Switch Energy Case Competition 2022

Team Nimbus 2.0

Team Number - 148

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Image Ref: google

Country: Ghana

Overview

Ghana

Population: 31 million (2022)

Rural population: 13.3 million (2022)

GDP per capita: 2329 US$
Global ranking: 75th

Average family income: 82 $

Access to electricity: 86%

Main Economic Sectors: Agriculture, Industry & Services

Area: 238,533 km²

Ref: World bank, statistica

Access to clean cooking fuel: 22%

HDI Ranking: 133

Inflation rate (July-Sept' 22) : 34%

CO_2 emission per capita: 0.7 metric ton

Life expectancy: 64 years

No. of states: 16
Capital: Accra

Energy Overview

Ghana

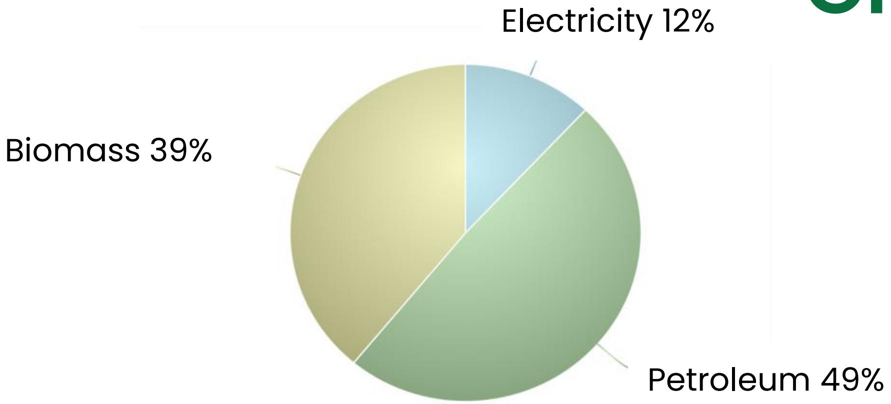


Fig: Energy Mix of Ghana

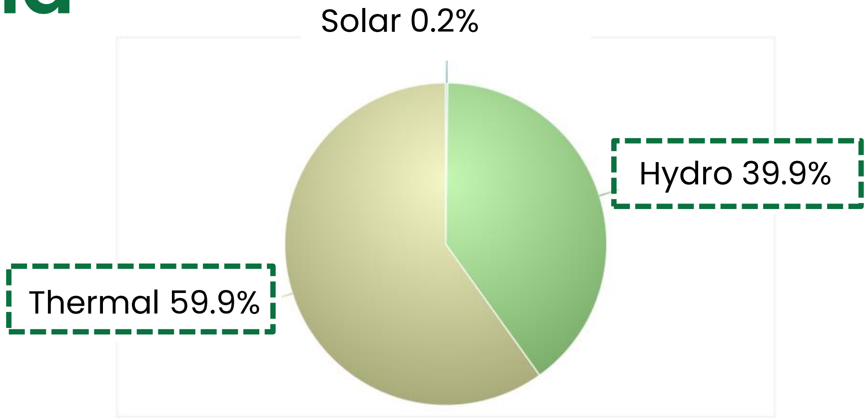


Fig: Electricity Mix of Ghana

Table: Ghana's National Energy Policy 2006-2022 vs. Unfortunate Reality!

GHANA	Generation capacity	Access to electricity	Renewable energy	Access to clean cooking fuel
2020 Target	22.3 TWh	100%	10%	50%
2020 Reality	14 TWh	86%	<1%	22%

Ref: Ministry of Energy, Ghana

Energy Timeline

Ghana

...

Ghana got Independence in 1957

Till 1990, hydropower was the only source of electricity. Electrification rate is 31%

2006: National Energy Policy has been launched with a target of 10% solar till 2020

Less than 1% power generation from renewables

Installed capacity → **1652 MW** | **1730 MW** | **2165 MW** | **3633 MW** | **5288 MW**

1980 | 1985 | 1990 | 1995 | 2000 | 2005 | 2010 | 2015 | 2020

30 year national electrification program has been launched & LPG Promotion program has been launched.

1998: Govt. reduced import duty & tax on solar & wind energy products

2011: Renewable energy law was passed.

Ahibenso stove was introduced. 40000 stoves were sold.

Gyapa stove was introduced in 2002. 2 lakhs stoves were sold.

Ref: Adusah-Poku et al.,2019, Ministry of Energy: Ghana website

Problem Overview

Problem

Energy Poverty

Energy Poverty Rate: 38%

Energy **Poverty** in Ghana

Accessibility

Electricity : 86%
Clean cooking fuel : 22%

Reliability

Electricity : 42%
LPG : 50%

Environmentally Benign

Fossil fuel based electricity: 60%
Population using unclean cooking fuels: 78%

Affordability

Households spend 22% of income on modern energy forms

Safety

Exposure to smoke from solid fuels causes 18000 deaths per year

Quality of Energy Services

Capacity factor(thermal plants): 50%
Capacity factor(hydro plants): 70%
Population using inefficient cookstoves: 78%

Ref: IISTE, Journal of Economics and Sustainable Development

Problem

Cooking Fuel Crisis

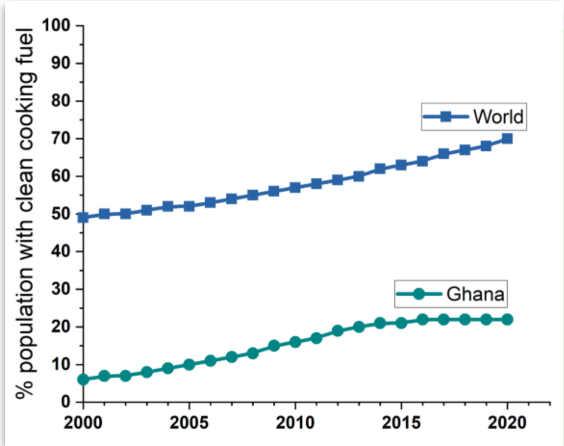


Fig: Year wise % population with clean cooking fuel

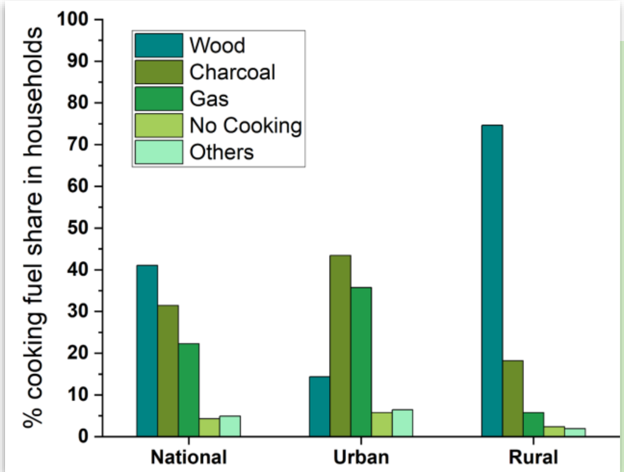


Fig: % cooking share in households

Exposure to smoke from solid fuels or inefficient fuels causes nearly **18,000 deaths/year in Ghana** (WHO, 2018)

Chronic illnesses & acute health impacts: Childhood pneumonia, cataracts, lung cancer, bronchitis, cardiovascular disease, and low birth weight

