ALLIANCE

1. Energy Opportunities | **2. Economic Analysis** | 3.Impact on people of Ghana | 4. Conclusion

Allocated Budget($ million)	Proposed Budget($ million)	Remaining($ million)
901	900.28	0.72

NPC per Mini Grid Hybrid Project: **$506,629**

Total Project Cost given: **$901,000,000**

Total estimated cost for the project: **$900,280,000**

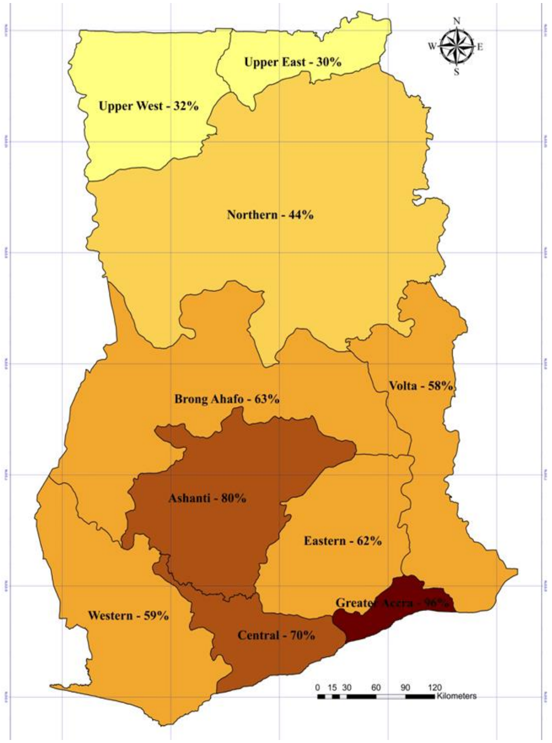
Total power generated by all plants: **256.9 GWh/Yr**

Number of mini grid Power Stations : **1777**

Based on the demand of energy over region

Region	No of hybrid Power stations
Ashanti Region	97
Brong Ahafo Region	180
Central Region	146
Eastern Region	185
Greater Accra Region	19
Northern Region	273
Upper East Region	341
Upper West Region	331
Volta Region	205

