TEAM NUMBER: 186
TEAM NAME: THE CATALYSTS

AISHA RANI

SAURAV KUMAR SHARMA

DIVYANSH VERMA

AYUSH DWIVEDI

MENTOR NAME: CHRIS STOREY SELECTED COUNTRY: GHANA HOME COUNTRY: INDIA

GHANA

Population: 31 million

Capital: Accra

Area: 238,535 km2

GDP: US $77.6 billion

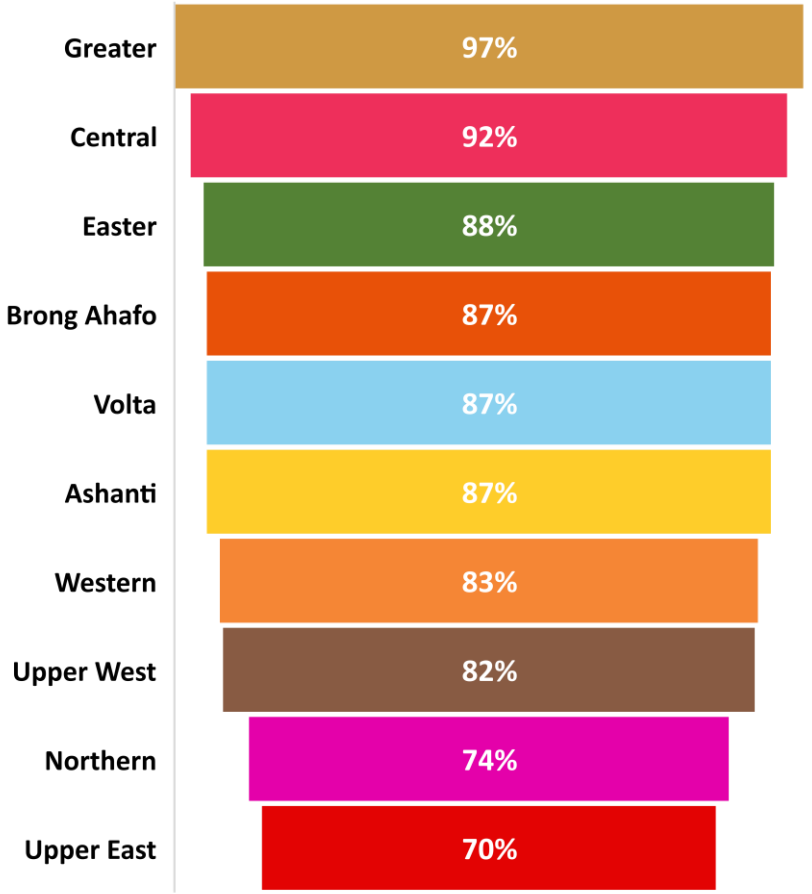
GDP per capita: US $2328

Current Regions: 16

Electricity access: 84.7%

Rural population: 40.02%

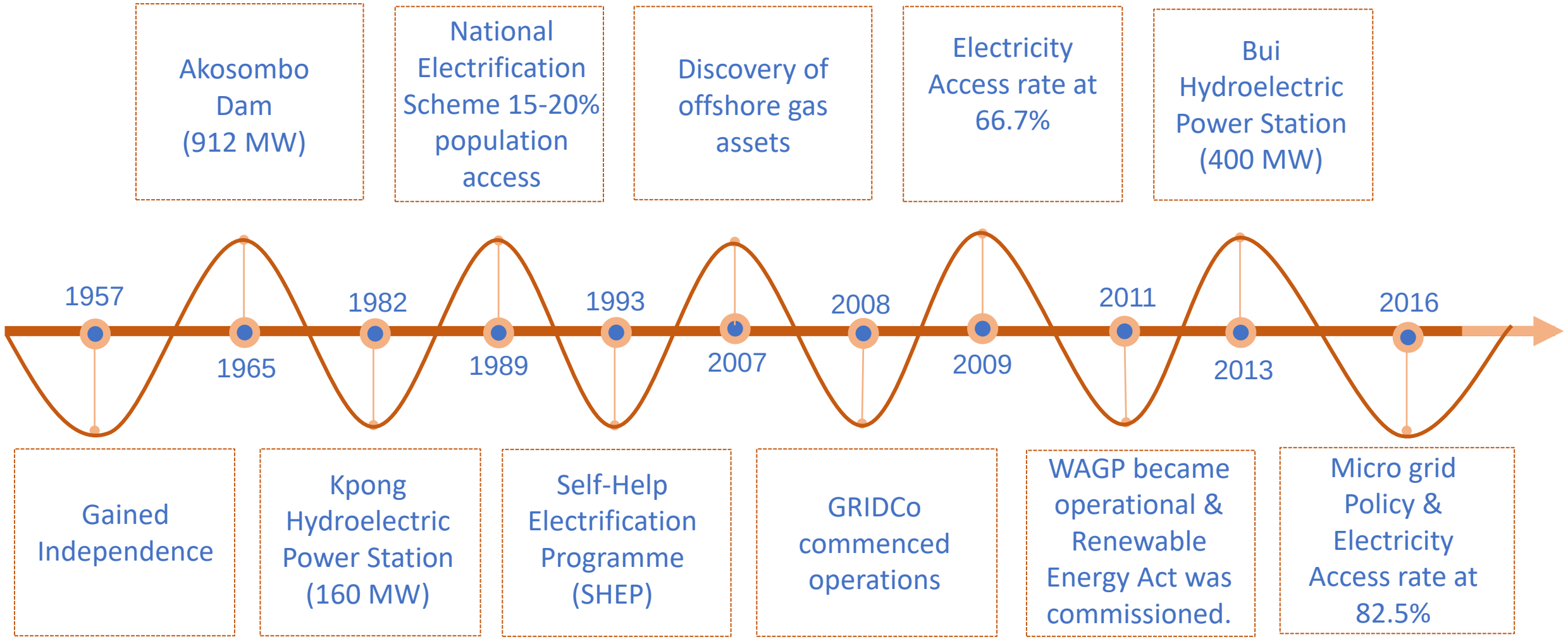
Population Access to Electricity



Sources: World Bank, Statista

SWITCH
ENERGY ALLIANCE

TIMELINE OF ENERGY SECTOR



Sources: Ghana MoE, BBC

SWITCH
ENERGY ALLIANCE

WHAT ENERGY POVERTY MEANS TO GHANA?

Affordability

13.3% of people live on less than **$1. 90/day.**

Clean Fuel

77% people use wood and charcoal as cooking fuel.

Air Pollution

Ghana's annual mean concentration of PM2.5 is **31.1 µ/m3** which is **6 times** higher than safe limit of 5 µ/m3 set by WHO.

Power Crisis

According to ISSER, Ghana loses approx. $2.2 million daily and **$686.4 million annually** (translating into approximately **2% of GDP**) due to power crisis.

Sources: WHO, World Bank, GhanaWeb

PROBLEM OVERVIEW

STORY OF 'DUMSOR'

Regular Power Outages is famously called as 'DUMSOR' in Ghana.

Reasons for Power Outages (DUMSOR):
- Tripped transmission lines.
- Gas/Fuel related shortages.
- Reduced water level at Bui reservoir.

Step taken by government- Arrival of IPP
- Came in the energy scenario to solve the issue of power cuts (DUMSOR).
- Led to a rapid development of the electricity power grid.
- Left public operators in poor financial health.

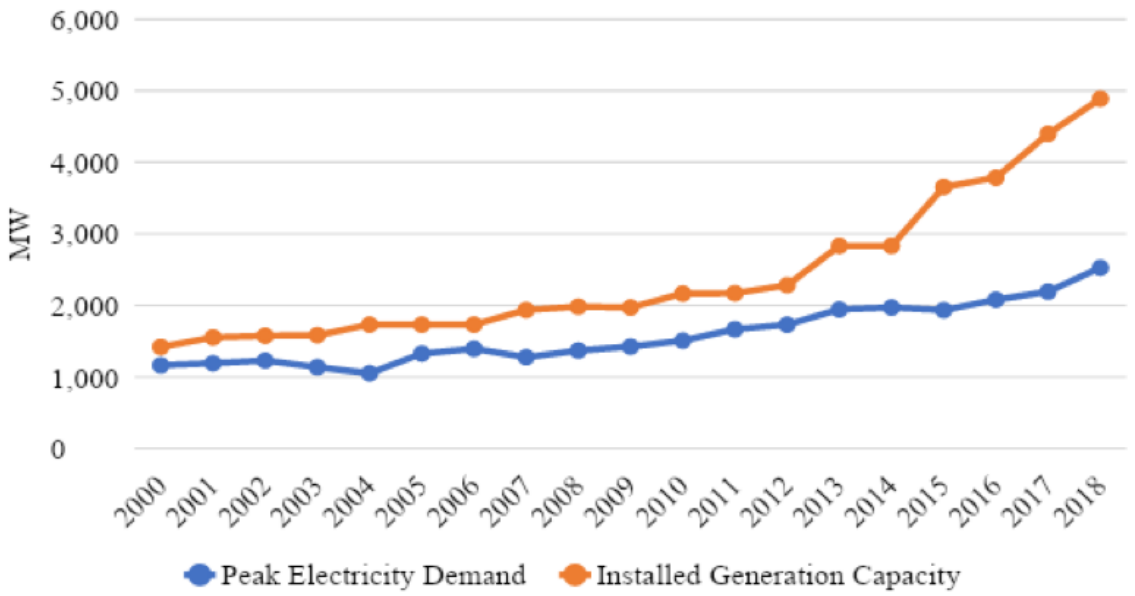
Effects of DUMSOR years on ECG:
- 25% of electricity bought was not sold.
- Insufficient recovery rate.
- Accumulation of debt from public services.
- Debt increased to 2.4 billion dollars in 2017.

Problem with the solution- Pitfalls of 'take or pay' contracts:
- Lack of flexibility
- Inflated prices
- Fixing prices in foreign currency
- Threatening competition
- Political expediency

ECG: Electricity Commission of Ghana **IPP**: Independent Power Producers

Sources: Ebenezer et al. 2017, International Trade Administration

OVERPRODUCTION AND MISMANAGMENT OF ELECTRICITY



Ghana's maximum electricity demand: **2700 MW**
Ghana's current electricity availability: **5083 MW**

Hence, Ghana has **overproduction of 2383 MW** which costs the government around **500 million USD** every year through 'take or pay' contracts.

CASE STUDY ON VALCO

Few things about VALCO or Volta Aluminium Company:

- Started in 1948.
- Was a joint venture with Kaiser Aluminium and ALCOA.
- Consumed **22%** of total electricity produced by Akosombo Dam in 2003.
- Contributed **8%** to Ghana's GDP in 2003
- In June 2008 ALCOA sold 10% stake to Ghana government.

Sequence of shutdowns:

- Electricity irregularities lead to its temporary shutdown.
- In May 2003, VALCO shutdown completely.
- Reopened in 2006.
- In early 2011, VALCO was operating at 20% of its capacity.

Conclusion: Stable electricity is extremely important for the smooth functioning of manufacturing sector.

Sources: Oxford Business Group, Statista, GhanaWeb

DEPENDENCY ON FOSSIL FUEL

- An amount of **US$ 63.23 Million** is required every month (US$758.8 Million for the year) to procure Natural gas and HFO for the operation of thermal power plants in 2021.
- **59.9%** electricity is produced by thermal power plants based on natural gas.
- Ghana receives most of its oil and natural gas from *Jubliee* , *OCTP Sankofa-Gye Nyame* and *TEN* fields.
- Huge Import bill leading to reduction in foreign reserves.

Dependency on West African Gas Pipeline:

- Led to serious near-term gas scarcity.
- Maintenance activities leads to shutdown of thermal power plants.
- Several cases of natural gas pressure reduction resulting in few flow disturbance.

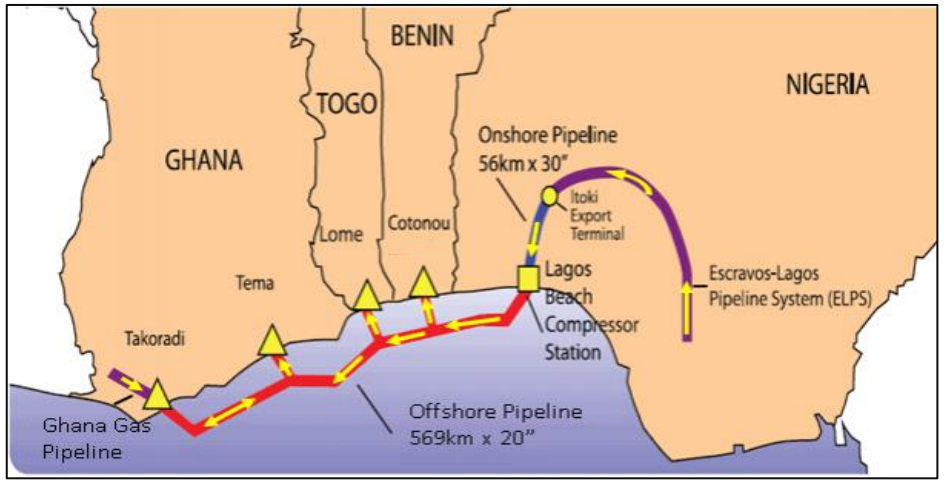
Environmental Impacts:

- Increased carbon footprint.
- Increased pollution.

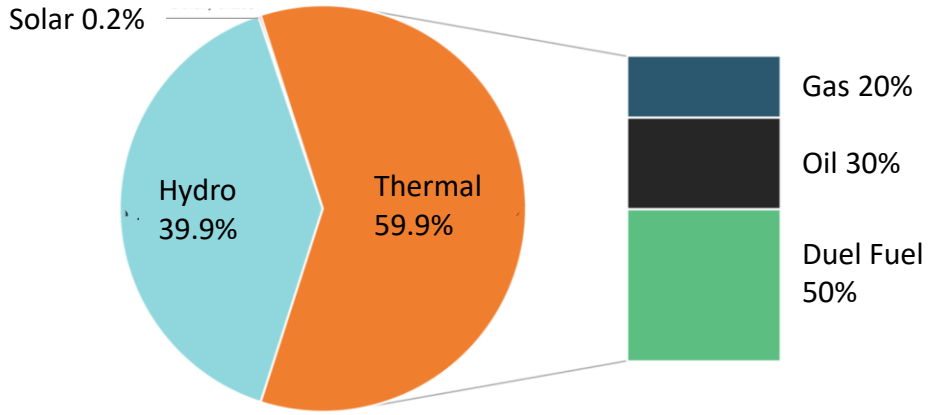
Field name	GNPC Share
Jubilee	13.6%
TEN	15.0%
Sankofa	20.0%

TEN: Tweneboa Enyenra Ntomme **OCTP:** Offshore Cape Three Points

West African Gas Pipeline Map



Ghana Electricity Mix



Sources: World Bank, IRENA

IMPACTS OF MAJOR POWER CUTS, ELECTRICITY AFFORDABILITY AND LOSSES

1984

- First Electricity Crisis
- *Reason:* Drought reduced the inflow of Akosombo dam by 15 %.