Women and young children most affected

> **2200 children die in Ghana / year** due to acute lower respiratory infections (WHO, 2018)

Ref: World bank, Maxwell et al., 2020

Problem

Unreliable & Unaffordable Electricity

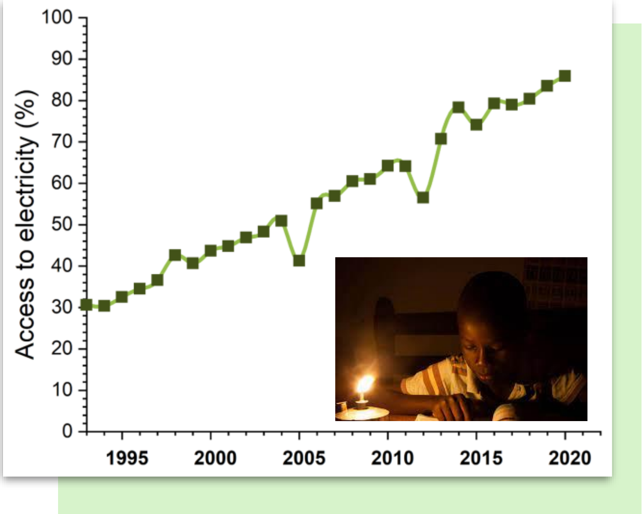


Fig: Access to electricity in Ghana

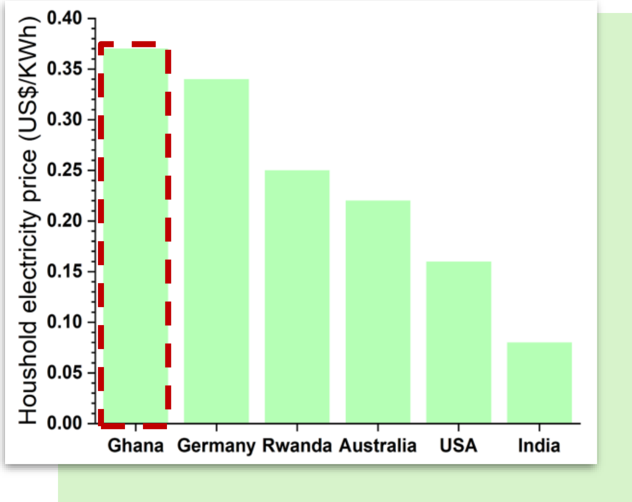


Fig: Country wise household electricity tariff

Electricity reliability: 42%

T&D losses: 25%

Rural: **76%**

Urban: **84%**

Ghana has moderately good but **expensive** electricity access, & the **supply** is **highly unreliable**

Ref: IEA, World bank, statistica

SOLUTION

Methodology

After days of intense brainstorming finally we came up with something we believe could solve the problem. Really amazed to see how new ideas emerge...

Design

Solution Methodology

Objectives & Targets: 2050

Objectives

-To cover **maximum population till 2050** with clean cooking fuel & reliable electricity.

-To **reduce** cooking fuel cost & electricity **prices.**

-To **reduce** indoor **pollution** & related health hazards

-To reduce **GHG emissions** & improve socio-economic standards

Targets

-Population with clean cooking fuel till 2050: **90-100%**

-To provide **90-100% accessible** & **reliable** electricity

-Reduce cost of cooking fuel **upto 80%** & for electricity upto **60-70%.**

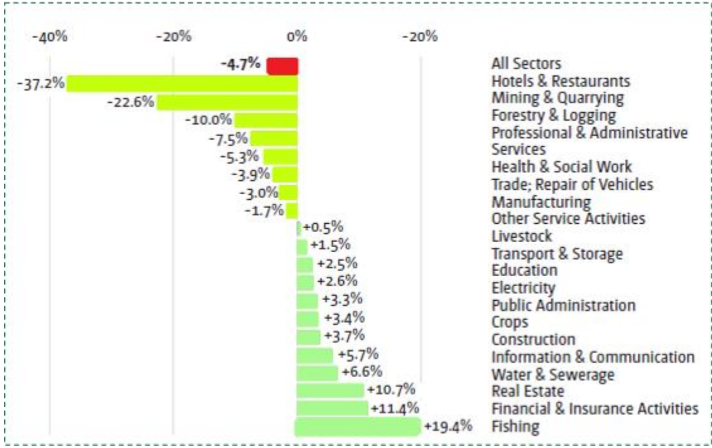
Factors taken into account while deciding objectives & targets

-Potential of various cooking fuel & renewable energy resources in Ghana

-Allotted Budget

-Ability to develop & progress

Effect of COVID-19 taken into account by considering 2020 as base year



Solution for Cooking Fuel Crisis

Cooking Fuel: Current Scenario

Current Scenario:

1. LPG is the only clean cooking fuel in Ghana
2. Merely **22%** population has access to LPG

Current Policies:

- Launched in 2013, the Ghana Sustainable Energy for all (SE4ALL) Action Plan provides the current framework for household energy.
- The draft 2018 energy policy aims to address institutional and market barriers to LPG uptake. Targets in the draft policy include increasing adoption of efficient cookstoves by 20% by 2020, and increasing LPG use from 18% to 50% by 2020. These target are far away from reality.

To cater to remaining population, other sources needs to be explored...

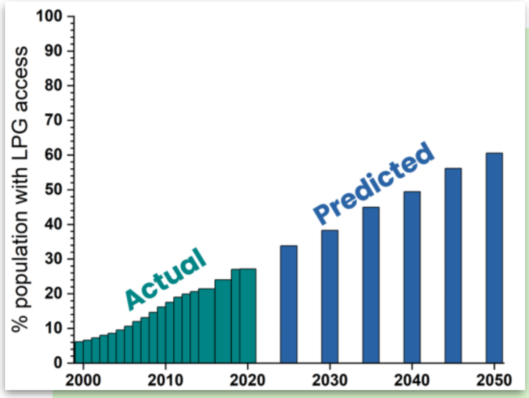


Fig: Population % with LPG access till 2050 (Prediction)

Region	Fuel type (%)						
	Non-woodfuels					Woodfuels	
	Electricity	LPG	Kerosene	Agric residue	Others	Firewood	Charcoal
Ashanti	0.6	7.5	0.7	0.1	0.7	50.6	39.9
Northern	0.1	1.3	0.2	0.2	0.1	81.8	16.4
Upper East	0.4	1.2	0	32.8	0.2	55	10.4
Upper West	0	1.1	0.2	—	0.3	80.2	18.2
Western	0.2	6.3	0.3	0	0.6	65.2	27.3
Central	0.1	4.6	0.9	0.1	0.2	63.1	31.1
Gt. Accra	0.3	29.4	2.1	—	—	7.2	59.8
Volta	0.1	2.3	0.4	0.2	0.1	73.2	23.7
Eastern	0.3	4.6	0.5	0.4	—	71.2	22.9
Brong-Ahafo	0.1	2.7	0.3	0.2	0.6	77.6	18.5
Ghana	0.3	8.5	0.7	1.3	0.5	56.6	32

Fig: Region wise household cooking source in Ghana (2015)