Energy Access to different region



Source: ECG

Solution: Ghanaian Energy Revolution 2050

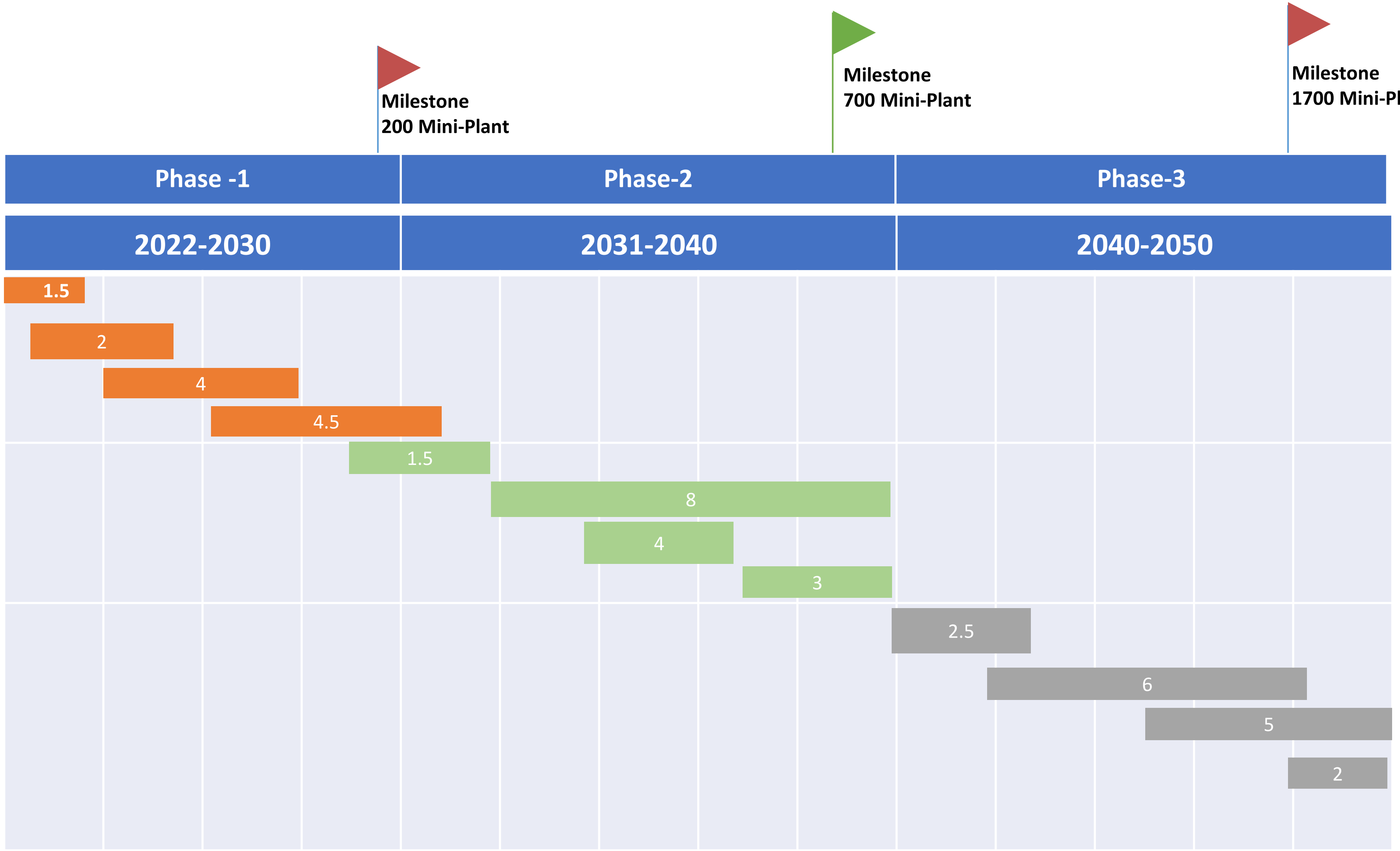
PROJECT TIMELINE

Activities

- Site Selection
- Training and rising awareness via workshop and session
- Capital Investment
- Installation & Commencement

- Cutting down dependence on hydro power
- Establishment of more plants
- Renewable and effective electrification marketing
- Accelerated outreach to rural households

- The profits will be used in upgrading the capacity of the power plant or in other projects
- Establishment of more plants
- Accelerated implementation
- Distribution of electric cooking devices to fully eliminate household fuels



*years

Solution: Ghanaian Energy Revolution 2050

Project Financing & Government Policies

Government Policies Towards Renewables

- China-Ghana South-South Cooperation on Renewable Energy Technology Transfer
- Renewable Energy Technology Transfer Project
- Renewable Energy Act, 2011
- Strategic national energy plan, 2006–2020
- The sustainable energy for all action plan (SE4ALL), 2012
- National energy policy, 2010
- Energy sector strategy and development, 2010