2007

- 1.8% of GDP lost
- Drop of productivity of 10% in tertiary sector.
- Led to bankruptcy of several MSME businesses

2014

- 1.4% of GDP lost
- *Reason:* Hydrocarbon supply shortage

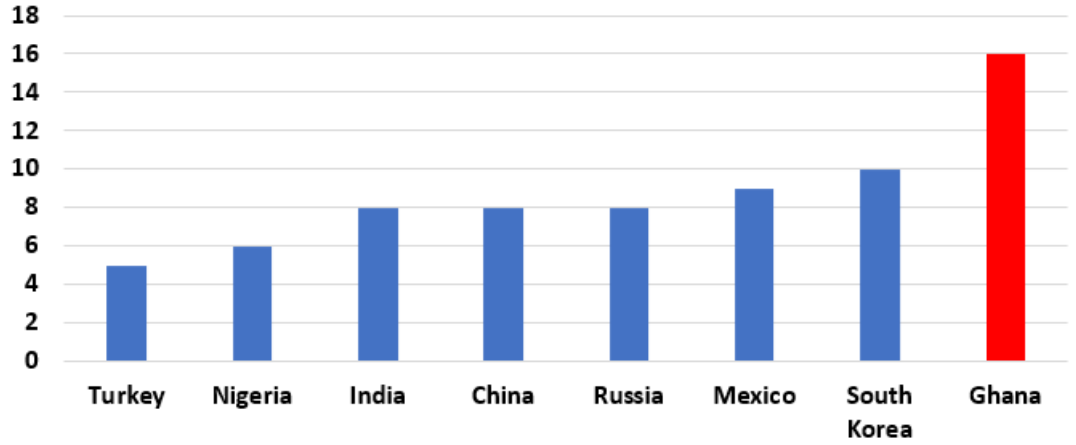
2015

- Energy demand never went up due to tariff increase and slow economic growth.

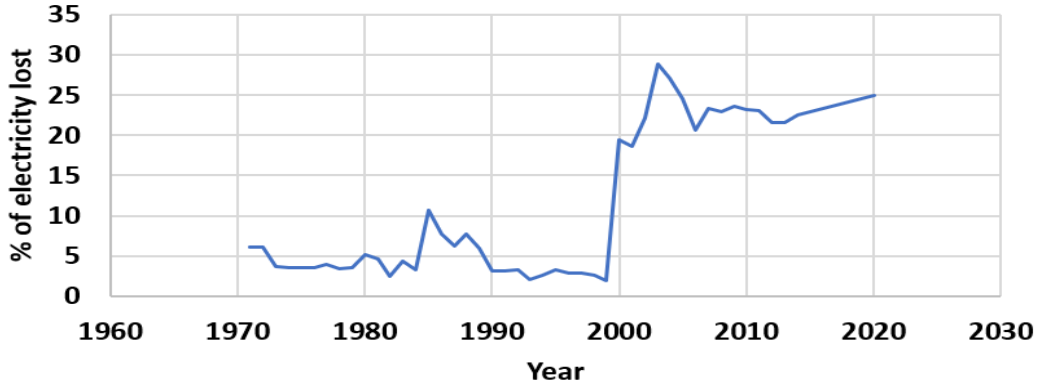
2016

- Government signed 43 power purchase agreements on “TAKE or PAY” basis.

Average Electricity Price (in U.S cents per kWh)



Ghana -(Transmission and Distribution Loss) % of Output

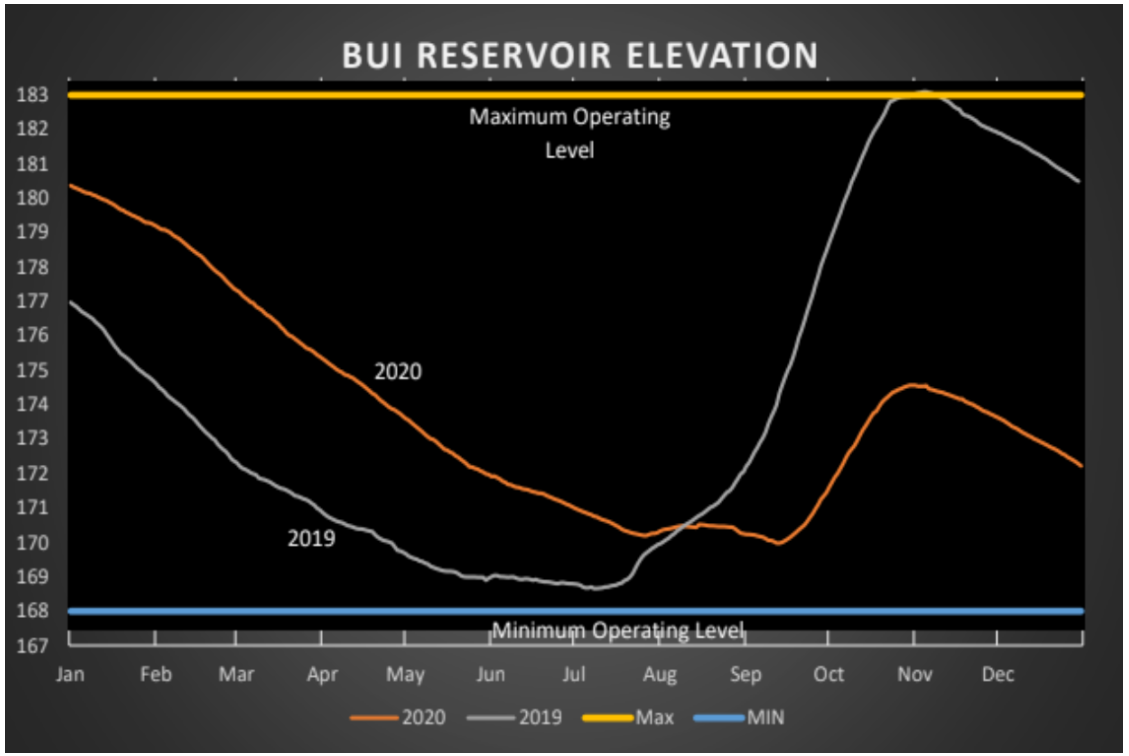


ANALYSIS OF CURRENT HYDROPOWER ASSETS

- Declining rainfall and higher evapotranspiration rates in Burkina Faso could **reduce** the Volta River's annual flow by **24% by 2050.**
- Water availability for hydropower generation depends on upper basin dam releases and abstractions in ***Burkina Faso.*** ***Trans-boundary cooperation*** is needed to reconcile basin development plans and address flood mitigation.

Hydropower Plant	Dependable capacity (MW)	Installed Capacity(MW)
Akosombo GS	900	1038
Kpong GS	105	160
Bui GS	360	400

- In 2010, **700,000** people were displaced after heavy rainfall destroyed a dam and in 2015 flash flooding in Accra killed more than 150 people and caused over **$100 million** in damage.



- Water level of Bui Dam drops below the operating level of ***168 metres*** resulting in it being offline for most of the year.

Sources: IFC, Bui Power Authority, VRA

WOOD AND CHARCOAL: A THREAT TO PUBLIC HEALTH

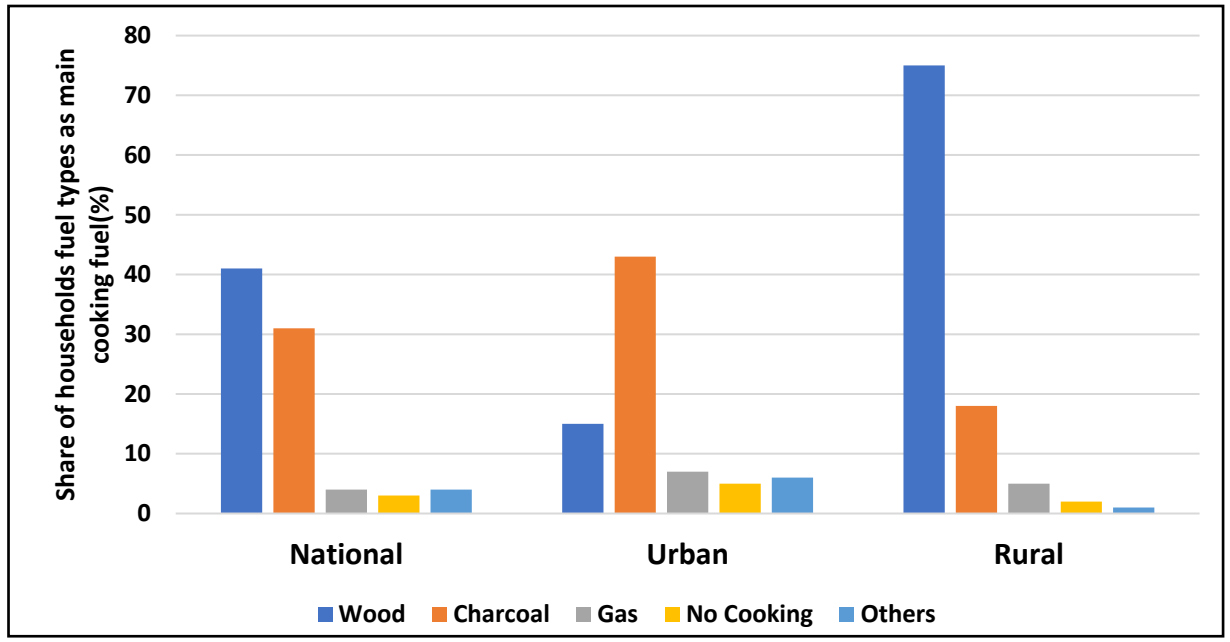
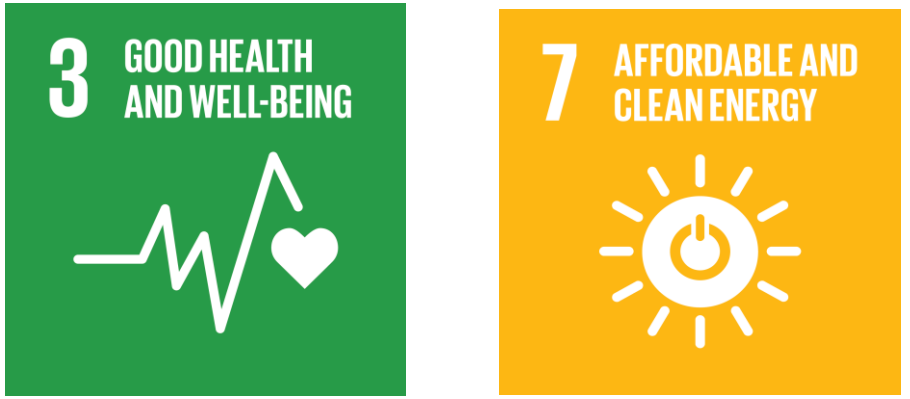


Figure: Cooking fuel sources

- *Firewood* as cooking fuel costs around **$457 million dollars** annually for the entire low income class (**$2-$10 /day**) which accounts **71%** of entire Ghanaian population.

Cooking Fuel:

- **77% people** use wood and charcoal as cooking fuel.
- Clean cooking solutions are unavailable and costly.
- Burning of wood causes increased health concerns like respiratory and pulmonary diseases.
- According to ISSER, In 2019 the polluter **PM2.5** caused **14,500 deaths** in Ghana.



Sustainable Development Goals around the issue

Sources: IRENA, WHO

IMPACTS OF ECONOMIC UNDERDEVELOPMENT ON HEALTHCARE FACILITIES

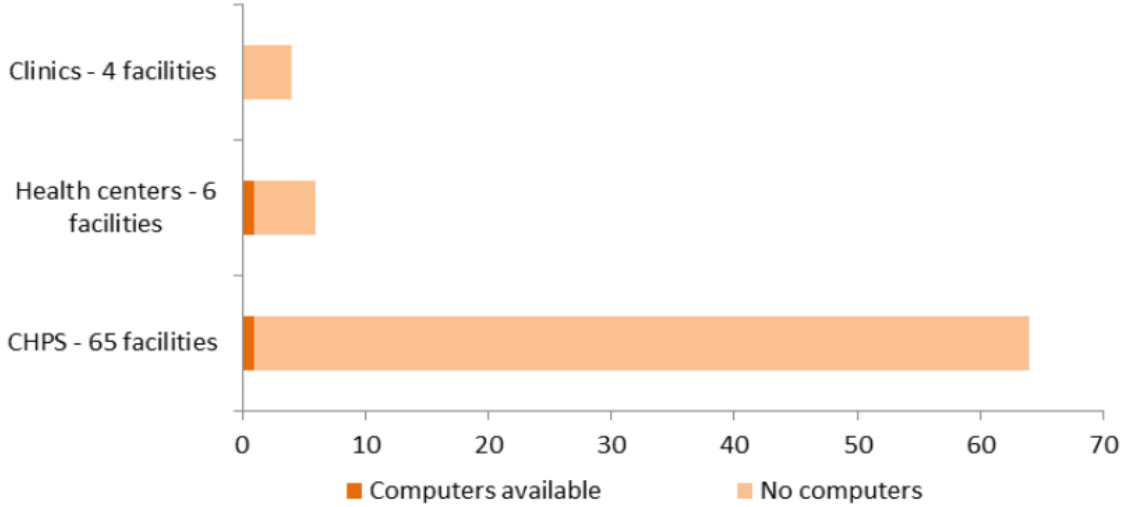
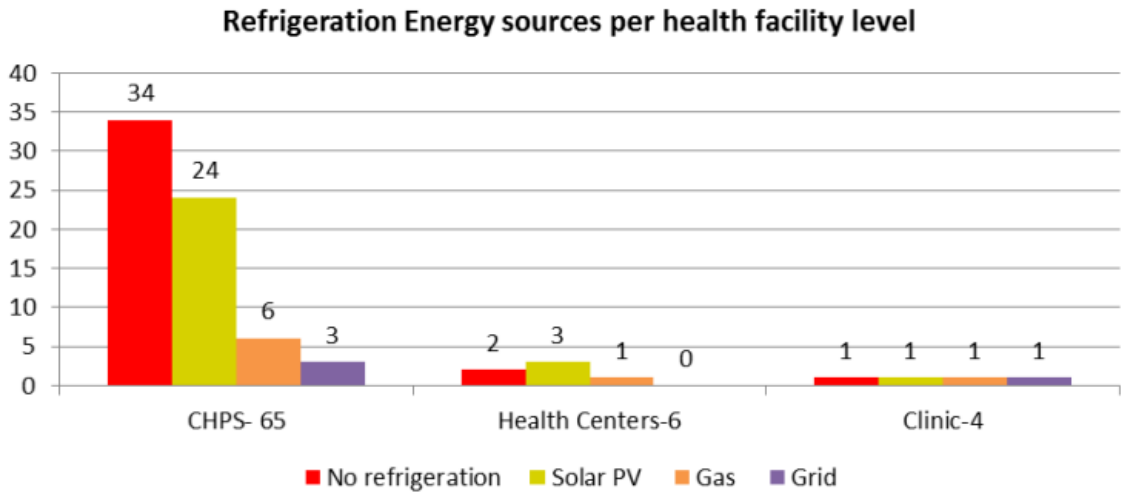