Ref: Ministry of Energy, Ghana, Arthur et al.,2010

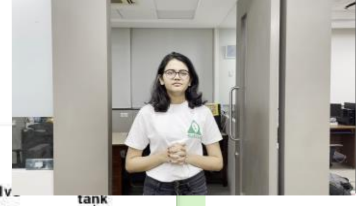
Solution for Cooking Fuel Crisis: Comparative Analysis

Alternatives cooking fuel sources

	Conventional Stove	Biogas	Improvised cooking stove	Solar cooker	Electric stove	LPG
Type of Input	Wood, coal, charcoal, cow dung, etc.	Agricultural, animal, & human, municipal waste	Wood, coal, charcoal, cow dung, etc.	Sun	Electricity	LPG
Ease of availability	Require daily collection time of 3-4 hrs	Weekly activity of waste segregation	Require daily collection time of 3-4 hrs	No efforts but subjected to sun's availability	Subjected to reliable electricity supply	Subjected to LPG refill
Affordability	Cheap	Cheap	Cheap	Cheap	Expensive	Expensive
Health Hazards	Very Hazardous	Nil	Hazardous	Nil	Nil	Nil

Solution for Cooking Fuel Crisis

Biogas: Design & Site Selection of Plant



- From the literature & surveys in Ghana, **fixed dome with inbuilt gas holder** is widely used **(66%)** & have following advantages.
- No moving parts
- No rusting steel parts hence long life (20 years or more)
- underground construction
- Affording protection from winter cold and saving space.

Construction of Biogas Plant

- Mixing tank: Present above the ground
- Digester: Biological reactions occurs
- Overflow tank: Spent slurry get stored

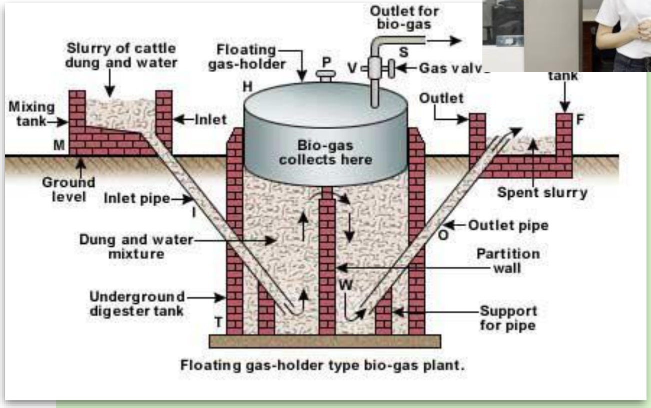
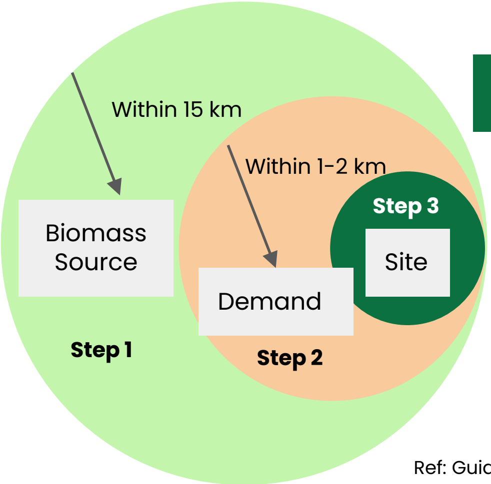


Fig: Design of fixed dome with inbuilt gas holder biogas plant



Site Selection Methodology

Step 1: Selection of the region

Step 2: Selection of the neighbourhood

Step 3: Selection of the site

Site selection differences in rural & urban area:

- In rural area, given site selection methodology will be used.
- For urban area, according to area & population of city which are using solid cooking fuels, distances will increase in the ratio of those parameters.

Ref: Guidelines for Selecting Suitable Sites for Biogas Plants, intelligence energy europe, Saleh et al. (2012)

Solution for Cooking Fuel Crisis

Biogas

Sources of Biogas generation in Ghana


Municipal solid waste


Animal waste


Field crop residue


Human excreta

Residue type	Quantity (Mt)	Biogas (Mm³ CH_4/year)
Field crop residue	20	1600
Process residue	--	750
Wood waste	0.35	19
Animal waste	2860	100
Municipal solid waste	2.1	230
Municipal liquid waste	0.56	17
Total	**2883**	**2716**

Table: Biogas Generation Potential in Ghana(Year: 2020)

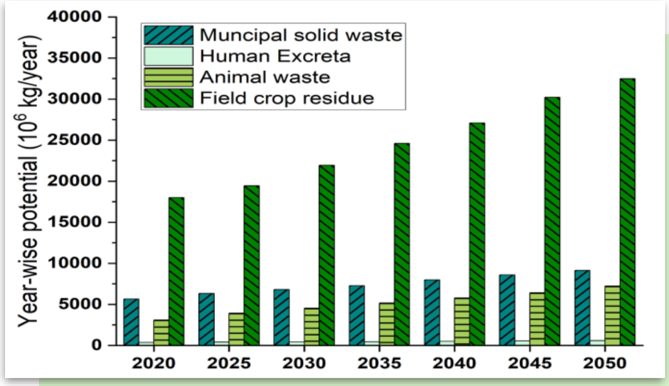
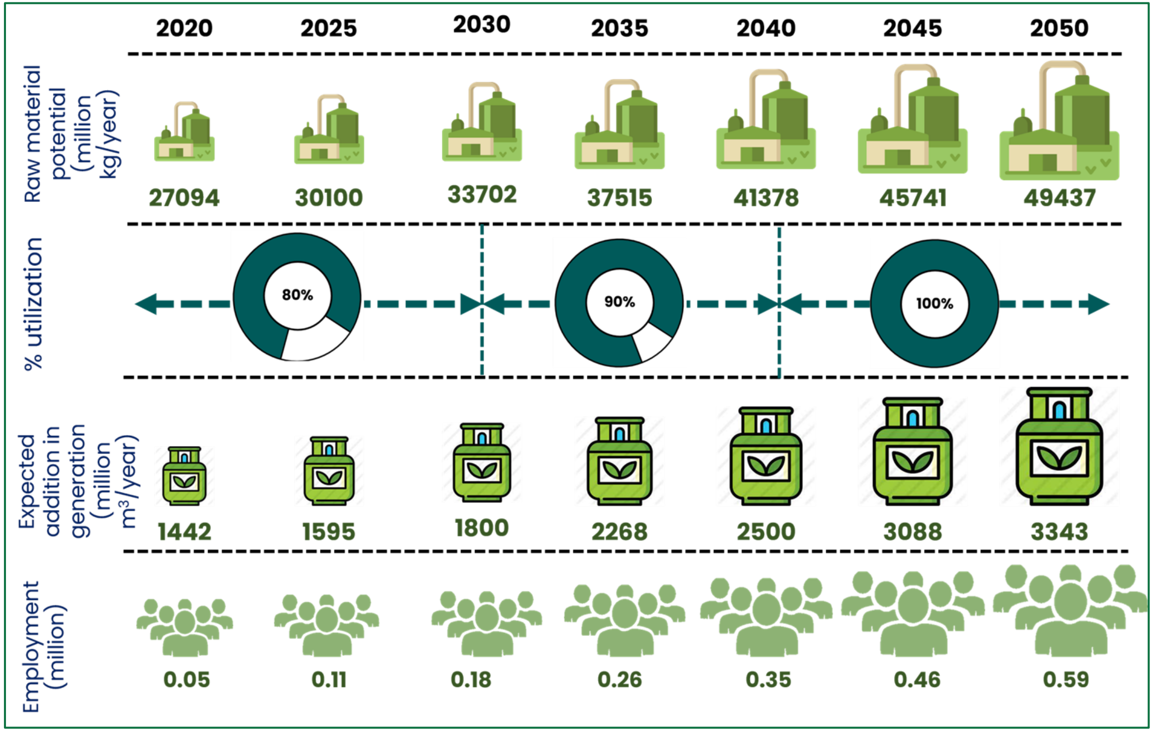