CalBank

CO-GUARANTEE PLATFORM

Sustainable Energy Fund for Africa

accelerating the energy transition in Africa

Source: https://www.intechopen.com/chapters/68202

Solution: Ghanaian Energy Revolution 2050

1. Energy Opportunities | 2. Economic Analysis | **3.Impact on People of Ghana** | 4. Conclusion

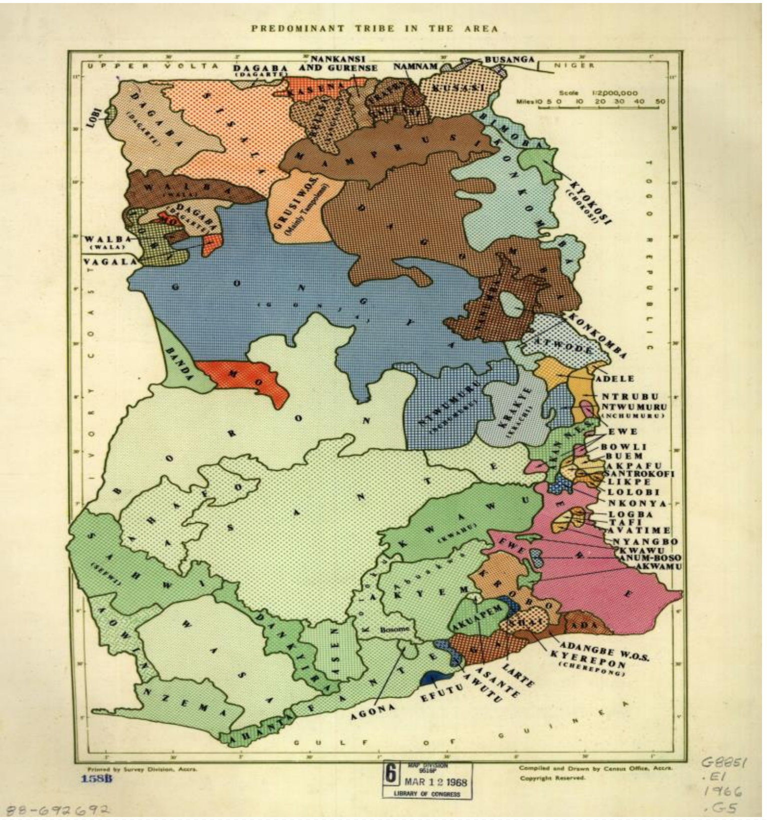
Unified Cultural Diversity and Energy Revolution

80+
Languages

24.2%
Below the poverty line

70+
Ethnic group

Prominent Tribes in Ghana



"Energy Togetherness"

- The tribes may not be accustomed to the Technological developments, but with awareness from Ghanian government the implementation can be handled easily
- All developments are sustainable with minimal or no negative impact on the environment and cultural diversity

"Energy Togetherness- from thought to reality"

Source: Government of Ghana

Solution: Ghanaian Energy Revolution 2050

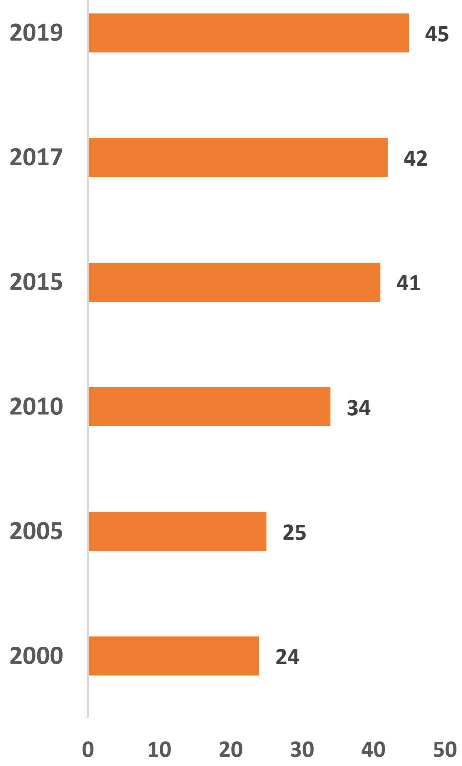
SWITCH ENERGY ALLIANCE

1. Energy Opportunities | 2. Economic Analysis | **3.Impact on People of Ghana** | 4. Conclusion

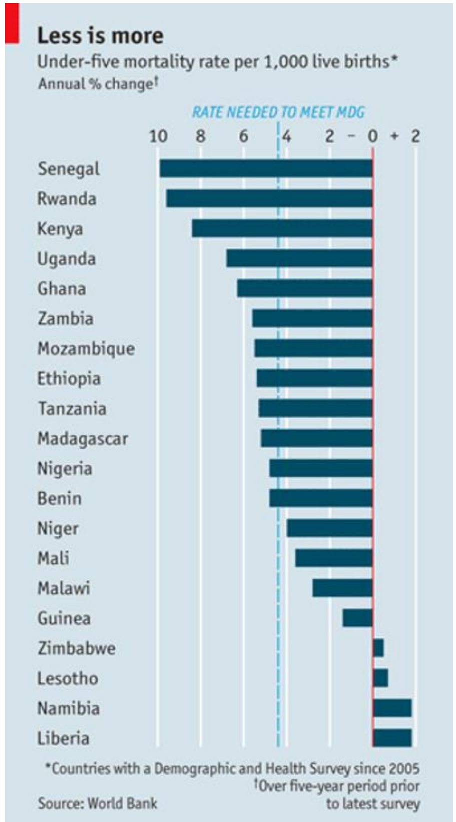
Cooking Fuel and Health Care

- In Ghana, about 80% of households cook by burning biomass like wood, charcoal, and crop residue in open fires.
- Burning biomass for cooking, and lower respiratory tract infection, which is highly associated with inhaling smoking from traditional fuels, is the 3rd leading cause of death in Ghana.