Fig: Graph representing availability of computers at healthcare centres



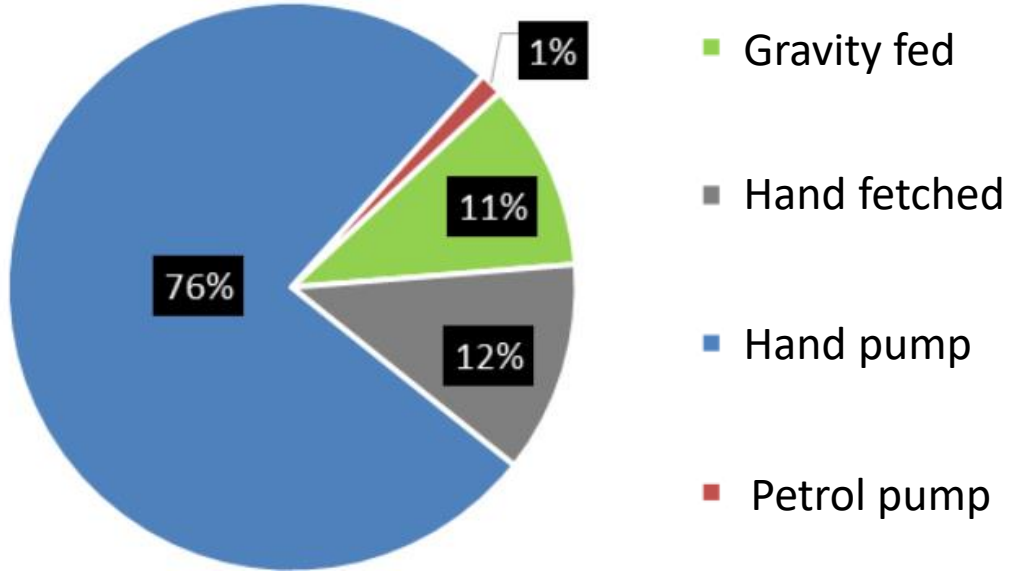


Fig: Graph representing current mode of getting water

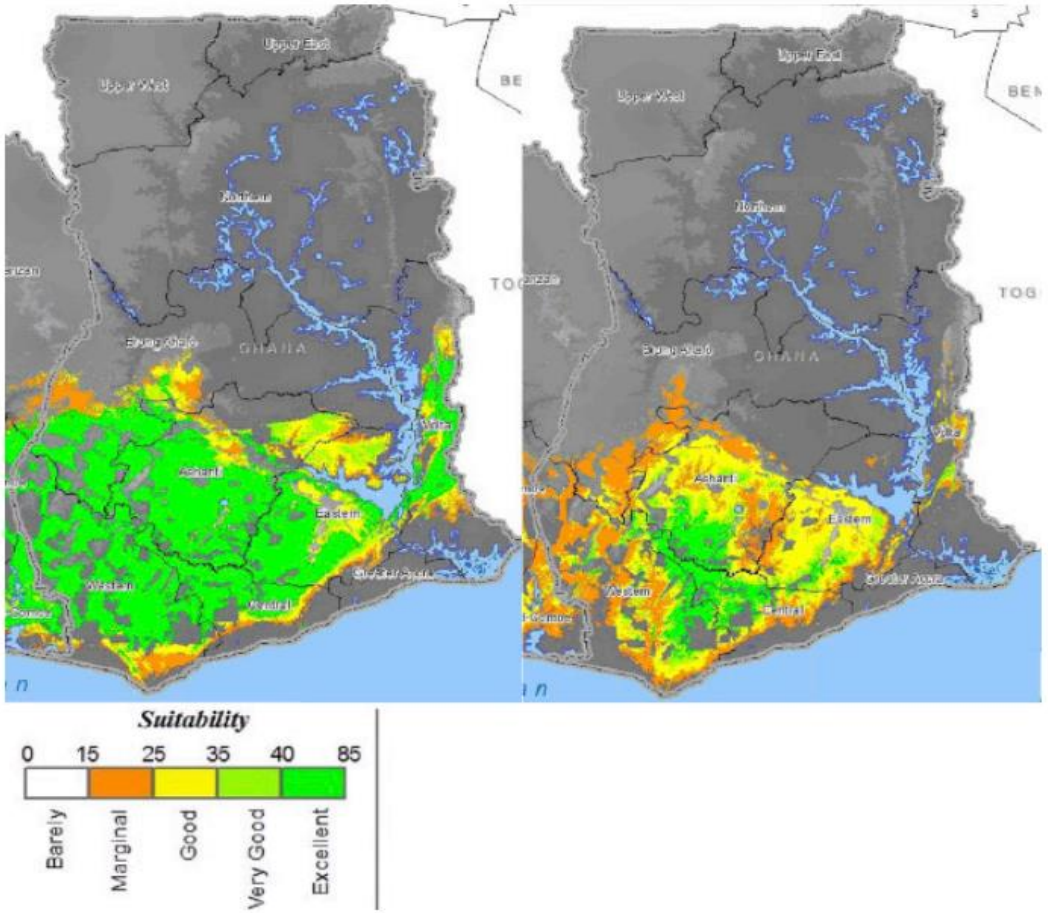
- **33% of births** were attended by a **unskilled** health-care professional.
- Under-5 mortality rate is **49**, due to lack of proper medical facilities.

Sources: WHO, health data

IMPACTS OF CLIMATE CHANGE

- The 2007 floods in the northern part of the country, immediately following a period of drought, affected more than **325,000 people**.
- Variation in rainfall due to climate irregularities had a major impact on the production of Akosombo dam which is responsible for about 70% of the country's electricity demand.
- **Cassava** yields are expected to **reduce** due to increased temperatures and periods of water stress. Projections of productivity losses are up to **13.5% in 2050**, and **53% in 2080**.
- Rice cultivation is expected to be subject to a similar decrease of **0-25%.**

Map 4 Area suitability for cocoa production, current (left) and 2030 (right)



Source: Läderach et al. (2011)

SOLUTION

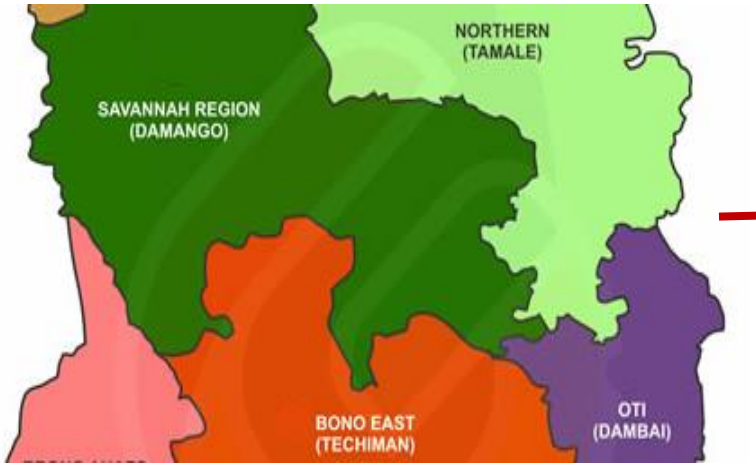
ON-GRID EXPANSION PLAN

***79 unelectrified** rural communities were modelled.*

Assumption:

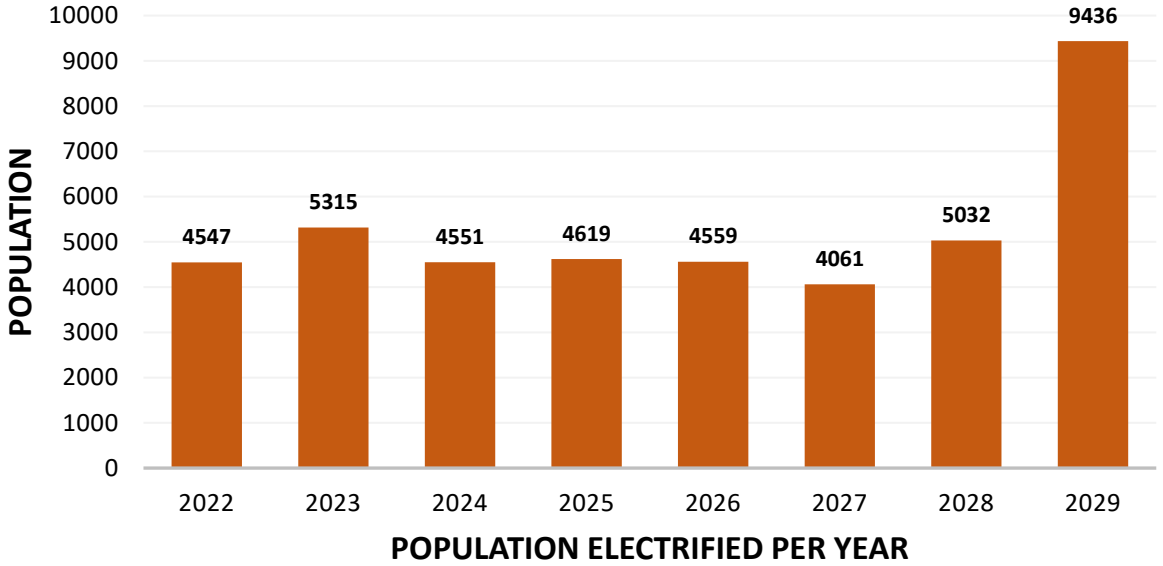
- 1st year: 30% connection rate
- Low income households resulting in low demand per household.
- Income levels will increase with increased connection.
- 90% will be connected by 2030.

Total cost for On-grid extension plan is **$17.2 million** for **79** communities.



- 79 regions were selected from Northern, Brong Ahafo and Bond East regions.

NDPC: National Development Planning Commission



Benefits of On-grid expansion:

- Benefits are worth ***US $26.98 million and US$ 5.28 million dollars*** in household income and health services respectively.
- Benefit-to-cost(BCR) ratio is around **4.5**.
- According to NDPC, "There will be **increase of 46%** in **household income** and improved health services.

Sources: ITA, AfDB

SWITCH ENERGY ALLIANCE

SOLVING OVERPRODUCTION

Formation of Industrial Hubs

- Formation of Industrial Hubs near electricity generation centres.
- Incentives by Ghana's government for establishment of free zones and sector-specific industrial parks as part of the government's Industrial Transformation Agenda.
- The ten-point agenda, introduced in 2017, aims to stimulate local production capacity and position the country as a center for manufacturing in the region.

Grid build-out

- Expansion of transmission infrastructure to bring supply to different corners of the nation.
- Expansion of transmission lines to specific economic zones of the nation to increase productivity.
- Government can negotiate partnership with the interested Industries to set up Transmission lines from power plant to the manufacturing Unit.

Set-up of Microgrids

- Installation of micro-grids to improve healthcare facilities as well as unstable voltage supply for industries.
- Rechargeable Lithium Ion battery to aid hospitals and other buildings during grid failure.
- Battery storage can be used to stabilize those grids, as battery storage can transition from standby to full power within milliseconds to deal with grid failures.

Sell to neighbouring countries

- Ghana is a member of the West African Power Pool, an initiative by Economic Community of West African States (ECOWAS), designed to develop a power transmission network that interconnects the entire West African Region.
- Ghana can sell over-produced electricity to neighboring countries through newly made high-power transmission lines.

BUILDING CROSS-COUNTRY RELATIONSHIP

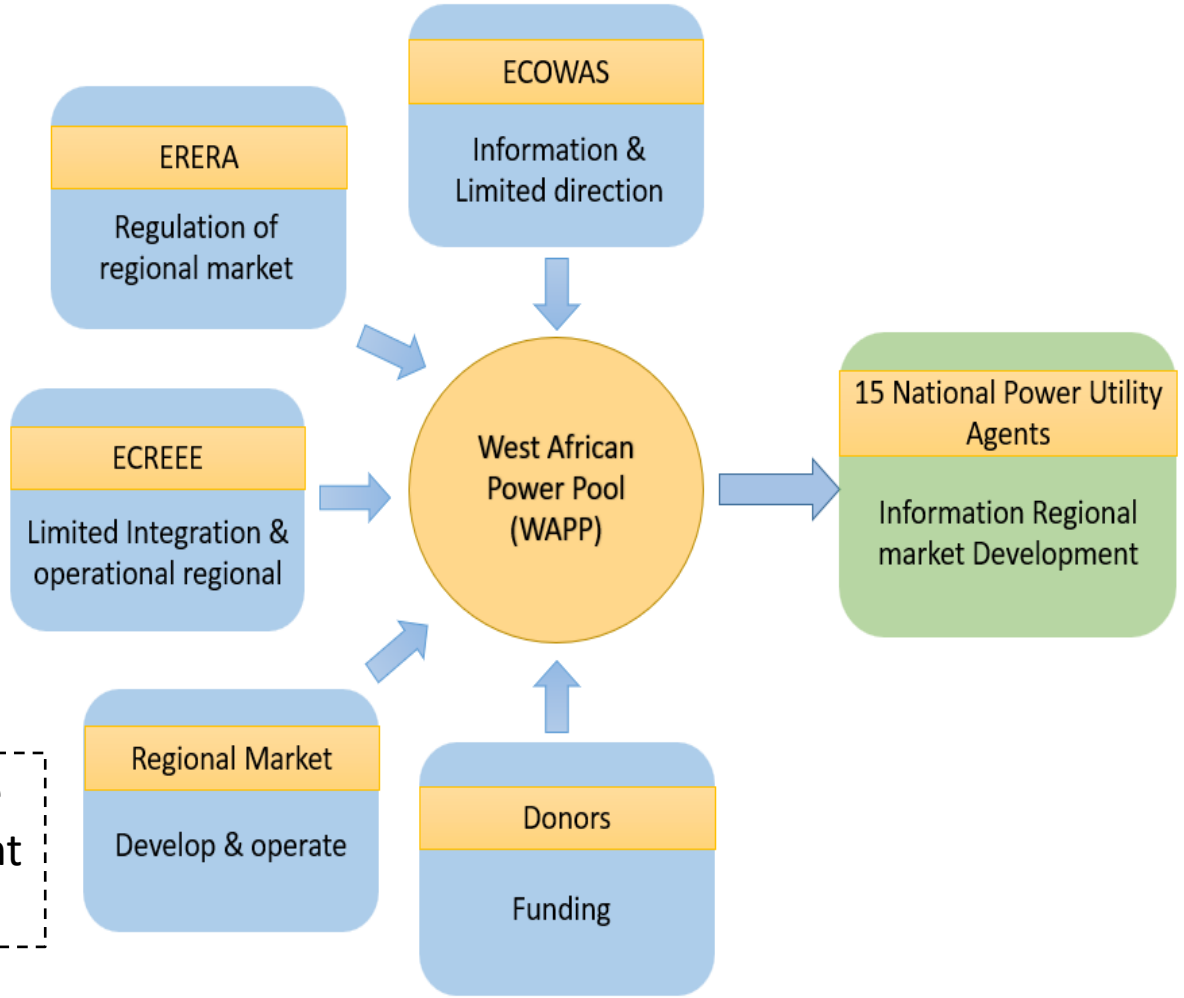
Planned extension:

a. ***225 kV*** power line was introduced between Ghana and Burkina Faso (operational since dec 2018).

b. ***300 kV*** coastal line connecting Accra-Lome-Porto Novo.