Fig: Year wise potential of waste

Ref: Seglah et al. 2022

Solution for Cooking Fuel Crisis

Biogas: Projections for Year-wise Capacity Addition



Implementation Roadmap for Biogas

	States	Proposed % of Biogas Installation (till 2050)
1	Greater Accra	7%
2	Ashanti	18%
3	Eastern	10%
4	Central	10%
5	Northern	8%
6	Western	7%
7	Volta	6%
8	Upper East	4%
9	Bono	4%
10	Bono east	4%
11	Upper West	3%
12	Western north	4%
13	Oti	4%
14	North east	4%
15	Savannah	4%
16	Ahafo	3%

Table: State wise capacity addition till 2050

Implementation

Solution for Cooking Fuel Crisis

LPG & Improvised Cookstoves

Proposed interventions for LPG adoption:

(a) Expanded distribution of LPG in rural areas

1. A cylinder recirculation program replaces the current system of individual ownership of cylinders
2. Motor-king (motorcycle with smaller trailer) distribution network from refilling stations to village retail outlets

(b) Elimination of LPG taxes: carbon credit

Subsidizing 23% tax on LPG by the government for the rural population

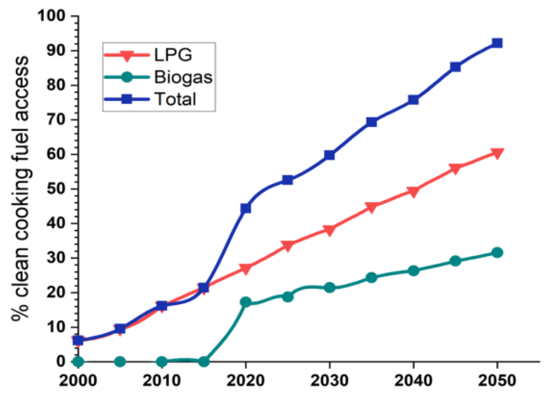


Fig: Proposed % clean cooking fuel access

LPG & Gyapa Stoves: Cost for consumers & Benefits

LPG Stoves & cylinder cost:

Cost of LPG stove	US$ 30
LPG cost/litre	US$ 0.5

LPG Benefits:

- Deployment is easier in urban areas so prefer urban areas first forthe LPG deployment.
- Easy to transport & skilled labours are present in the supply chain of LPG

Improvised Cookstoves: Gyapa cost:

Cost of Gyapa stove	US$ 17.8
Stove O&M	US$ 2.1
Total cost	US$ 19.9

Gyapa Benefits:

- Faster cooking & 2.5-60% less fuel required
- Less smokey
- Distribution country wide at US$ 110 Million

Solution for Cooking Fuel Crisis

Implementation Roadmap: Biogas & Gyapa Stoves

- Region-wise feasibility analysis
  - Raw material
  - Capacity required
  - Site identification
- Scouting for suitable funding agencies
- Distribution of improvised cooking stove, "Gyapa", to 6 million household without LPG

Capacity addition (Mm³)

Period	Capacity addition (Mm³)
2022–2025	1398
2025–2030	1800
2030–2035	2268
2035–2040	2500
2040–2045	3088
2045–2050	3343

Solution for Cooking Fuel Crisis

Implementation Roadmap: Supply Chain Analysis

Waste Material Tapping

SKILL DEVELOPMENT
- Government
- Private

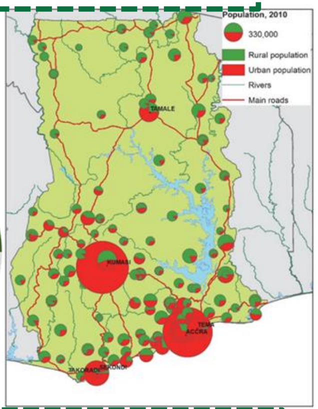
FINANCE
- World Bank
- IMF
- Public Private Partnership

PROCUREMENT
- Public
- Private

TECHNICAL ASSISTANCE
- Das Biogas
- Beta Engineering Limited
- Council for Scientific & Industrial Research (CSIR)
- Germany

GENERATION
- Government
- Private

DISTRIBUTION
North Ghana with less population density: Community Kitchen



DISTRIBUTION
South Ghana with large population density: Piped network to homes

Tapping of Waste Material for Biogas

Step 1: Aware people to segregate municipal solid waste into dry waste & wet waste. Inform them to store Agricultural waste & animal excreta. Human excreta will get collected through pipelines reaching directly to the biogas plant

Step 2: Govt trucks will collect all the waste in (1-2 small trucks for each biogas plant) & they will transport it to Biogas plant

Solution for Unreliable & Unaffordable Electricity

SOLAR

Solution for Electricity Crisis

Current Scenario

Current Scenario:

- Ghana's power supply sources are from hydroelectricity, thermal fueled by crude oil, natural gas and diesel, and also imports from La Cote D'Ivoire. Ghana also exports power to Togo, Benin and Burkina Faso.
- The total installed capacity for existing plants in Ghana is 4,132MW consisting of Hydro 38%, Thermal 61% and Solar less than 1%

Current Policies:

- Renewable energy Act (Act 832), passed in 2011, seeks to create the enabling environment for attracting private sector investment in the renewable energy sector to ensure the achievement of the 10% policy target
- National roadmap to integrate nuclear power into Ghana's energy mix has been developed and accepted by the International Atomic Energy Agency (IAEA)