Ghana Health Care Index



Infant Mortality Rate



Cooking Fuel Share

Main energy source	Frequency	Percentage
Crop residue/sawdust	185	2.24
Fuelwood	4762	57.64
Charcoal	2477	29.98
Kerosene	49	0.59
LPG (gas)	766	9.27
Electricity	23	0.28
Total	8262	100.00

"There is dire need to shift to cleaner cooking fuel to improve Health Care Index of Ghana"

Source: worldbank.org

Solution: Ghanaian Energy Revolution 2050

1. Energy opportunities | 2. Economic Analysis | 3.Impact on people of Ghana | **4. Conclusion**

Project Outcomes & Conclusion

- 96% electrification by 2050
- Eradication of Dumsor completely and reduction of Ghana's dependency on hydropower
- Boost public health and provide local hospitals with sustainable electricity for medical treatment
- Significant reduction in the equivalent CO2 emissions
- Beneficiation of isolated rural people who have no access or less access to energy
- Addition of around 256 GWh of sustainable clean electricity to the grid
- Facilitate rural communities access to education resources
- Employment in the construction and operation related jobs

MEET OUR TEAM

ANDREAS MATZAKOS
Mentor

AJAY KUMAR
Petroleum Engineering
IIT (ISM) Dhanbad

RAJ KUMAR
Petroleum Engineering
IIT (ISM) Dhanbad

BHAUTIK AGRAWAL
Petroleum Engineering
IIT (ISM) Dhanbad

RANJAN KUMAR
Petroleum Engineering
IIT (ISM) Dhanbad

TEAM NUMBER :194

THANK YOU

SWITCH
ENERGY ALLIANCE

Appendix

Selected PV module technical specifications.

Parameter	Specification
Nominal Maximum Power (Pmax)	340 W
Maximum Operating Voltage (Vmp)	38.2 V
Maximum Power Current (Imp)	8.91 A
Open Circuit Voltage (Voc)	47.5 V
Short Circuit Voltage (Isc)	9.22 A
Module Efficiency STC	17.52%
Operating Temperatures	−40 °C~ +85 °C
Temperature Coefficient of Pmax	−0.38 %/°C
Temperature Coefficient of Voc	−0.31 %/°C
Temperature Coefficient of Isc	0.06 %/°C
Nominal Operating Cell Temperature (NOCT)	45 ± 2 °C

Key technical specifications for designing a battery bank

Variable	Value
Nominal Voltage	12 V
Maximum capacity	83.4 Ah
Capacity ratio	0.403
Rate constant	0.827 1/hr
Roundtrip efficiency	80%
Maximum charge current	16.7 A
Maximum discharge current	24.3 A
Maximum charge rate	1 A/Ah
Initial state of charge	100%
Minimum state of charge	40%
Throughput	800 kWh
Lifetime	5 years

Source: https://doi.org/10.1080/23311916.2022.2034376

SWITCH
ENERGY ALLIANCE

Appendix

Salient parameters for sensitivity test

Input parameter	Unit	Sensitivity ranges
Discount rate	%	6, 8, 10, 14, 16
Capital subsidy	%	25, 75, 50, 100
Price of biomass feedstock	$/t	2, 4, 6, 8
Increase in electricity demand	%	+25, +50, +75, +100

Estimation of manure for anaerobic digestion

Livestock type	Population X_{live}[a] (heads)	Amount of manure[b] (kg/head/day)	Recoverability Fraction[c] (kg/kg)	Technical Manure Potential Estimated (kg)
Cattle	300	12	0.2	720
Goat	1,568	2	0.2	627.2
Sheep	980	1.2	0.2	235.2
Pigs	190	2.5	0.5	273.5
Poultry (chicken)	5,251	0.07	0.3	110.27