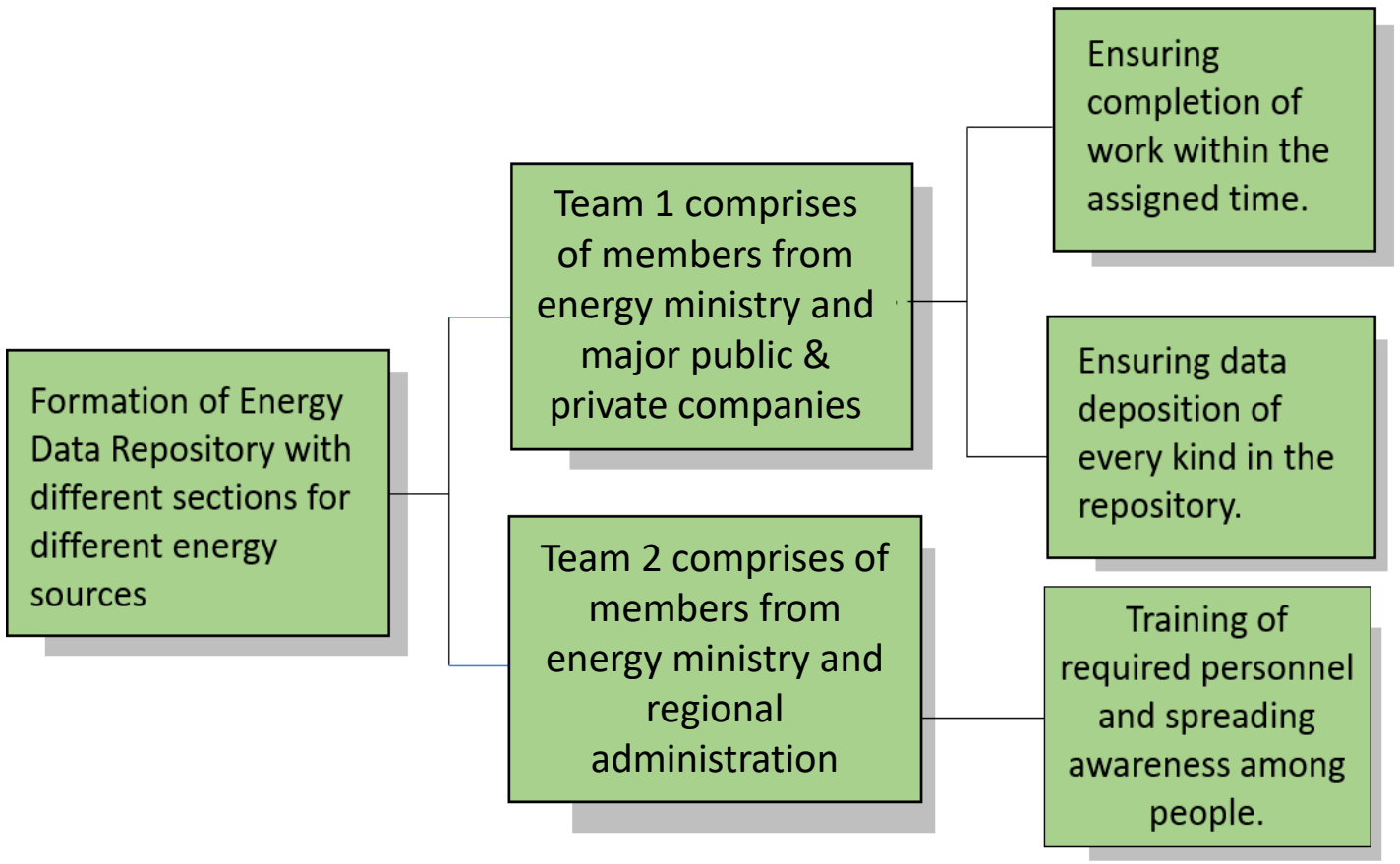
WAPP (West African Power Pool): Primary objective is to develop a power transmission network that interconnects the entire West African Region.

- Country ***30.64%*** of electricity is generated from Akosombo dam whose water-level depends on release from dams of ***Burkina Faso.*** Hence, need for maintaining good trans-boundary relations.



Sustainable Development Goal 17

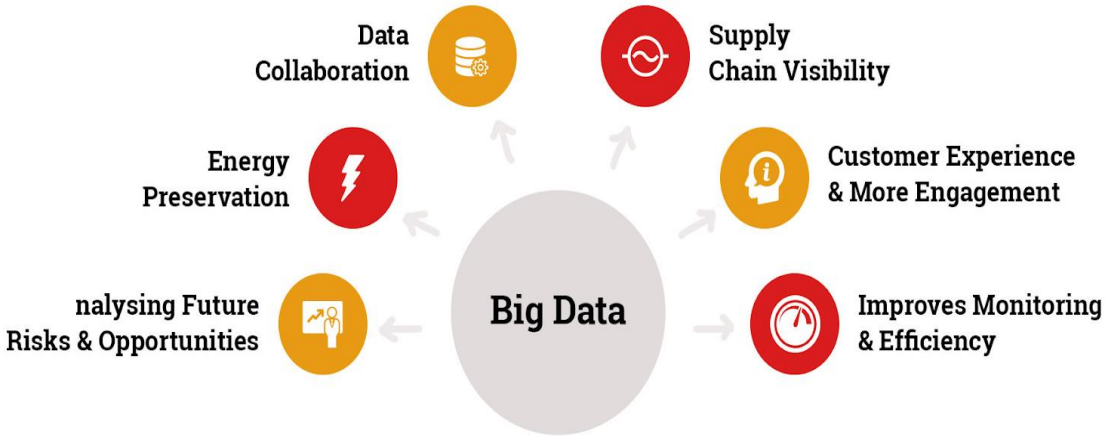
BRINGING TRANSPARENCY TO SYSTEM: NATONAL DATA REPOSITORY SYSTEM



Future Benefits from the repository:

- The techniques of data collaboration, analytics should be used for Analyzing Future Risks and Opportunities, Energy Preservation, Customer Experience & More Engagement.
- Deposition of data into the repository to ensure better efficiency during subsequent works in the same province.

There are many ways in which big data is adding a bigger advantage in the energy sector. Here are few;



WHY OFF-GRID SOLUTIONS OVER GRID CONNECTION?

PROBLEM	SOLUTION
Too many power outages especially in northern part of the country.	Makes you completely energy independent: Power Outages are unpredictable and occur without warning.
The regions are very discreetly populated.	Installation possible virtually anywhere.
The cost of current on-grid electricity is constantly increasing with a high prevailing inflation rate in the country.	Sets free from rising electricity charges.
Too many environment problems caused due to electricity produced from crude oil & natural gas.	Environment friendly.
Not too high demand of electricity as most of the regions are underdeveloped.	An easy alternative for the rural areas.

SCOPE OF SOLAR IN GHANA

Why Solar in Ghana?

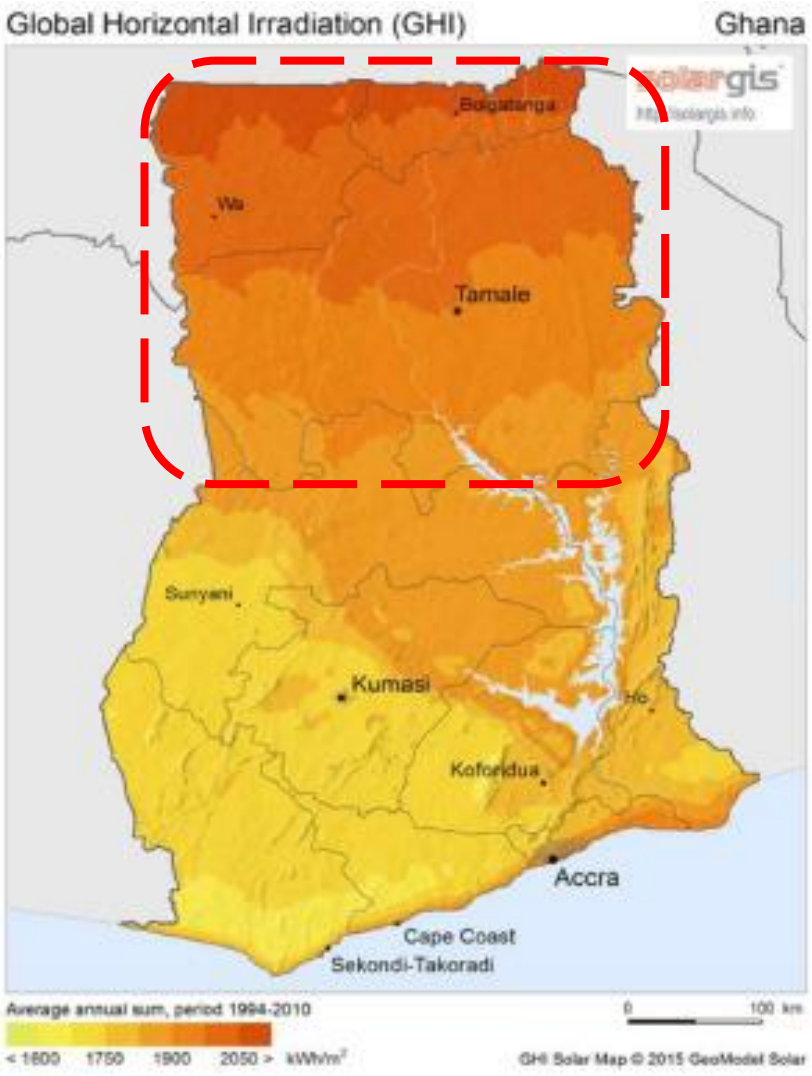
- Receives one of the highest amounts of radiation, globally.
- Daily solar insolation levels range from 4 kWh/m2 to 6 kWh/m2.
- Annual sunshine duration range between 1800 and 3000 h per annum.

Solar at various scales:

a. Community Scale
b. Household Scale
c. Installation at healthcare facilities.

Goal 7:

Ensure access to affordable, reliable, sustainable and modern energy for all.



Power Station	Capacity
Nzema Solar Power Station (BUI)(Planned)	155 MW
Kaleo Solar Power Station(VRA)	13 MW
Gomoa Onyaadze Solar Power Station	20 MW
BXC Power Plant in Accra	20 MW
Navrongo Solar Power Station(VRA)	2.5 MW
Cross Boundary Energy Ghana Limited Solar Plant in Tema	970 KW
Solar Plast Project Company Limited rooftop solar PV plant at Miniplast	782 kWp

Sources: Statista, VRA, BPA

FROM WHERE TO START?

Region	National Grid Connection	Local Mini Grid	Private Generator	Solar Home System	Solar Lantern/ Lighting System	Other	No Electric Power
Western	82.9	0.0	0.1	0.1	0.6	0.8	15.0
Central	84.4	0.0	0.1	0.2	0.9		13.8
Greater Accra	93.7	0.0		0.0	0.1	0.0	5.8
Volta	75.3	0.0	0.0	0.1	0.7	0.3	23.7
Eastern	73.8	0.6	0.2	0.2	0.6	0.2	24.0
Ashanti	89.2	0.0	0.0	0.0	0.2	0.6	9.5
Brong Ahafo	72.5	0.8	0.1	0.1	0.1	0.2	25.9
Northern	66.1	0.0	0.0	0.4	0.3	0.2	32.1
Upper East	47.7	0.0	0.2	0.7	5.3	0.6	38.8
Upper West	57.8	0.9	0.0	0.4	0.2	0.0	40.5

Fig. representing current electricity scenario of each region of Ghana

Reasons for selecting the above regions:

a. Discrete population factor
b. Amount of solar intensity received on average.
c. There is less industrialization.
d. Plain lands available for solar plants installation.

Regions selected for initial Off-Grid Solar (OGS):

a. Upper West
b. Upper East
c. Northern

Assumption:

a. Number of member in a family: **6**
b. Average solar intensity is assumed to be **5.5 kw/sq m/day** for Northern, Upper east and Upper west region.

Table representing information about chosen regions

Region	Population	Families	Electricity demand (Kwh)
Upper East	688328	114721	424468
Upper West	1034688	172448	638057.6
Northern	2445031	407501	1507787

Total electricity demand = **2570314.15 kwh**

Sources: USAID, IRENA

SOLAR AT VARIOUS SCALE

Solar Home Systems

CHALLENGES

- High cost of inverters and batteries, making systems expensive.
- Households with seasonal income have difficulty making payment for fee-for-service installations.
- Difficulty in finding the perfect business model to implement SHS in rural communities

STRATEGIES

- Continue providing incentives through the energy levy
- Provide focused training for technicians in the maintenance of systems
- Encourage local assembling/ manufacturers to supply solar systems and components
- Remove import duty and taxes on raw materials for the production of RE systems.

Community Scale Solar System

CHALLENGES

- Limited access to long term finance.
- Inadequate reserve margin limits integration of larger utility scale solar plant
- Land requirement is significant and could compete with other land use options

STRATEGIES

- Mobilize funds domestically to finance major RE projects;
- Provide government on lending facilities to RE investments;
- Institutionalize competitive procurement to achieve price reduced tariff.
- Upgrade the National Interconnected Transmission System.

SOLAR AT VARIOUS SCALE

Implementation of PV solar panels and solar water pumps in health sectors.

Reasons for low standards of health sector in Ghana.

- There is a lack of easily accessible and reliable data on the availability of energy in healthcare facilities.
- Decentralized energy sources provide critical, yet insufficient, energy services to surveyed health facilities not currently connected to the grid.
- Almost 85% of the CHPS compounds surveyed were not connected to the grid and of these, 70% did not have an acceptable electricity supply.
- The accessibility, quality and reliability of energy-dependent health services varies from service to service and is generally inadequate for maternal and child health service provision.