In 30 years, electricity demand is predicted to increase by 6x

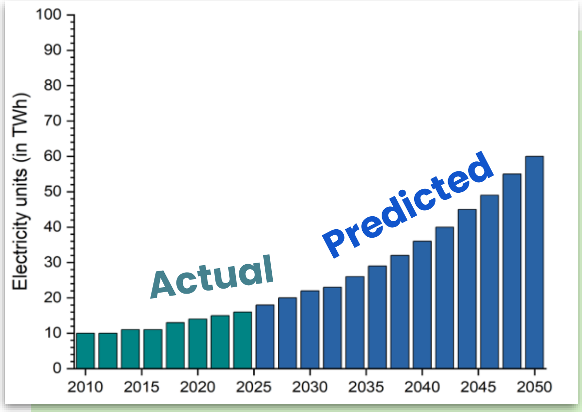


Fig: Predicted electricity demand till 2050

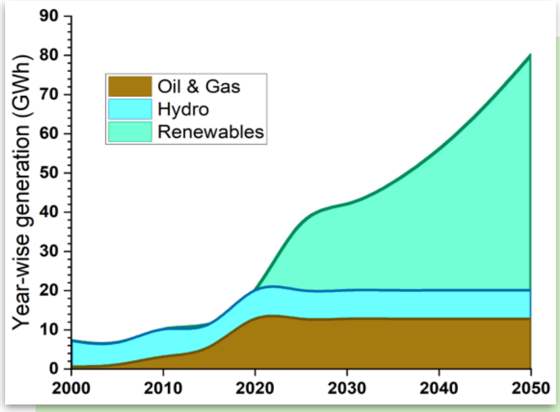
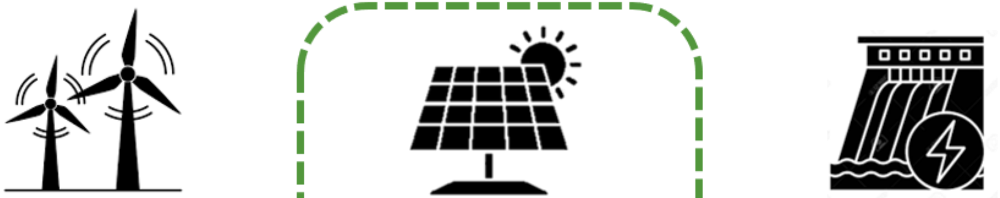


Fig: Proposed electricity mix till 2050

Ref: Ministry of Energy, Ghana

Solution for Electricity Crisis: Comparative Analysis

Alternatives Renewable Sources

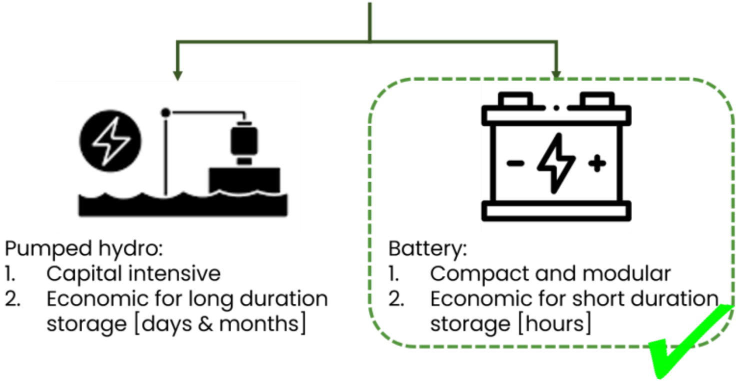


	Wind Energy	Solar PV	Hydro Power
Potential	12 TWh	9.8 PWh	5.36TWh
Remarks	Low and Scattered	1. Fulfils total demand by covering < 1% of landmass 2. Easy to handle and install	1. Exhausted all possible resources 2. Unreliable during drought

Solution for Electricity Crisis

Solar PV + Storage

Storage options for Ghana



Need for storage:
60% of power is consumed at night

**Proposed solution:
Solar PV + Battery storage**

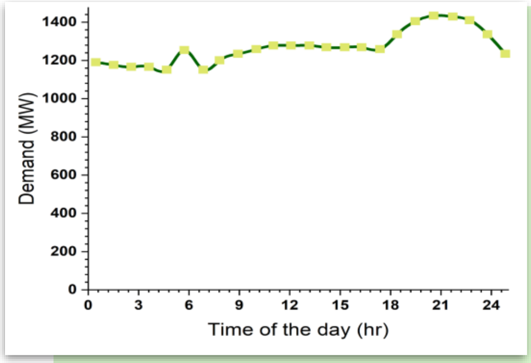


Fig: Demand curve of Ghana

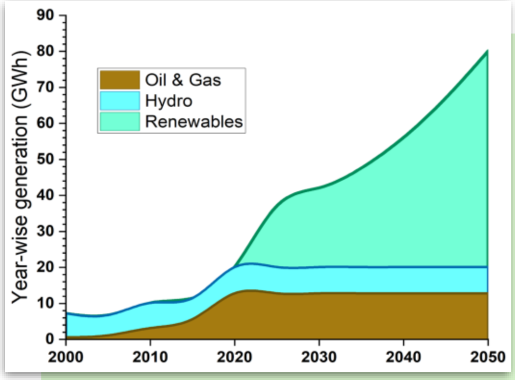


Fig: Proposed year-wise generation from different sources

Our Proposal

- 2020 onwards all new capacity installment based only on renewable energy using solar PV
- Existing hydro and fossil fuel plants shall be used till 2050, with no new addition
- By 2050, solar PV will have contribution of 75% in total electricity mix

Implementation Roadmap: Solar PV + Storage

2022 2025 2030 2035 2040 2045 2050

Phase-I

- Installing floating PV on Kpong, Akombo, and Bui dams; utilize existing T&D infrastructure of hydro power for floating PV
- Feasibility analysis for phase-II
- Policy planning for phase-II
- Site survey for grid development
- Land procurement

Phase-II

- Audit of installed plants in phase-I
- Revise targets for based on audit reports (if needed)
- Installing PV plants on the land
- Feasibility analysis for phase-III
- Site survey to extend gridlines
- Land procurement

Phase-III

- Audit of installed plants installed in phase-II
- Installing PV plants on the land according to recommendation in phase-II
- Revised targets based on audit report (if needed)
- Land procurement
- Future planning & policy recommendations