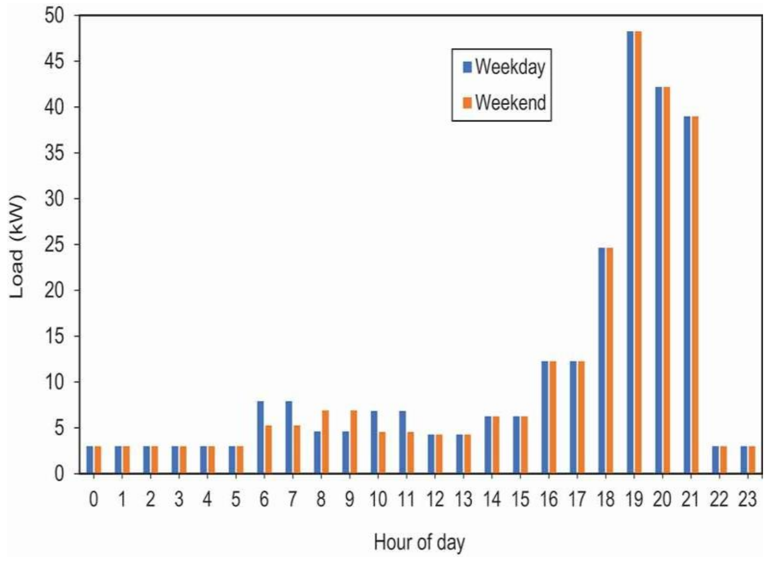
Top 10 selected feasible PV/biogas hybrid system configurations

PV (kW)	Biogas Genset (kW)	Battery (kWh)	Converter (kW)	LCOE ($/kWh)	NPC ($)	Operating cost ($/yr)	Initial Capital ($)	Fuel cost ($/yr)	Capacity Shortage (%)
50	20	237	42.1	0.265	506,629	14,304	221,317	342.8	0.09
50	20	235	42.5	0.265	506,675	14,321	221,011	343.3	0.09
50	20	241	41.9	0.265	506,852	14,273	222,153	341.2	0.09
50	20	237	42.7	0.265	506,958	14,311	221,503	342.8	0.09
50	20	234	43.1	0.265	507,022	14,339	220,999	343.7	0.08
50	20	240	42.5	0.265	507,076	14,286	222,111	341.6	0.08
50	20	228	44.2	0.265	507,170	14,396	220,021	345.9	0.08
50	20	239	43.1	0.265	507,347	14,301	222,099	341.9	0.07
50	20	243	42.8	0.265	507,497	14,269	222,879	340.5	0.07
50	20	237	44.2	0.265	507,835	14,330	222,001	342.8	0.06

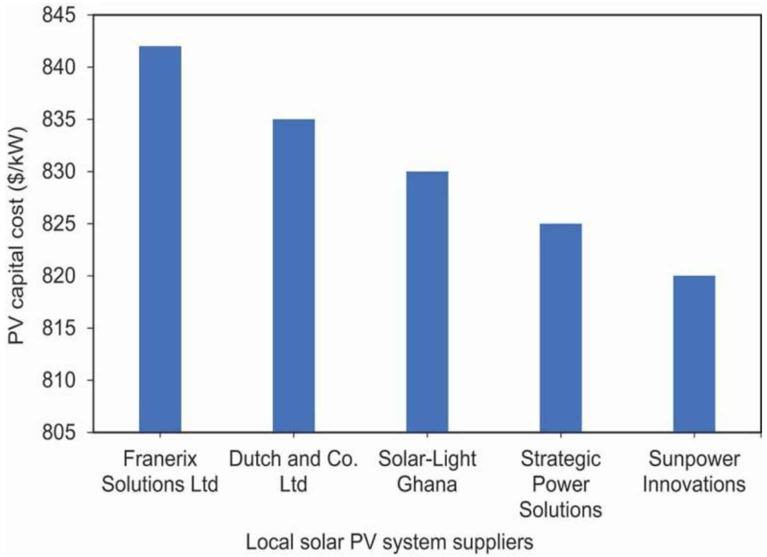
Source: https://doi.org/10.1080/23311916.2022.2034376