Methods to improved health facilities.

- Installation of computers in clinics for efficient storage and transportation of every kind of data.
- Installation of independent solar power panels to overcome the problems of electricity outage.
- Installation of refrigerators working on solar energy for preservation of CHPS compounds and other items requiring a particular temperature storage.
- Installation of solar water pumps to improve the water outage problems.

COST CALCULATION FOR SOLAR PLAN

Community /Village Centres	
Family Annual Electricity Needs (kWh)	
Family Annual Electricity Needs	5,500
Daily total	15.1 kwh/day
Solar panel output	9.35 kwh/day

		Unit Cost
	2 Kwh *2	2000 USD
	Shipping & installation	500 USD
	Power storage Batteries	1500 USD
Cost per Community/village		**4000 USD**
Est. # of Villages		**20,000**
Total cost Community/village		**80 Million USD**

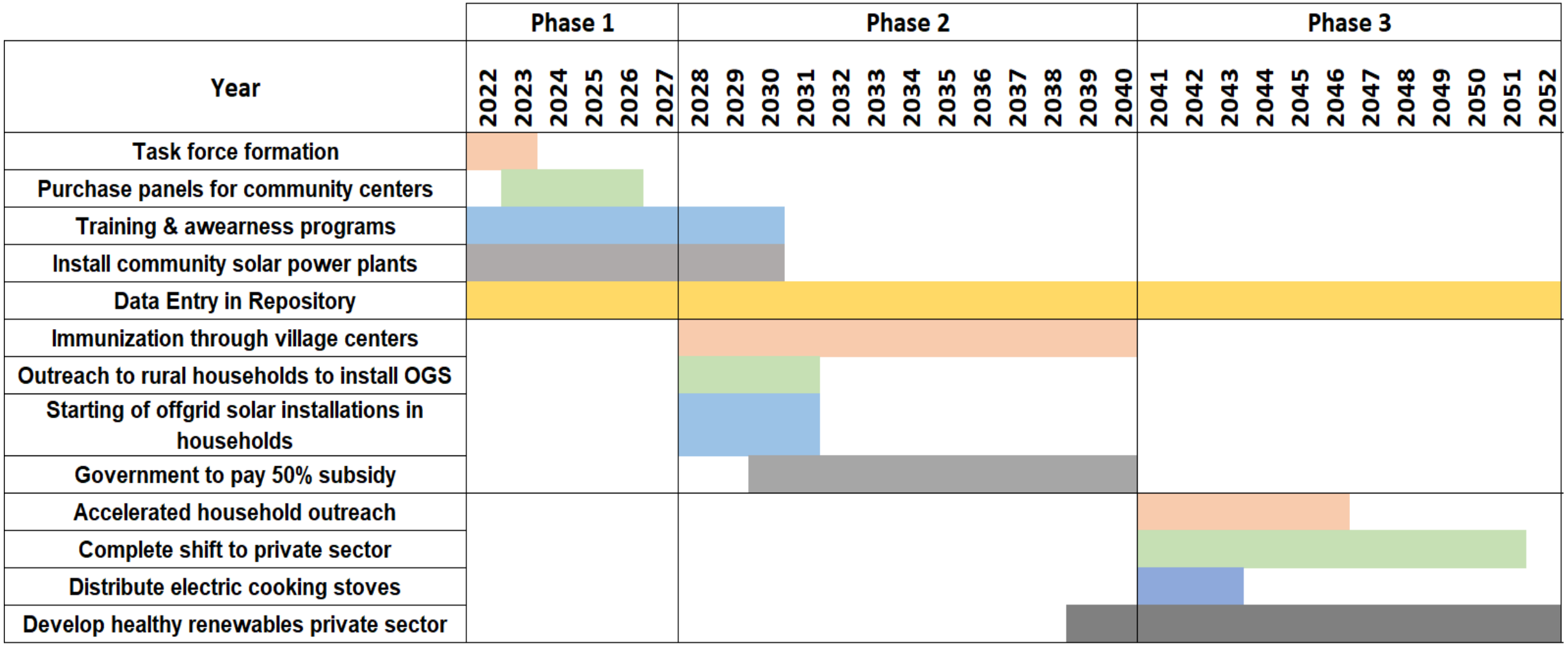
Family Homes	
Family Annual Electricity Needs (kWh)	
Total	1,350
Daily total	3.7 kwh/day
Solar panel output	4.675 kwh/day

		Unit Cost
	1 Kwh	500 USD
	Shipping & installation	200 USD
	Power storage Batteries	300 USD
Cost per household		**1000 USD**
Total cost of the Project for 80% Households of the above mentioned regions		**555.74 Million USD**

***This Plan will bring clean and green electricity for about 555,736 family.**

Sources: United Nations, Alibaba.com, EnergyUseCalculator

TIMELINE FOR SOLAR PLAN IMPLEMENTATION



Sources: AfDB, Prior Estimates

OUTCOMES OF SOLAR ELECTRIFICATION

Targets regions of improvement through electrification:

- Lighting
- Water supply
- Information and communication technology (ICT)
- Sterilization
- Refrigeration

Benefits through solar electrification:

- Average increase of about **25%** in electricity access time.
- The storage time of any medicine **increases by 50%.**
- Solar water pumps reduce both time and labour required for water access through hand pumps and tube wells.
- Solar water heater will improve the sector in proper sterilization techniques.
- Information and communication technology advancements with no power outage will help in proper handling and monitoring of critical data.

Facilities health centers will receive under the scheme:

- Installed independent 2kw solar panel with 573 Amp battery storage.
- Installed solar water pumps (Lorentz PS2-100) to overcome water outage.
- Installed solar water heaters.
- Installed solar water purifiers.

Economic Perspective:

Scheme	Cost (in $ Million) for 1704 Health centers
Solar panel installation	23.85
Operation, Maintenance and installation for 25 years life span	11.5
Installing a Lorentz PS2-100 solar photovoltaic water pump	11.928
Solar water heater installation	2.7
Solar water purifier installation	6.1
Total	**56.08**

Sources: United Nations Foundation, Ghana MoE

WHY BIOGAS?

Why Biogas?

- Inefficient and poor storage facilities leading to massive wastage of *cassava* production (**40-50% of entire production**).
- Environmental concerns of mass-scale deforestation and loss of forest cover due to procurement of wood for cooking fuel.
- Lack of basic sanitation and hygiene facilities.

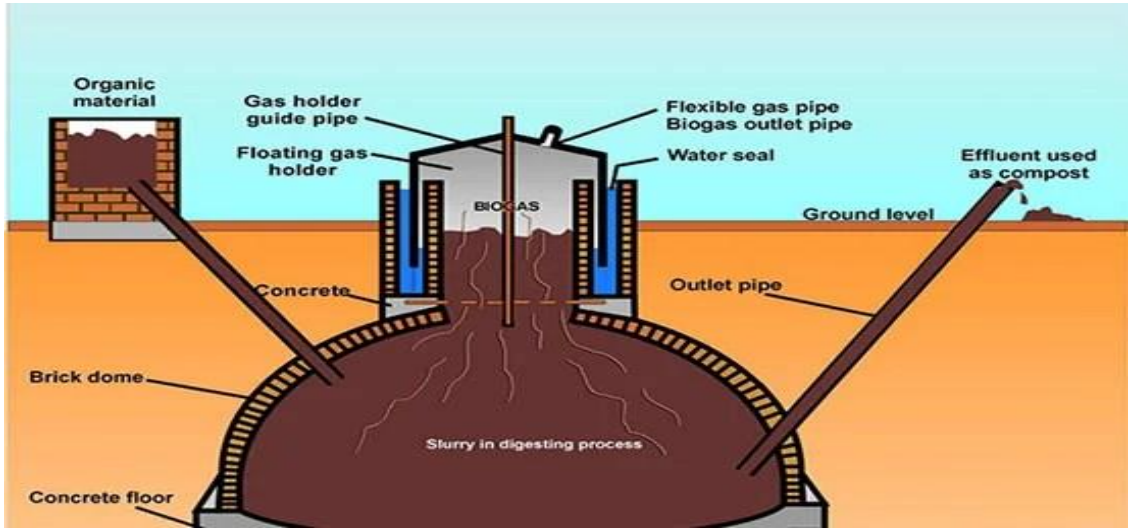


Fig. representing biogas setup

Sources of bio-waste: Human faeces, cocoa husks, kitchen waste.

→ Sustainable Development Goal 11

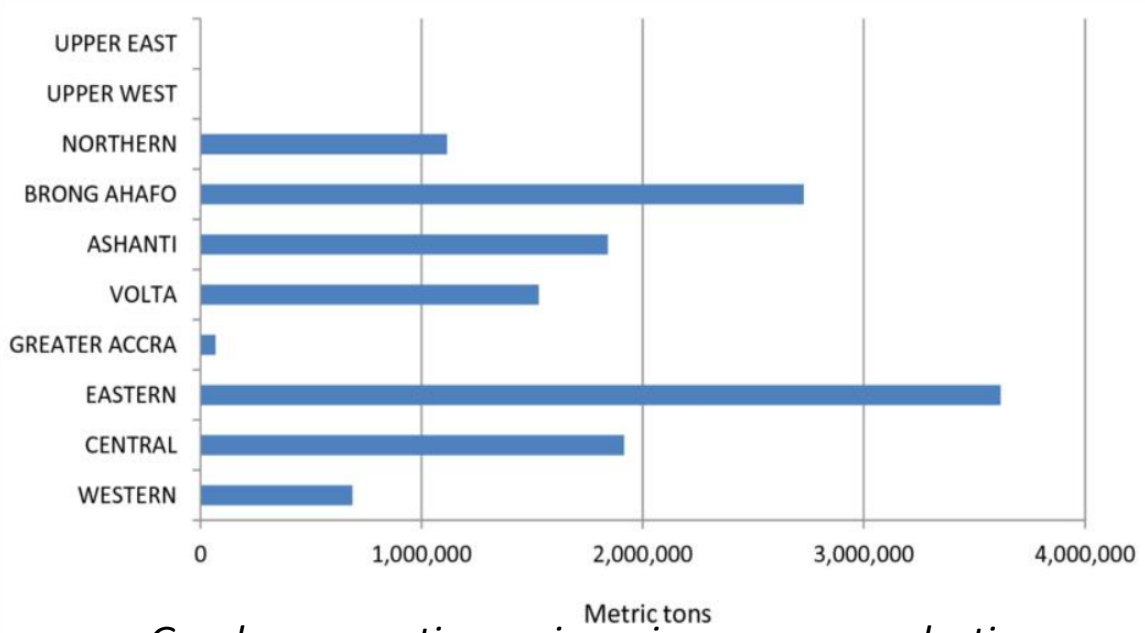
Ghanian population distribution based on income

Income Class	Income Range (in $)	Population %	Total Population
Poor	<2	22.8%	7,425,569.89
Low Income	2-10	71.0%	23,123,485.19
Middle Income	10-20	4.7%	1,530,709.58
Upper Middle Income	20-50	1.4%	455,956.05
Upper Income	>50	0.1%	32,568.29
Total:		**100%**	**32,568,289**

Sources: Pew Research Centre, statsghana

CASSAVA WASTE: A WASTE TO ENERGY INITIATIVE

- *Use:* Cassava can be used for the production of bioethanol, which when blended with gasoline could be used in the existing automobile engines with little or no modification as ***E10 fuel***.
- *Effect:* ***30% of waste*** generated during cassava production could ***offset 9.6%*** of gasoline import.
- *Economic Perspective:* The reduction in import due to offset of gasoline using **10%** of ethanol mix, could generate an additional savings of **71.09 Million USD** as of 2022.
- *Further expansion:* The savings generated shall go in building up transportation pipeline, to transport ethanol from the biofuel plant to the *Tema Oil refinery in greater Accra*.



Graph representing region-wise cassava production

12 RESPONSIBLE CONSUMPTION AND PRODUCTION

Ensure sustainable consumption and production patterns

:Fig. Cassava

Sources: University of Navarra, Kwame et al. 2012

BIOGAS ECONOMIC FEASIBILITY

Economic Feasibility:

- Biogas project is implemented for the income brackets of poor, low and middle income class.

Expenditure	Amount (In million USD)
Investment Cost	200.5
Annual Maintenance Cost	16.04
Total Maintenance Cost (For 30 yrs.)	352.8
Total Cost	553.38

Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation

Benefits: The ***net recovery*** over a span of 30 years amounts to **USD 814.75 million** from the charges procured from the population.

Transition into Reality: The biogas project is planned to launch through ***PPP (Public Private Partnership),*** with the loan amount on the part of the government being procured from international financial institutions **World Bank**.

Loan repayment: The recovered amount shall be used to ***repay*** the loan taken by the government (70 million USD), which amounts to ***259 million USD*** at the end of span of 30 years.

SAVINGS PER HOUSEHOLD PER DAY	INCOME CLASS	NO. OF HOUSEHOLDS	SAVINGS
0.28	Poor	1,650,126.64	5,059,288,286.42
0.28	Low Income	5,138,552.26	15,754,801,242.79
0.252	Middle Income	425,197.11	1,173,288,895.37
	Total	**7,349,577.22**	**21,987,378,424.57**

Sources: Prospect, Safege

ECONOMIC FEASIBILITY

BIO-GAS

INCOME CLASS	NO. OF HOUSEHOLDS	YEARS TO PAY IN	CHARGES PER DAY PER HOUSEHOLD
Poor	1,650,126.64	100% Subsidy	0
Low Income	5,138,552.26	2045-2052~ 07	0.05
Middle Income	425,197.11	2040-2052~ 12	0.085
Upper Middle Income	126,654.46	NA	0
Upper Income	9,046.75	NA	0
Total	**7,349,577.22**		

- ***Poor income class*** is exempted i.e. ***100% subsidy*** is being provided for this class by the government for 30 years.
- Low and middle income classes are charged at the rate of ***0.05 USD*** and ***0.085 USD*** per day per household respectively.
- The charges are a fraction of their current spend on firewood and charcoal. (**17.85% and 33.7%** respectively).

BIO-FUEL

Background: Ghana imports ***97.5%*** of its gasoline consumption which costs ***710.9 million dollars annually***.

Plan of Action: 18 total bioethanol plants in 6 different regions in Ghana, running on cassava production waste.

- *175.77 million dollars of investment and 197.75 million USD of maintenance.*
- Offsetting 10% of gasoline import with ethanol results in an **annual savings of 71.09 million USD**.
- Returns accounted over 30 years amounts to 1776.5 million USD.
- Returns curtail down to **1.5 billion USD** after repaying the loan received for installation for a 30 year period from the **Africa Development Bank**.
- The recovery amount shall be used in setting up *pipeline distribution network for transmission to Tema Oil Refinery in Greater Accra*.
- Pipeline are setup considering the rate of *1Million USD/mile*, with 30% additional offset.