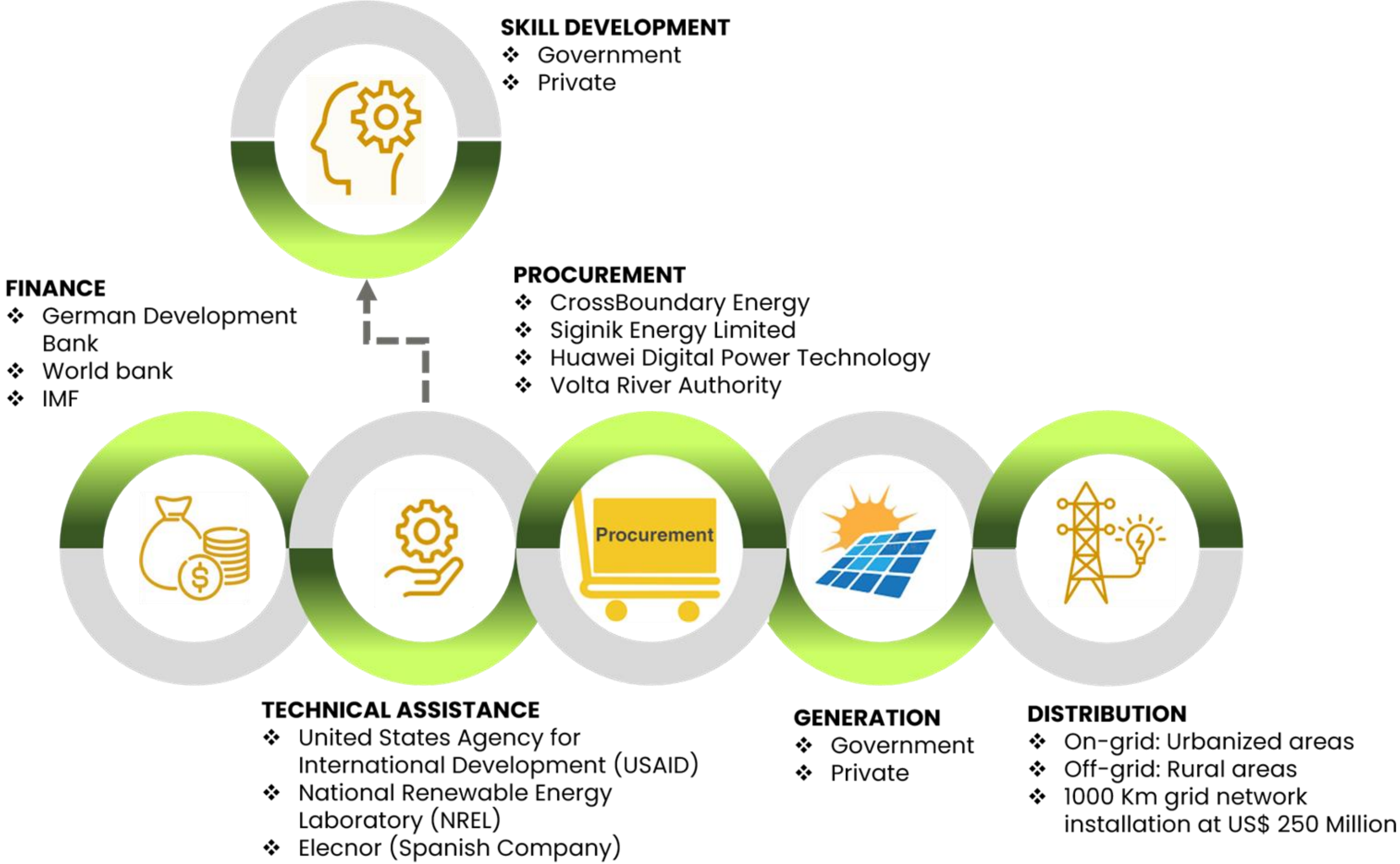
Solution for Electricity Crisis

Solar PV: Projections for Year-wise Capacity Addition

	2020	2025	2030	2035	2040	2045	2050
Capacity factor (%)		21.5	23	24.3	25.7	27.2	28.6
REQUIRED: Units of generation (TWh)	0.024	3.4	4.7	5.4	8.2	12.0	12.7
REQUIRED: Solar PV Installation (MW)*	50	6500	8500	9300	13300	18400	18500
LCOE (US$/kWh)	0.18	0.16	0.14	0.12	0.10	0.08	0.06
Employment generation (Millions)		0.15	0.23	0.27	0.43	0.67	0.74

Solution for Electricity Crisis

Implementation Roadmap: Supply Chain Analysis



Financial Plan: Biogas

Financial Plan

Biogas: Background

Cost of Biogas Plant over the years

	2020	2025	2030	2035	2040	2045	2050
Fixed capital cost for 1 m^3 of biogas plant (US$)	90	110	137	170	207	253	280

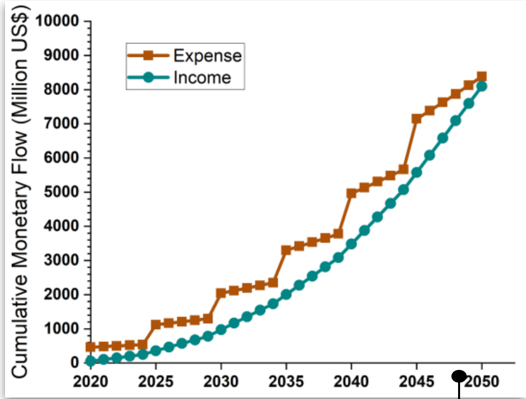
Cost of biogas for consumers

Biogas required per household	1.6 m^3/day
Selling price to customer	US$ 0.035/m^3
O&M cost (% of fixed capital cost)	4
Inflation (%)	2

Finance

Financial Plan: Invest-Recoup-Reinvest

Biogas: Roadmap



Cumulative Cash flow

Phase 1 Investment recouped by 2030

2020 2025 2030 2035 2050

Investments

Phase-I: $88 Million/year

Phase-II: $108 Million/year

Recouped money from Phase-I is reinvested in Phase-III

Capacity addition (Mm^3/year)

1442

1595

1800

3343

The government share of expenses at the end of 2050 is US$ 282.18 Million

Financial Plan: Solar PV

Financial Plan

Solar PV: Model Selection

Model 1

Only Govt Installations
Capital Needed = 38 billion US $

- Exceeding the budget. Not a cheaper option
- Govt past targets haven't been reached yet

Model 2

Only private player Installations & govt. Provides interest free loans.(govt. Pays interest to the banks with 2% interest rate
Capital Needed = 2.44 billion US $

- Exceeding the budget. Not a cheaper option
- Lack of regulations & possibility of natural monopoly

Model 3

Both Govt & Private players' installations
Capital Needed = 123 million US $

- Well under the budget & cheaper option than other two models.
- Access to private sector finance & potentially increased transparency.