Appendix

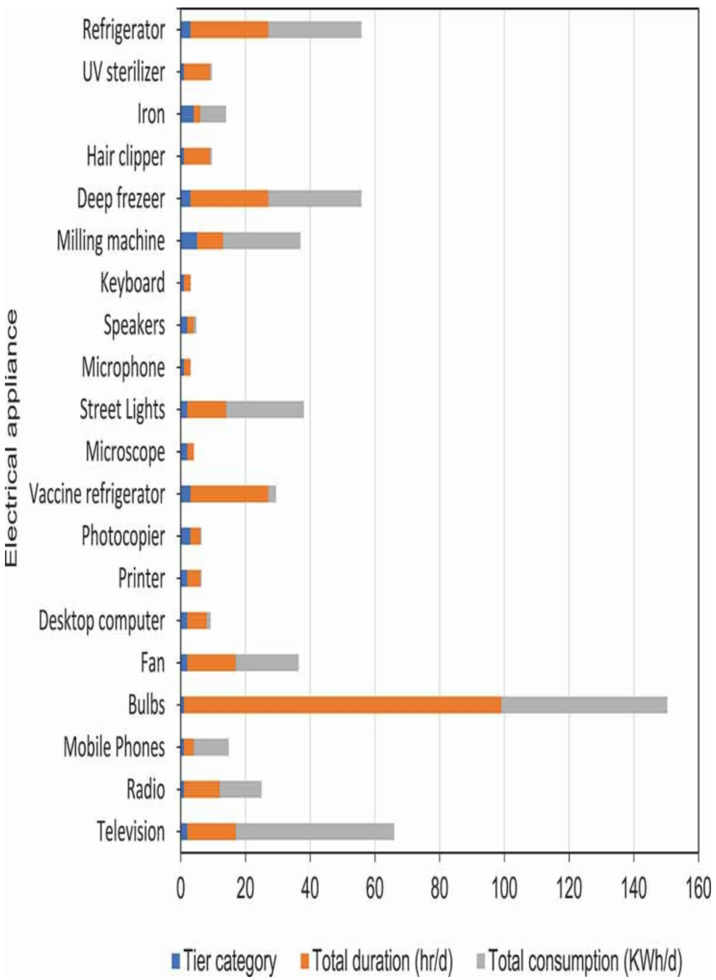
Mankramso's daily hourly load Profile



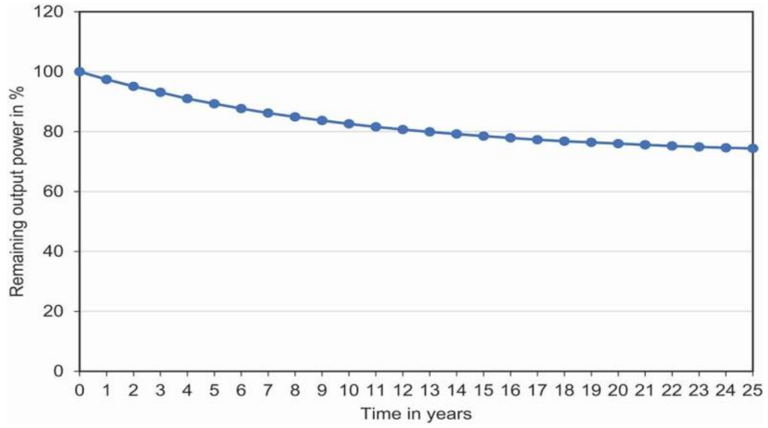
PV module supply and installation costs from local vendors.