GOVERNMENT POLICIES AND INCENTIVES

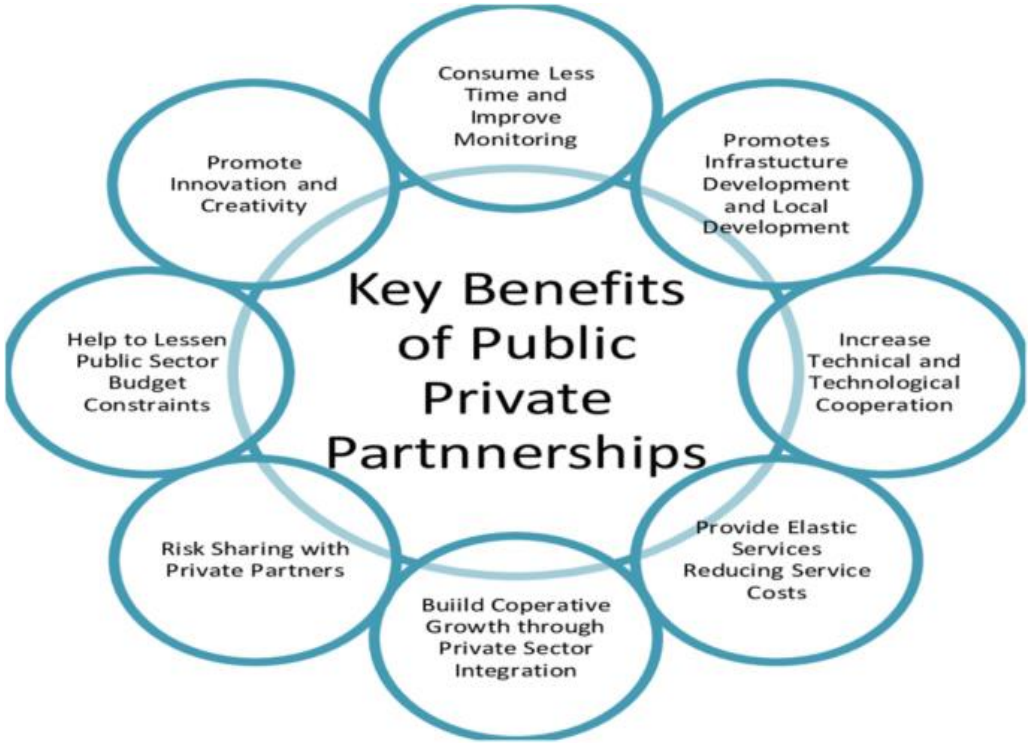
Fiscal Incentives:

- Import-duty exemptions on products used to produce renewable electricity.
- VAT and import-duty exemptions for on-site equipment required.

According to our suggested plan, Return-on-Investment(***ROI***) for Bio-gas Project: ***47%*** and Off-grid Solar Project: ***22.30%*** which is higher than standard ROI demanded by private parties. Hence, Inviting private parties for investment will be ideal.

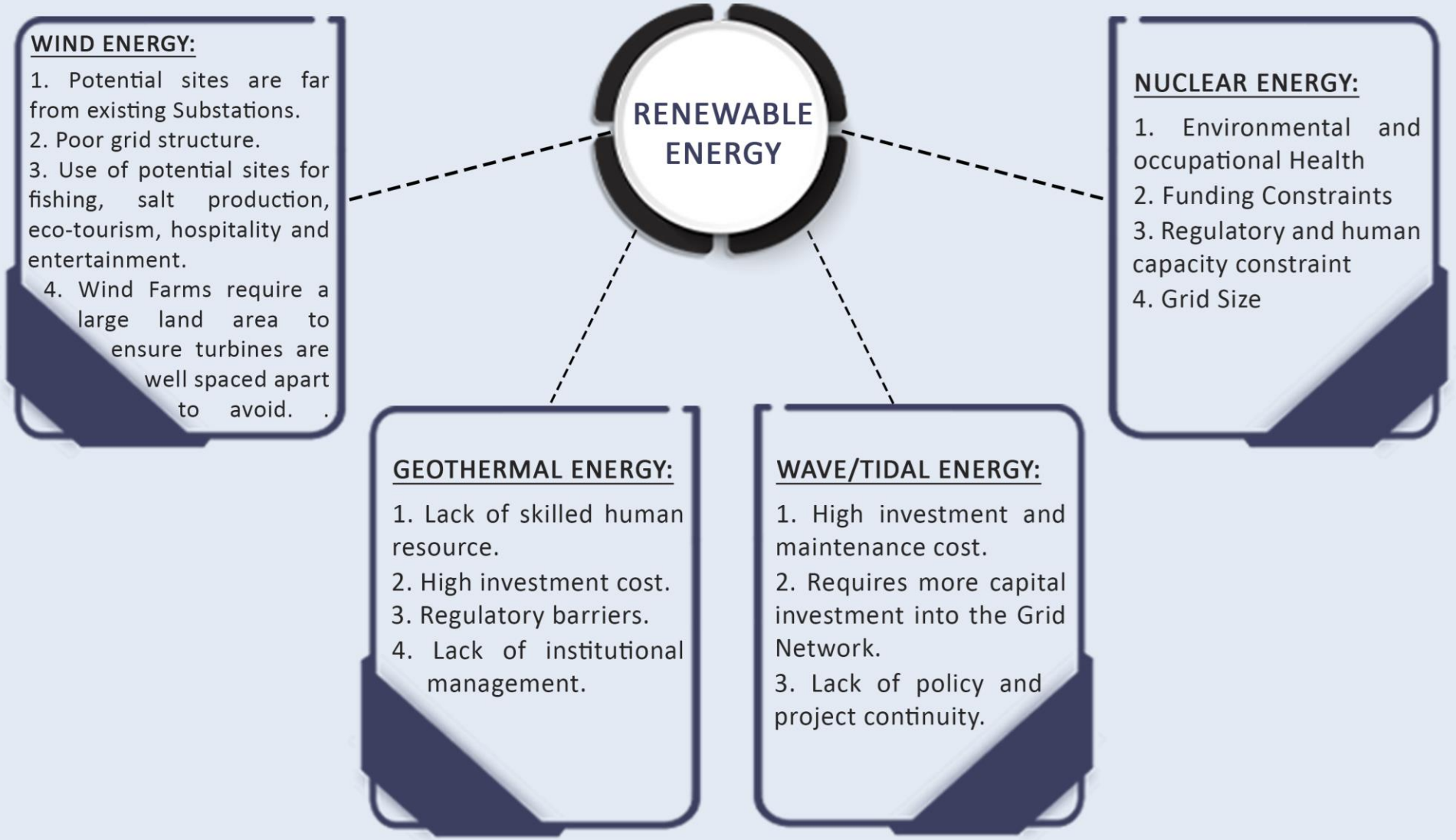
COMPARISON OF PPP WITH PUBLIC-UNDERTAKING PROJECTS

- United Kingdom National Audit Office(UKNAO) reported that, " PPP(Public Private Relationship) underwent ***24%*** cost overrun as compared with ***73%*** cost overrun by companies from public sector.



Sources: World Bank, APMG International

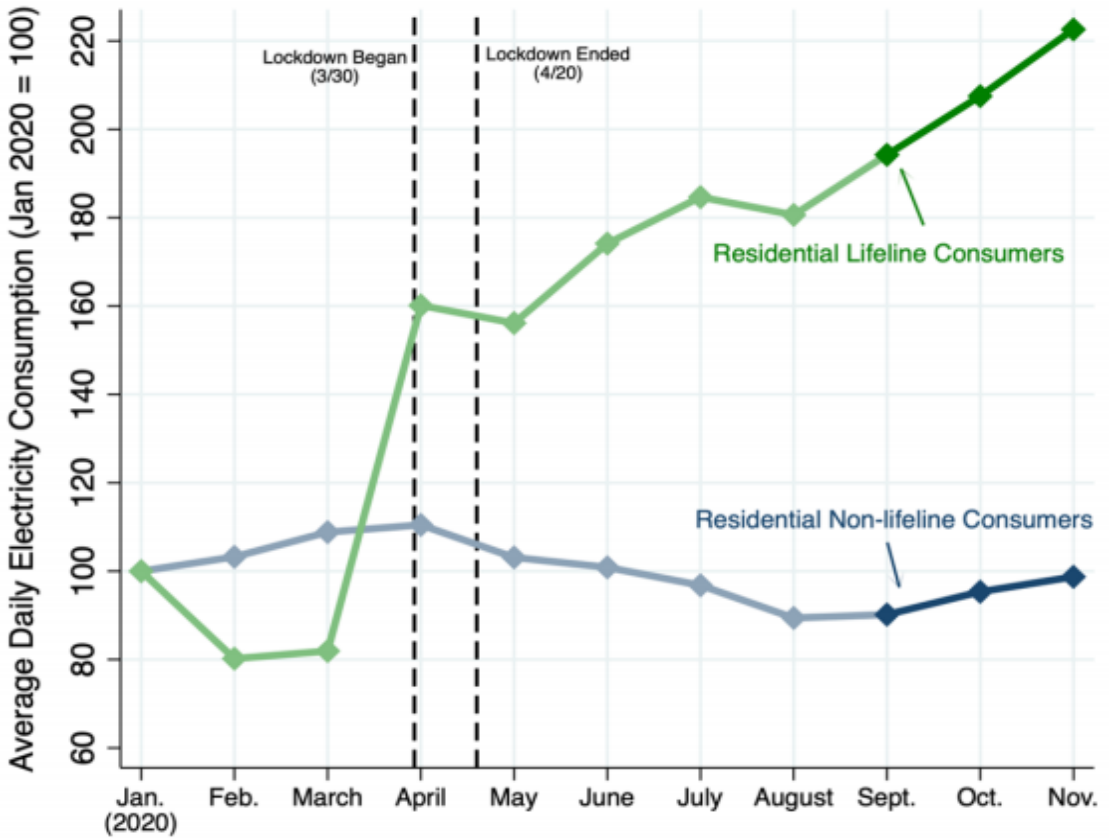
CHALLENGES WITH DIFERENT RENEWABLES



IMPACT OF COVID-19 PANDEMIC

- For northern Ghana, average electricity consumption **increased by 9%** between March and June 2020 when the partial lockdown was imposed.
- Residential consumption increased by 13% from March to June 2020 though it was forecasted to have grown by only 5.3% during the same period.
- In the case of industry, there was **no significant change** in consumption.
- Generally, electricity consumption between March and June 2020, **increased by 5.3%** in southern Ghana.
- In the case of industry, Special Load Tariff-Low Voltage **(SLT-LV) and SLT-HV** customers' consumption reduced significantly by **1.9% and 17.2%** respectively over the period March to June 2020.

Figure 4: Average daily electricity consumption by residential lifeline and non-lifeline consumers in Ghana, Jan-Nov 2020



Sources: World Bank, International Growth Centre, Energy Net

FINANCE

OVERALL COST CALCULATION

Solution	Projects	Target Population	Total Installation cost ($ million)	Total Maintenance cost for 30 years (in $ million)	Total Estimated Cost(in $ million) for 30 years	Return (in $ million) for 30 years	ROI in %	Additional cost in Million USD	Cost to government (Subsidy, investment etc.) in $ million
Off- Grid	Household Solar	Households of Northern, Upper West, Upper East **(3.3 Million)**	$500.74	$55.00	$555.74	$656.71	**18%**	$5.00	**$165.00**
	Community Solar	Rural villages of upper east, upper west, Brong Ahafo, northern **(2million)**	$78.00	$2.00	$80.00	NA	NA		**$80.00**
	Health Facilities	All Health Centers (**1704 Health facility**)	$38.90	$19.18	$58.08	NA	NA		**$58.08**
On- Grid	Grid Extension	People living Near grid	$16.67	$1.03	$17.70	NA	NA	NA	**$17.70**
Biogas Plants	Bio- fuel	Population using transport facility	$175.77	$197.75	$373.52	$1,776.50	NA	$15.00	**$197.75**
	Bio gas for clean cooking	Population in poor, low income bracket (**93.8% Population**)	$203.55	$353.00	$556.55	$814.75	**47%**		**$353.00**

ENTIRE ESTIMATED COST OF OUR PROPOSED SOLUTION = 891.53 MILLION USD

ON-GRID EXTENSION

ON-GRID EXTENSION INVESTMENT

Year	No. of communities	Total distribution line length	Cost of medium voltage lines	Cost of low voltage lines	Other costs	Total
2022	10	15600	702000	521664	60746	1284410
2023	10	25794	1160730	608608	62919	1832257
2024	10	28437	1279665	560560	62961	1903186
2025	10	27642	1243890	570856	63294	1878040
2026	10	39909	1795905	565136	63221	2424262
2027	10	37754	1698930	539968	60486	2299384
2028	10	44827	2017215	663520	69929	2750664
2029	9	34869	1569105	1257256	87858	2914219
Total	**79**	**254832**	**11467440**	**5287568**	**531414**	**17286422**

REVENUE GENERATED FROM ON-GRID EXTENSION

Year	Cumulative population included	Electricity consumed per day per family	Total amount of revenue generated	Total revenue generated in until 2052
2022	4547	3.5	$34,853	$1,045,583
2023	9872	3.5	$75,669	$2,194,398
2024	14423	3.5	$110,552	$3,095,464
2025	19042	3.5	$145,957	$3,940,837
2026	23600	3.5	$180,894	$4,703,244
2027	27661	3.5	$212,022	$5,300,539
2028	32693	3.5	$250,592	$6,014,204
2029	42129	3.5	$322,919	$7,427,132
			Total	**$33,721,401**

DETAILED COST CALCULATION FOR SOLAR INSTALLATION

Family Homes	
Family Annual Electricity Needs (kWh)	
One fridge	400
Two fans 6 hrs/day 75 watt	300
Two CFL Lights 8 hrs/day	150
Other potential needs	500
Total	1,350
Daily total	3.7 kwh/day
Solar panel output	4.675 kwh/day

	Unit cost
1 Kwh	500 USD
Shipping & installation	200 USD
Power storage Batteries	300 USD
Cost per household	1000 USD
Total cost of the Project for80% Households	**555.74 Million USD**

Community /Village Centres	
Family Annual Electricity Needs (kWh)	
Area Fans x 5	2500
Big CFL lights 8hrs/day	2000
Other potential needs	1000
Total	5500
Daily total	15.1 kwh/day
Solar panel output	9.35 kwh/day

	Unit cost
2 Kwh *2	2000 USD
Shipping & installation	500 USD
Power storage Batteries	1500 USD
Cost per Community/village	**4000 USD**
Est. # of Villages	**20,000**
Total cost Community/village	**80 Million USD**