Public Private Partnerships

Year	Govt. Contribution
2025	20%
2030	20%
2035	20%
2040	10%
2045	10%
2050	10%

Table: Year-wise government contribution

Financial Plan

Solar PV: Financial Results

Table: LCOE of electricity from solar over the years

	2020	2025	2030	2035	2040	2045	2050
LCOE (US$/KWh)	0.18	0.16	0.14	0.12	0.10	0.08	0.06

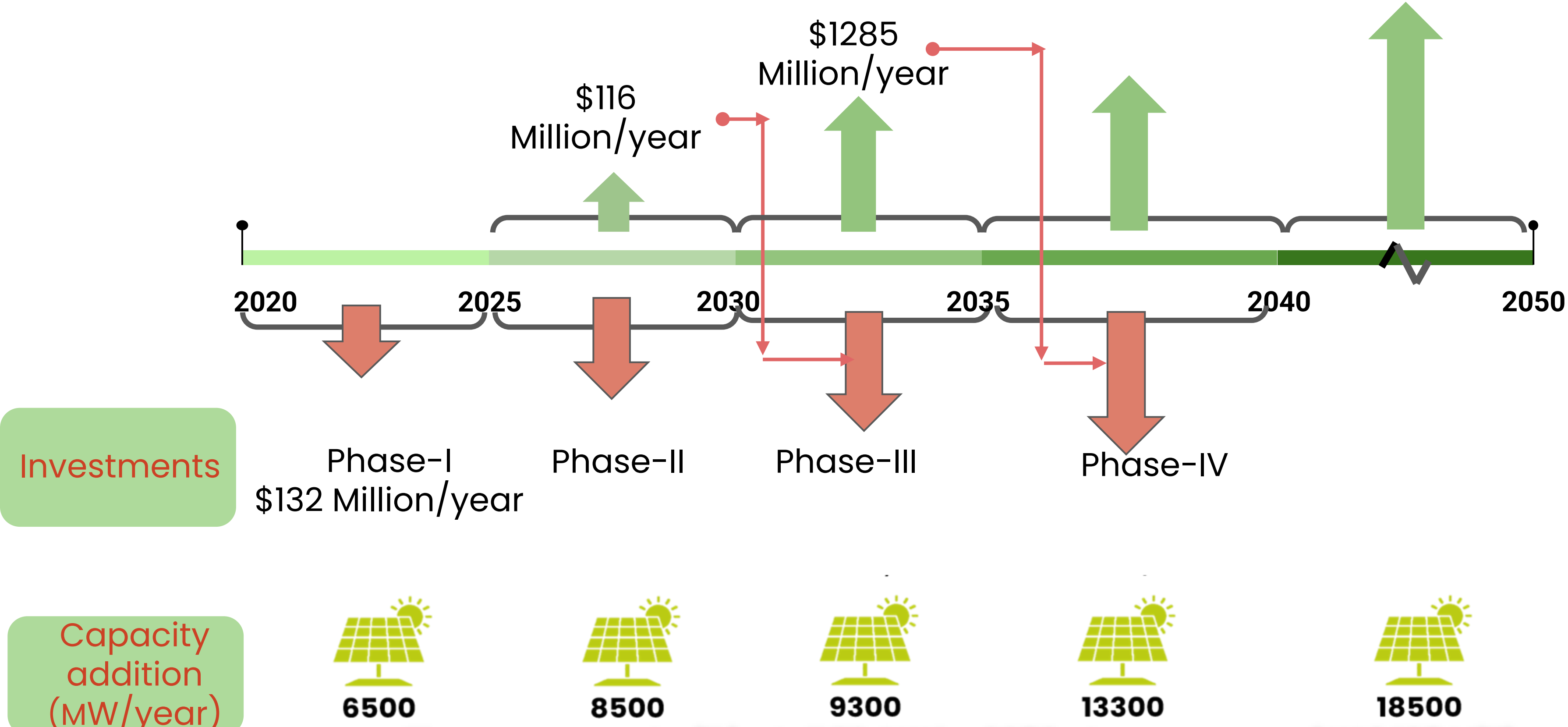
Table:Assumptions

Solar PV fixed cost (Million US$/MW)	0.5
No. of sunshine days	240
No. of sunshine hour	10
O&M cost (% of fixed capital cost)	10
Inflation (%)	2

Ref: IRENA 2020

Financial Plan: Invest-Recoup-Reinvest

Solar PV: Roadmap



The government will install 70 GW by 2050 at an expense of US$ 135 Million

Final Fund Break-Up

Finance

Combined Financial Plan

- Total budget allocated: 900 Million US$
- 15% budget of total budget kept as contingency to meet any unexpected financial demands from ongoing projects

Quantitative Metric

	Units/US$	Beneficiary/US$
Biogas	479 m^3/US$	0.4 people/US$
Electricity	4269 KWh/US$	0.04 people/US$

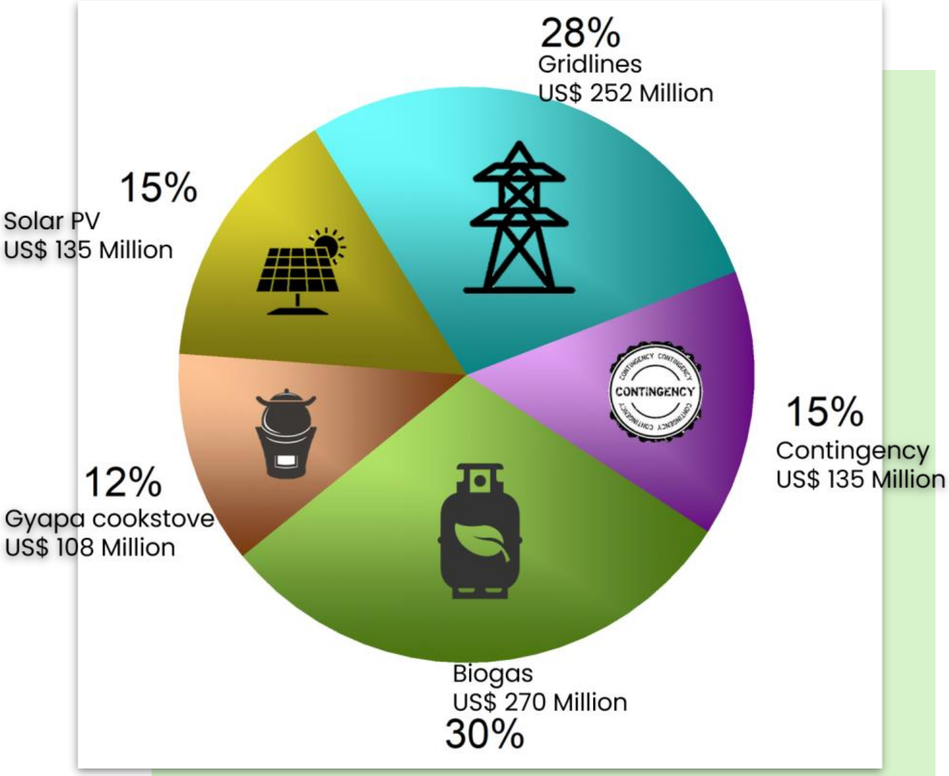


Fig: Total budget distribution

Monetizing Carbon Credits

Finance

Carbon Credits

Definition: Carbon offsets occur when a polluting company buys a carbon credit to make up for the greenhouse gas it has emitted

Carbon credit demand expected to increase 15x by 2030 and 100x by 2050!

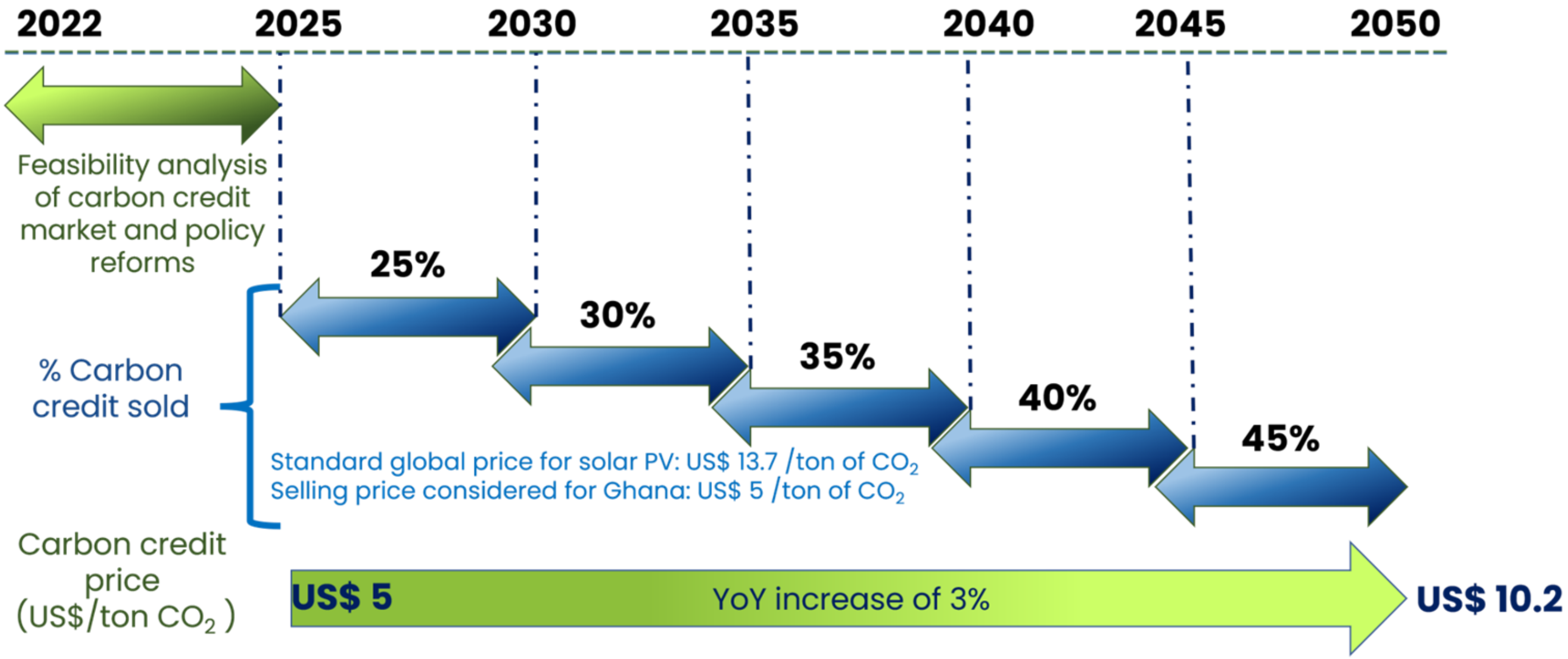
Cost for carbon credits expected to reach between US$20 and US$50 per metric ton of CO_2 by 2030