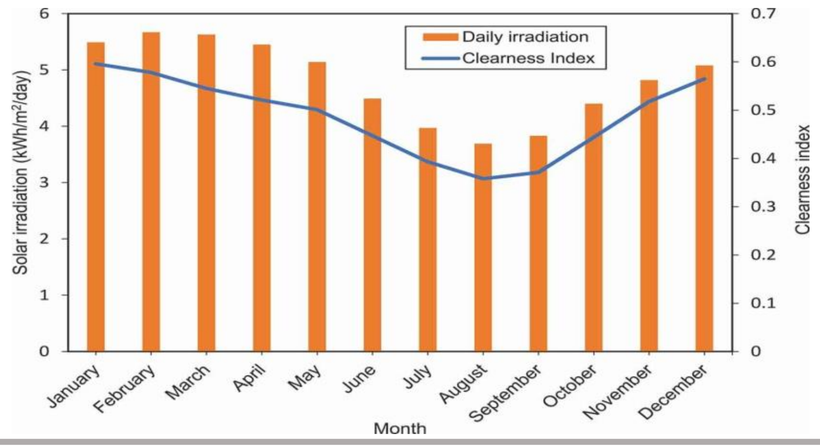
Appliance distribution by tier category, duration, and electricity consumption



Degradation of PV modules



Mankramso's monthly solar irradiation and clearness index.



Source: https://doi.org/10.1080/23311916.2022.2034376

SWITCH ENERGY ALLIANCE

Appendix

Electrical appliances under various tier categories for load estimation

Energy Access Index	Index type	Appliances	Tier category	Quantity	Rated Power (W)	Time of use (hr/d)	Usage (hr/d)	AC loads (KWh/d)
Household use	Households							
		Television	2	200	80	19:00–22:00	3	48
		Radio	1	400	6	6:00–8:00	2	4.8
			1			17:00–20:00	3	7.2
		Mobile Phones	1	600	6	18:00–21:00	3	10.8
		Bulbs	1	1200	10	18:00–22:00	4	48
		Fan	2	200	30	19:00–22:00	3	18
Community use	Nursery school							
	3 classrooms	2 bulbs each	1	6	10	6:00–8:00	2	0.12
	1 office	Bulb	1	1	10	6:00–8:00	2	0.02
		External bulb	1	1	15	18:00–6:00	12	0.18
	Primary School							0
	6 classrooms	2 Bulbs each	1	12	10	6:00–8:00	2	0.24
	1 office	Bulb	1	1	10	6:00–8:00	2	0.02
		External bulb	1	1	15	18:00–6:00	12	0.18
		Desktop computer	2	1	100	9:00–12:00	3	0.3
		Printer	2	1	100	10:00–12:00	2	0.2
	Junior High School							0
	3 classrooms	2 Bulbs each	1	6	10	6:00–8:00	2	0.12
	1 office	Bulb	1	1	10	6:00–8:00	2	0.02
		External bulb	1	1	15	18:00–6:00	12	0.18
		Desktop Computers	2	3	100	9:00–12:00	3	0.9
		Printers	2	1	100	10:00–12:00	2	0.2
		Photocopier	3	1	200	8:00–10:00	2	0.4
	Health Clinic							
	2 wards	Bulbs (3)	1	6	10	00:00–23:00	24	1.44
	1 office	Bulbs (2)	1	2	10	19:00–7:00	12	0.24
		Vaccine refrigerator	3	1	100	00:00–23:00	24	2.4
		Microscope	2	1	30	9:00–11:00	2	0.06
		Small radio	1	1	6	12:00–18:00	6	0.036
		Television	2	1	80	8:00–20:00	12	0.96
	Street Lightning	Street Lights	2	20	100	18:00–6:00	12	24
	Community building	Bulbs	1	8	10	8:00–10:00	2	0.16
		Microphone	1	4	8	8:00–10:00	2	0.064
		Speaker	2	4	100	8:00–10:00	2	0.8
		Keyboard	1	4	15	8:00–10:00	2	0.12
Productive use	Grain milling	Milling machine	5	3	1000	8:00–14:00	8	24
	Cold store	Deep freezer	3	3	400	0:00–23:00	24	28.8
	Small business (tailoring, barbering salon, bars, grocery shops)	Hair clipper	1	5	15	8:00–16:00	8	0.6
		Iron	4	4	1000	10:00–12:00	2	8
		UV sterilizer	1	5	15	8:00–16:00	8	0.6
		Refrigerators	3	4	300	0:00–23:00	24	28.8
		Bulbs	1	5	10	8:00–16:00	8	0.4
		Fan	1	4	30	8:00–17:00	12	1.44

Source: https://doi.org/10.1080/23311916.2022.2034376