Sources: United Nations, Alibaba.com, USAID

DETAILED COST CALCULATION FOR SOLAR INSTALLATION

	Investment & Maintenance costs						
Years	2022-2027	2027-2032	2032-2037	2037-2042	2042-2047	2047-2052	TOTAL
On grid extention	12.4 Million USD	4.3 Million USD	0.2 Million USD	0.2 Million USD	0.3 Million USD	0.3 Million USD	17.7 Million USD
Community based solar	30 Million USD	50 million USD	0.8 Million USD	1 Million USD	1.2 Million USD	2 Million USD	85 Million USD
Off grid solar	NA	55 Million USD	125 million USD	125 Million USD	125 Million USD	125 Million USD	555 Million USD

Economics of Private Firms for Off-grid Solar	
Charging rate per kwh of solar electricity used	0.035 per kwh
Total estimated demand in per day	2570314 kwh per day
Total estimated revenue per year	32.85 Million USD
Total revenue generated in 30 years	656.71 Million USD
Benefit To investment Ratio	18%
Calculated subsidy by government in first 10 years	165 Million USD

Potential private investors		Current investment in Ghana
Existing parties	Beijing Xiaocheng Company	30 million USD
	Blue Energy plc.	400 Million USD
	Meinergy Ghana	29 Million USD
New Interested private parties	Mobisol (UNDER ENGIE)	NA
	JABO LLC	
	BIOLITE	
	ECOZOOM	

POTENTIAL DONORS

Project	Lenders	Borrowed amount (in $ million)	Interest Rate	Payback period	Payback amount (in $ Million)
Bio-gas Plant	World Bank	70	5%	20 Years	175
Bio - Fuel Plant	Africa Development Bank	75	5%	20 Years	187.5

Other Potential Donors

- USAID
- CIDA
- The International Renewable Energy Agency (IRENA)
- United Nations Environments Programme (UNEP)
- Global Environment Facility (GEF)
- The French Development Agency
- The European Union
- Export-Import Bank of Korea
- Japanese International Cooperation Agency

SOLAR FOR HEALTHCARE FACILITIES

Solar Panels	
Cost for 2kw Facility level Micro-grid (48V) along with 573Ah Battery storage	$14,000.00
Total number of Health Facility	1704.00
Cost for installation of solar panels	$23,856,000.00
Maintenance cost per year per health facility	$250.00
Operation cost per year per health facility	$125.00
Cummulative operational and maintenance cost	11.5 Million USD

Pump	
Cost for ONE LORENTZ- PS2-100 solar photo voltaic water pump	2000
Operation and Maintenance cost per year per health facility	200
Cost for LORENTZ- PS2-100 solar photo voltaic water pumps for all health facility	11.928 Million USD

Solar heater & purifier			
Organisations	Government	Quasi - Government	TOTAL
No. Of Health Facilities	1625	79	1704
Cost Of Water Heater(USD)	1608.15		
Total Cost of Water Heater(USD)	2613243.75	127043.85	2740287.6
Cost Of Water Purifier(USD)	3600		
Total Cost Of Water Purifier(USD)	5850000	284400	6134400
Total Amount(USD)	8463243.75	411443.85	$8,874,687.60

BIO GAS

Current expenses of using firewood and charcoal as a cooking fuel

Income Class	Total Firewood Consumption (Kg per year)	Firewood Cost, Annually	Firewood Cost (per kg)	Firewood expense per day for one household
Poor	1,837,251,003	$648,933,840	$0.08	**$0.24**
Low Income	5,721,264,091			
Middle Income	419,329,386			**$0.22**
Upper-middle Income	124,906,625			
High Income	8,921,901			
Total	**8,111,673,009**			

Income Class	Total Charcoal Consumption (Kg per year)	Total Charcoal Cost, Annually	Charcoal Cost (per kg)	Charcoal Expense per day for one household
Poor	726,385,748	$96,898,660	$0.03	**$0.036**
Low Income	2,261,990,706			
Middle Income	183,132,393			**$0.035**
Upper-middle Income	54,550,074			
High Income	3,896,433			
Total	**3,229,955,357**			

BIO GAS

Savings per household per day	Income Class	Investment Cost	Annual Maintenance Cost	2022-2027 Installation	Maintenance Cost: 2027-2030	2030-2035	2035-2040	2040-2045	2045-2052	Total Maintenance Cost	Total Cost
0.28	Poor	$46,409,812	$3,712,785	$46,409,812	$0	$18,563,925	$18,563,925	$18,563,925	$25,989,495	$81,681,269	$128,091,081
	Low Income	$144,521,782	$11,561,743	$144,521,782	$0	$57,808,713	$57,808,713	$57,808,713	$80,932,198	$254,358,337	$398,880,120
	Middle Income	$9,566,935	$765,355	$9,566,935	$0	$3,826,774	$3,826,774	$3,826,774	$5,357,484	$16,837,805	$26,404,740
0.252	Upper Middle Income	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Upper Income	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Total:	**$200,498,529**	**$16,039,882**	**$200,498,529**	**$0**	**$80,199,412**	**$80,199,412**	**$80,199,412**	**$112,279,176**	**$352,877,411**	**$553,375,940**

Savings per household per day	Income Class	No. of Households	Years to pay in	Charges per day per household	2022-2027 Charges	2027-2030	2030-2035	2035-2040	2040-2045	2045-2052	Returns
0.28	Poor	$1,650,127	100% Subsidy	$0.000	$0	$0	$0	$0	$0	$0	$0
	Low Income	$5,138,552	2045-2052~ 07	$0.050	$0	$0	$0	$0	$0	$656,450,052	$656,450,052
	Middle Income	$425,197	2040-2052~ 12	$0.085	$0	$0	$0	$0	$65,958,701	$92,342,182	$158,300,883
0.252	Upper Middle Income	$126,654	NA	$0.000	$0	$0	$0	$0	$0	$0	$0
	Upper Income	$9,047	NA	$0.000	$0	$0	$0	$0	$0	$0	$0
	Total:	**$7,349,577**			**$0**	**$0**	**$0**	**$0**	**$65,958,701**	**$748,792,233**	**$814,750,934**

Savings from shifting away traditional cooking fuel

Amount to be charged to the low and middle income brackets.

Installation followed by 3 years of maintenance free operation

BIO GAS

Total Investment Amount	Loan taken by govt	Interest rate	Pay back period	Principle+ Interest
$200,498,529	$70,000,000	5%	20 Years	$175,000,000

BIO-FUEL

Gasoline Import in 2021	2227814570	litres
Gasoline Consumption in 2021	2275496689	litres
Density of gasoline	755	kg/cubic metre
10% of gasoline or Ethanol Production	227549669	Litres
Bio fuel Generation Factor	63	L per tonne of waste
Required Cassava Waste in Tonnes	3605033	tonnes
Total Cassava Production in 2021	21800000	tonnes
Cassava Waste Generated	9810000	tonnes
Net Waste to be collected	36.75%	

Cost of Import /year	$710.60	Million USD
Import Bill Savings/year	$71.06	Milliion USD
Import Bill Savings~25 years	$1,776.50	Million USD

Year	2022-2027	2027-2052
Investment Cost	$175,774,570	$0.00
Annual Maintenance Cost	$7,909,856	
Maintenance Cost	$0.00	$197,746,391

Loan Amount	75000000
Interest Rate	5.00%
Interest	$112,500,000.00
Amount	$187,500,000.00
Payback Period	20

Import savings by **offsetting 10%** of gasoline import with indigenously produced ethanol.

BIO-FUEL

Volume of Ethanol in Litres	Investment Cost	Awareness+Storage+Miscelaaneous	Total Cost	No. of Plants Required
$222,781,457	$175,774,570	$25,000,000	$200,774,570	18

10% of entire gasoline import to be offset with bioethanol

Regions	Cassava Production (tonnes)	Waste Generated (tonnes)	Total Ethanol Production (Litres)	Waste Required(tonnes)	% of Total generated Waste
Eastern	3700000	1,665,000	63,371,356	1,003,982	60%
Brong Ahafo	2800000	1,260,000	50,697,085	803,186	64%
Central	1900000	855,000	38,022,814	602,389	70%
Ashanti	1800000	810,000	38,022,814	602,389	74%
Volta	1500000	675,000	25,348,542	401,593	59%
Western	750000	337,500	12,674,271	200,796	59%

Ethanol production in accordance with ethanol generation factor of **63.12 L** per tonne of cassava waste.

Regions of Setting up a Plant			
	Eastern	5 years for set-up	5
	Brong Ahafo		4
	Central		3
	Ashanti		3
	Volta		2
	Western		1
Total			18

Highest cassava producing Ghanian regions.

Number of plants based upon production rate and nearness to the oil refinery.

COMMUNITY BENEFITS

SWITCH ENERGY ALLIANCE

COMMUNITY BENEFITS

Solar Installation

- Household's work efficiency will be enhanced by 45-61% using solar PV panels.
- Each end user will receive the subsidy of 50% of its solar electricity from the government for the first 10 years.
- Community centres will provide free solar power in areas which are deprived of the electricity till now.

Bio-fuel

- Biogas helps solve the sanitation problem in Ghana.
- Remains after biogas production could be used as an organic fertilizer in food production.
- On a societal level illnesses like cholera, dysentery and other gastrointestinal diseases related to unhygienic situations will occur less often.

Bio-gas

- E10 fuel blending would save the foreign reserves, which would otherwise had been used in purchase of gasoline.
- Bioethanol generation serves a passive income for cassava producers, for dispatching their produce waste to the nearby biofuel manufacturing plant.
- Creation of new career options and employment opportunities for the youth.

Transmission lines expansion

- Electricity will provide internet and help rural community to diversify their skillsets.
- Farmers will be enabled to use machinery and increase the productivity.
- Improvement in the quality of healthcare provided.

Sources: IRENA, WHO, UNDP

APPENDIX

TRANSMISSION LINES STRUCTURE AND ITS STAKEHOLDERS

Fig. National Transmission Lines

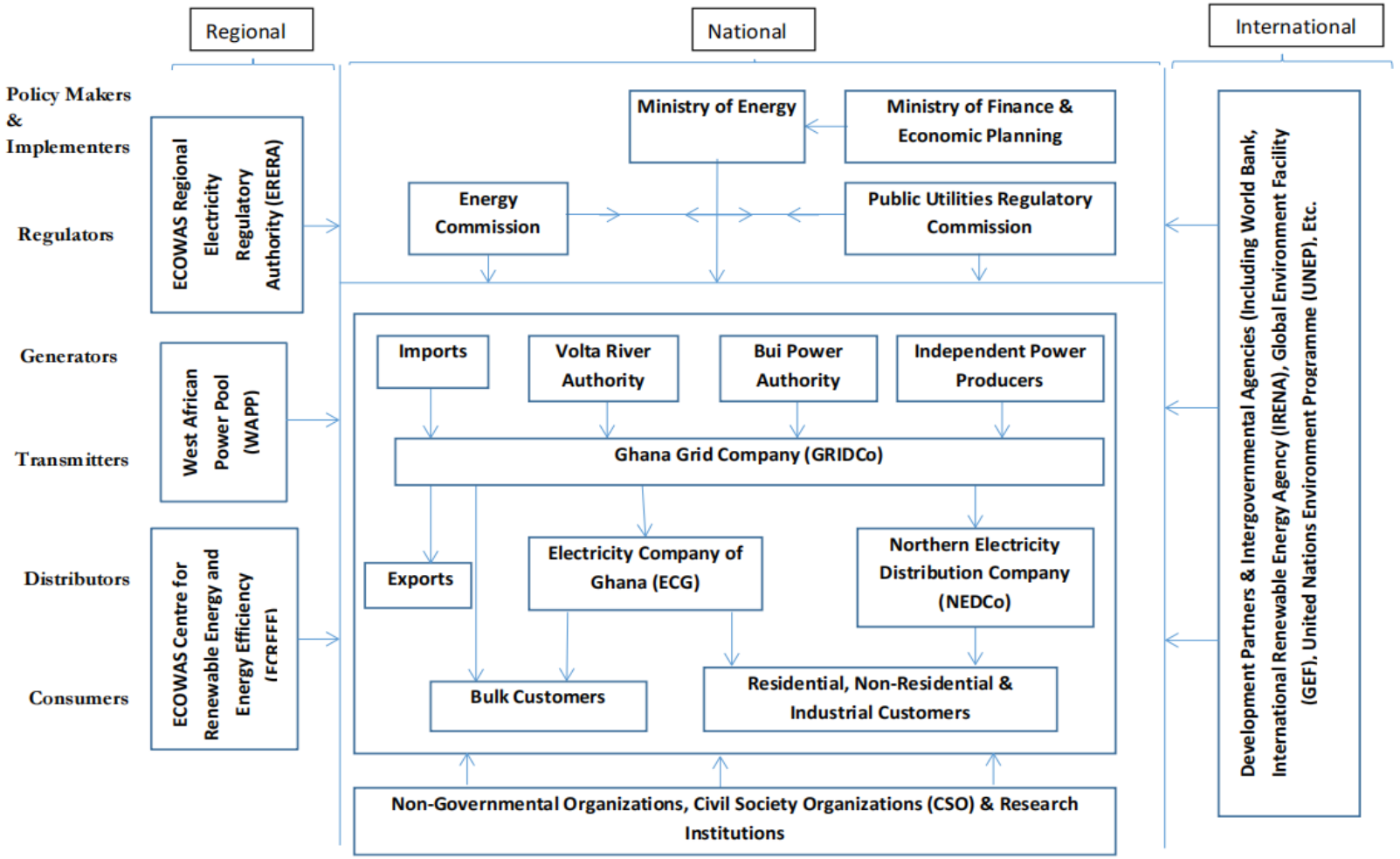


Fig. Stakeholders in Ghana's power sector

Source: Mondaq

SOLAR PANELS INDEGINOUS PURCHASING OPTIONS

Solar Energy Companies in Ghana

Add Your Company to the Directory >>

Total Records: **24**

1. **ADDOSOLAR**
Jungle Road, A&C Square, Accra, Ghana
Telephone Number: 054 550 0706
Business: Retailer
Products: Solar Energy
Web Site: http://www.addosolar.net

We re-sell solar lanterns, solar chargers and solar home systems. The goal is to provide affordable portable sola solutions for power outages.

2. **Cabah**
Ea Accra, Accra 233, Ghana
Telephone Number: 002365844
Facsimile Number: 023568415
Business: Manufacturers
Services: Project Development
Products: Solar Energy
Web Site: http://www.cabah.com

3. **Eco-solar & Construction Ltd**
p.o.box aj,14,Accra North,Ghana,West Africa, Alajo 233, Ghana
Telephone Number: +233248482392
Services: Consulting, Design, Installation
Products: Solar Energy
Web Site: http://www.ecosolarconstruction.com

4. **Milky-Way Energy Ltd**
No. 28 Old Ashongman, Accra, Ghana
Telephone Number: +233-269630174, +233-269630175
Facsimile Number: 0542565513
Services: Engineering, Installation
Products: Alternative Power Systems, Batteries and Accessories, Solar Energy
Web Site: http://www.milkywayenergy.com

our services installation of solar pv systems for customized applications solar water heating systems solar wate pumps professional house wiring training and consultancy services.

5. **Mundeco Ghana Limited**
12 Shitor Close, Accra, Ghana
Telephone Number: 0243 555 766
Business: Retailer
Services: Installation, Maintenance & Repairs
Products: Solar Energy, solar accessories
Web Site: http://www.mundeco.com

mundeco Ghana Limited is a full-service solar energy provider for home owners, businesses and communities. Th company is a subsidiary of mundeco GmbH, based in Dortmund - Germany.

6. **KUPATECH GHANA LIMITED**
off the Odorkor-Mallam High Way, ACCRA 233, Ghana
Telephone Number: +233(0)244514620
Business: Importers, Retailer
Services: Installation
Products: Alternative Power Systems, Batteries and Accessories, Hydro Energy, Solar Energy, Wind Energy
Web Site: http://www.kupatech.com

HURDLES TO ECONOMIC DEVELOPMENT AND IMPACTS OF CORRUPTION

Energy Consumers

- Higher energy prices.
- Less affordable
- Reliable energy supply

IPP

- Distortion of competition
- Unfair competition
- Efficiency losses

Financial Institution

- Higher risks
- Danger of reputation

Fig. representing Impacts of Corruption on its Stakeholders

IPP: Independent Power Producers

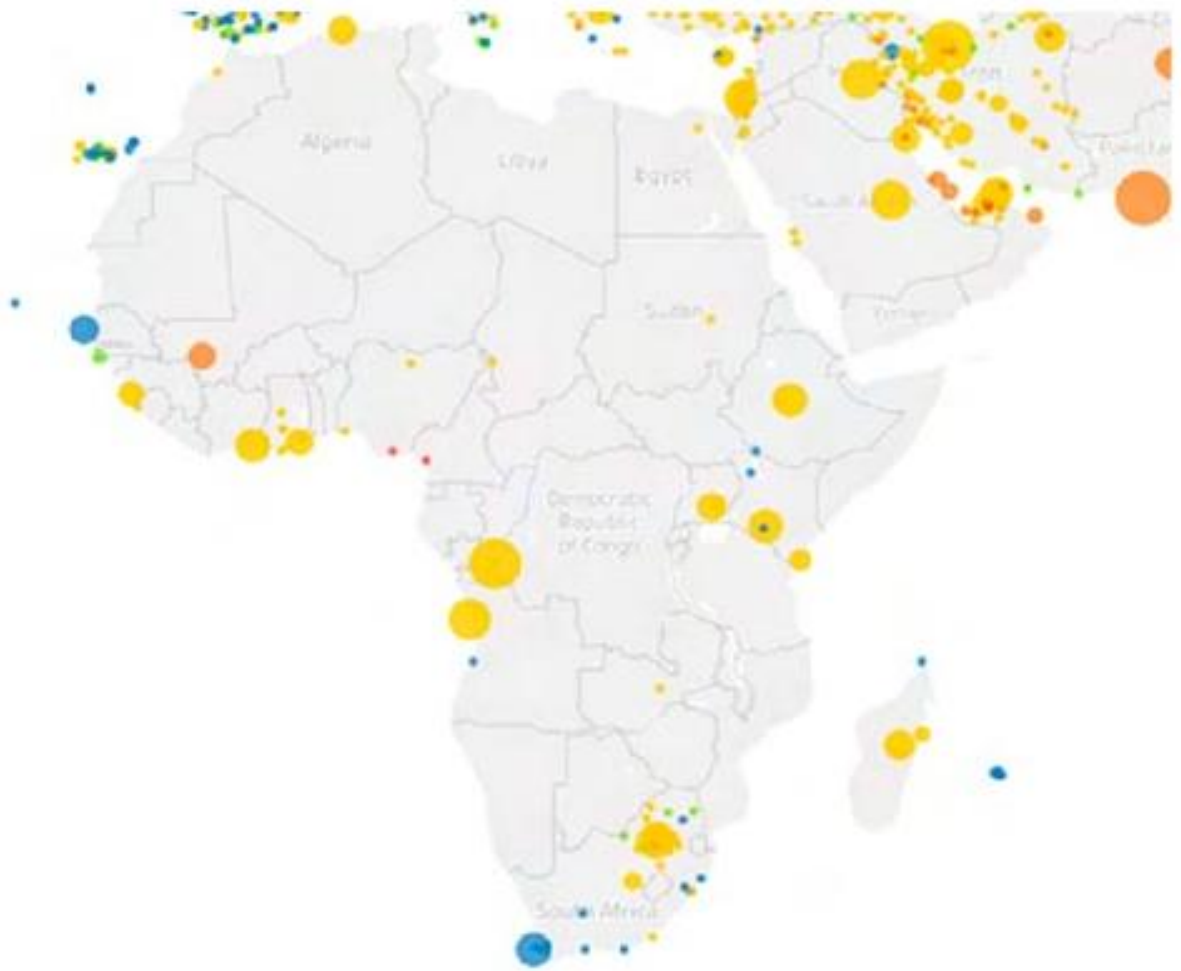
INSTALLED CAPACITY LIFECYCLE STATUS

Name	Owner	Phase Out (Year)	Installed Capacity(MW)	Reliable Capacity (MW)	Fuel1	Fuel2
Akosombo	VRA	2065	1020	900	Hydro	
Kpong	VRA	2042	160	140	Hydro	
BUI	SPA	2065	260	120	Hydro	
Aboadze Tl	VRA	2011	330	300	NG	LCO
Aboadze T2 (TICo)	IPP	2013	220	220	NG	LCO
Terna TT1PP	VRA	2014	126	110	NG	LCO
TEMA TT2PP	IPP	2035	49.5	45	NG	Diesel
OSONOR (CENIT)	IPP	2037	126	120	NG	LCO
Tokaradi 3	VRA	2038	132	120	NG	LCO
Terna Mine Reserve Plant	IPP	2032	80	40	NG	Diesel
Sunon Asogli	IPP	2035	200	180	NG	

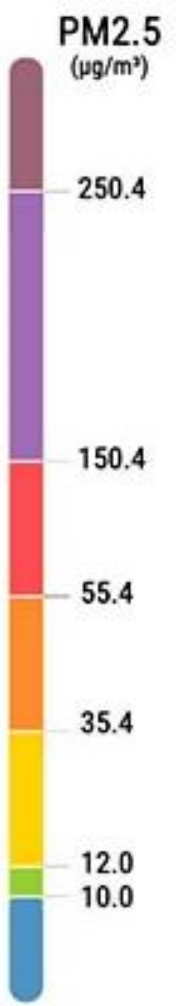
LCO: Light Cycle Oil **NG:** Natural Gas

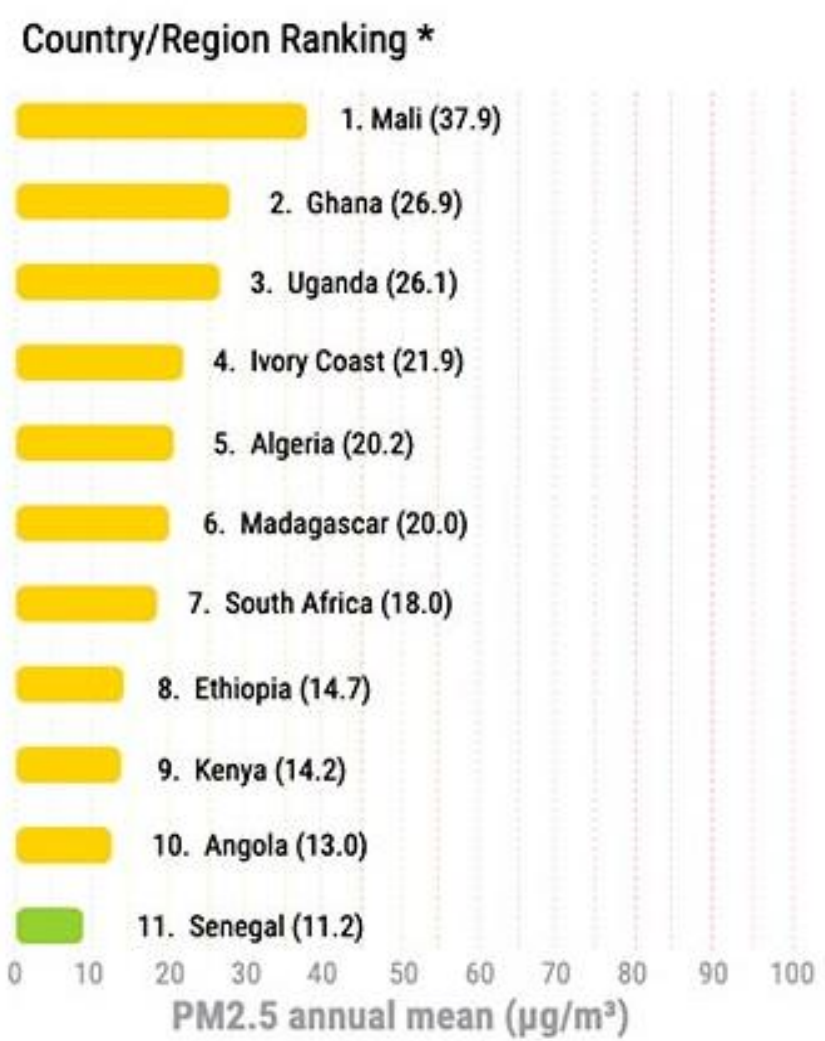
Sources: International Energy Agency

COMPARISON OF AIR POLLUTION OF MAJOR CITIES OF SOUTH AFRICA



Available cities with real time monitoring in 2020

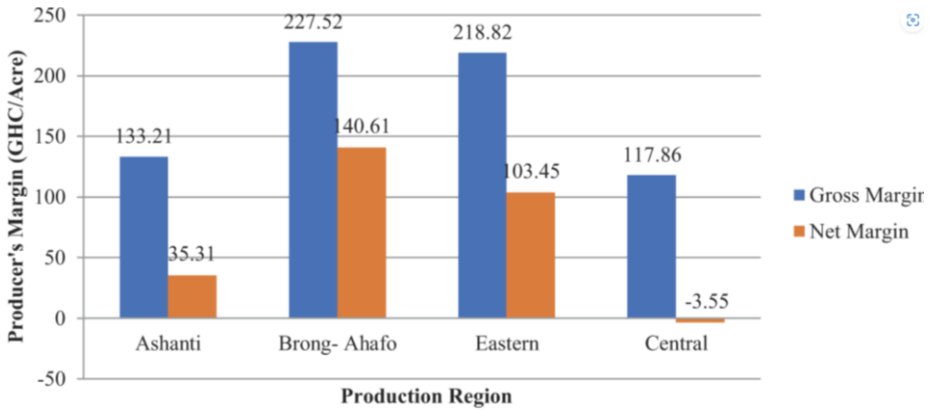




Sources: Air Quality Index

SUSTAINABLE DEVELOPMENT GOALS

BIO-FUEL



Source(s): Aidoo *et al*., (2016)

Appendix 1. Profitability of cassava production across Regions for the 2012 cropping season.

A. Variable costs (All costs and revenues in GHC)	Ashanti	Brong-Ahafo	Eastern	Central	Greater Accra	Volta	Western	Pooled sample
Land clearing	207.29	300.68	185.57	158.42	224.16	179.84	108.13	200.16
Land preparation	151.60	274.86	104.74	108.26	183.87	127.73	121.00	140.80
Planting materials	156.11	224.05	182.80	297.76	194.95	148.24	72.29	185.10
Coppicing planting materials	47.32	66.69	69.57	154.45	48.73	41.65	51.65	65.40
Carting planting materials (T&T)	47.18	91.26	51.57	51.62	69.28	31.67	23.07	49.39
Planting cassava sticks	157.53	155.89	145.28	94.40	210.11	103.26	65.95	135.12
First weeding	197.63	255.83	174.41	98.68	214.11	152.07	44.40	173.82
Second weeding	171.13	209.59	171.74	91.14	215.42	151.42	38.89	160.85
Herbicides (chemical weeding)	55.27	81.29	81.99	64.48	61.08	57.14	71.89	69.14
Herbicides application	50.55	62.88	45.77	57.38	37.42	38.45	26.75	47.64
Insecticides	29.25	24.20	43.00	48.46	49.70	31.73	28.67	38.87
Insecticides application	23.75	39.20	31.25	50.14	38.33	32.33	27.00	36.83
Total cost of knapsack rent	8.11	7.24	21.20	39.04	14.53	13.37	82.78	21.29
Harvesting	219.01	339.90	263.46	104.06	162.16	113.23	55.40	204.83
Gathering/heaping harvested cassava	70.35	99.07	68.16	50.76	46.36	39.54	28.22	66.51
Carting harvested produce to market/home (T&T)	138.31	371.72	133.42	71.55	69.00	81.97	39.44	146.92
Other variable costs	40.93	45.00	32.10	22.00	50.00	47.92	0.00	36.53
Total VC for whole farm	1,771.33	2,649.35	1,806.01	1,562.58	1,889.19	1,391.57	885.53	1,779.20
Acres of cassava cultivated	2.15	3.90	2.66	3.42	2.97	2.39	1.31	2.74
Total Variable Costs per acre	823.72	679.53	679.57	457.16	635.30	583.03	676.29	649.39
B. Revenue								
Yield/acre (120kg bags)	23.72	33.08	24.43	12.47	23.26	17.1	14.68	20.76
Unit price (GHC)	40.3429	27.42	36.774	46.1121	50.2632	44.7885	64.2381	42.2604
Gross revenue (B)	956.93	907.05	898.39	575.02	1,169.12	765.88	943.02	877.33
C. Gross margin (B-A)	133.21	227.52	218.82	117.86	533.82	182.86	266.73	227.93
D. Fixed cost								
Land rental	87.99	77.58	105.57	111.63	101.94	74.81	140.40	97.32
Cutlass/hoe	9.9167	9.3354	9.8079	9.7768	10.2105	11.2636	8.8537	9.9623
Total fixed cost (D)	97.91	86.92	115.38	121.41	112.15	86.07	149.25	107.28
E. Net margin (C-D)	35.31	140.61	103.45	-3.55	421.67	96.78	117.48	120.65
F. Total cost (A+D)	921.63	766.44	794.94	578.57	747.45	669.10	825.54	756.67
G. BCR (B/F)	1.04	1.18	1.13	0.99	1.56	1.15	1.14	1.16
H. Returns on investment (E/D)	36.06%	161.78%	89.66%	-2.93%	375.99%	112.44%	78.71%	112.46%

Source: Computed from field data, 2014.

SWITCH
ENERGY ALLIANCE

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