African Development Bank (AfDB) has launched a two-year technical assistance program – **African Carbon Support Program**

Top companies buying carbon credits

Finance

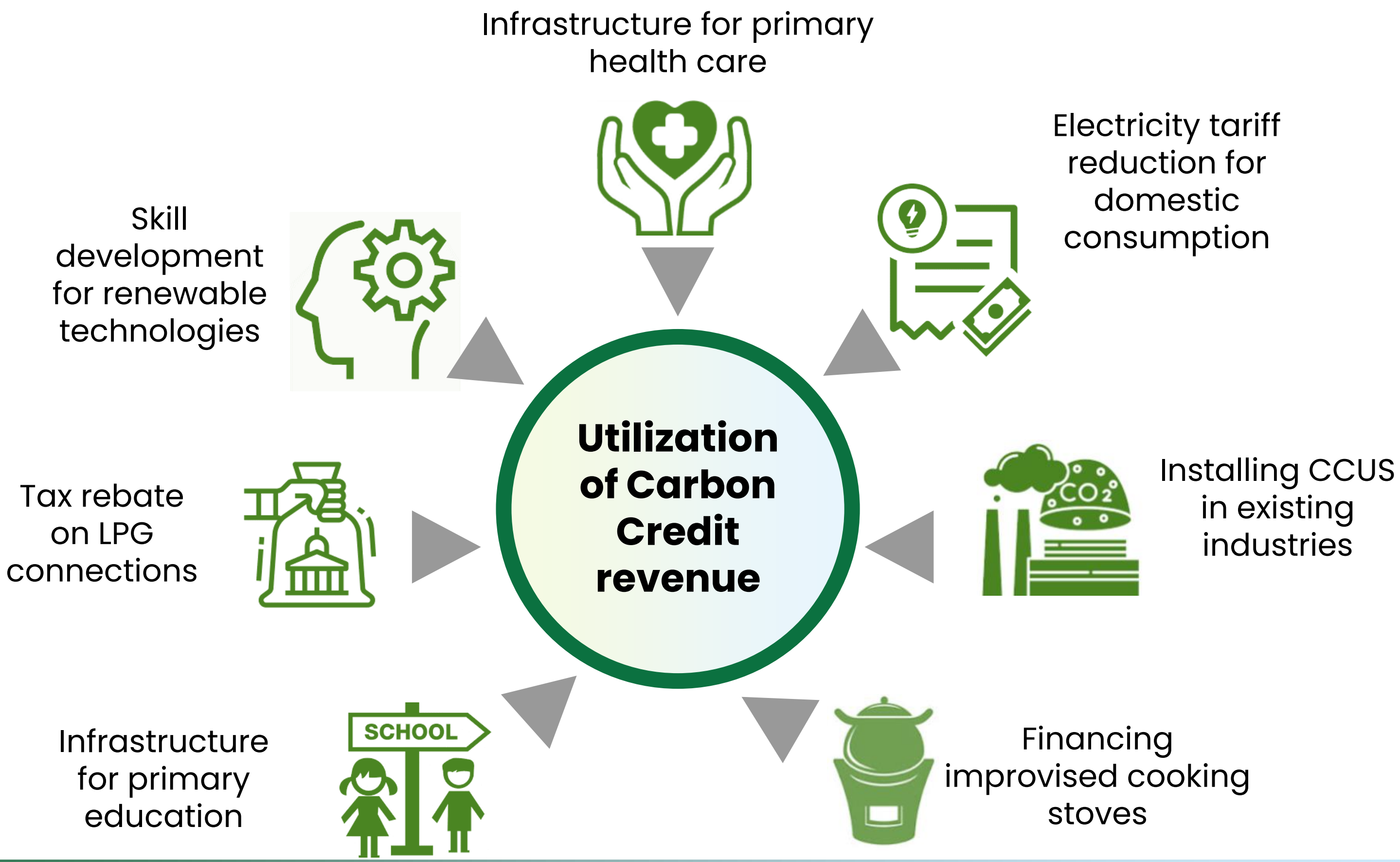
Carbon Credits: Implementation Plan



Ghana is expected to generate a cumulative revenue of US$ 500 million by end of 2050

Finance

Carbon Credits: Use of fund



Impact Analysis

Social & Environmental Impact

Our solution methodology impacts at least 10 sustainable development goals

Improving agricultural yield using biofertilizer

Reducing indoor air pollution by substituting solid fuels

Time save and use in other productive activities

Time saved from collecting Woodstock invested in education

Clean cooking stoves and solar PV will contribute in reducing deforestation

Deployment of clean fuel options could help empower women and girls

Mitigation of climate change

Increase share of RE and access to clean fuel

Decentralised plants to cater to all sections of society

Employment through construction work

Ref: SDG, UN

Benefits of reducing energy poverty

Economy
Revenue generated
Debts settled
Increase in long-term GDP
More domestic and foreign investment

Environment
Reduction in GHG emission
Reduction in deforestation

Health
Decrease in mortality rate
Reduction in respiratory disorder
Increase in life expectancy

Welfare
Education
Skill training
Cheaper power
Improved standards of living

Policy Recommendations

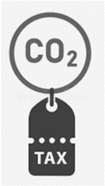
Govt. can encourage renewable energy on domestic activities

Govt must work on reducing T&D losses from 25% to 5% in the next 10 years

Escaping the Energy **Trap**

Govt. must open the electricity sector for private players

Govt must work on improving energy efficiency by making energy audits mandatory for industries



Revenue from CO_2 emission tax should be used towards Renewable development

TEAM

Nimbus 2.0

We are Team Nimbus from Indian Institute of Technology Bombay, India. We thank Switch Energy Alliance for organizing the competition and providing assistance & support during the competition. We are extremely thankful to our mentor Mr. Patrick Welch for guiding us & supporting us throughout the competition

Thank You

Back-up

Solution for Electricity Crisis

Solar PV + Storage: Feasibility Analysis

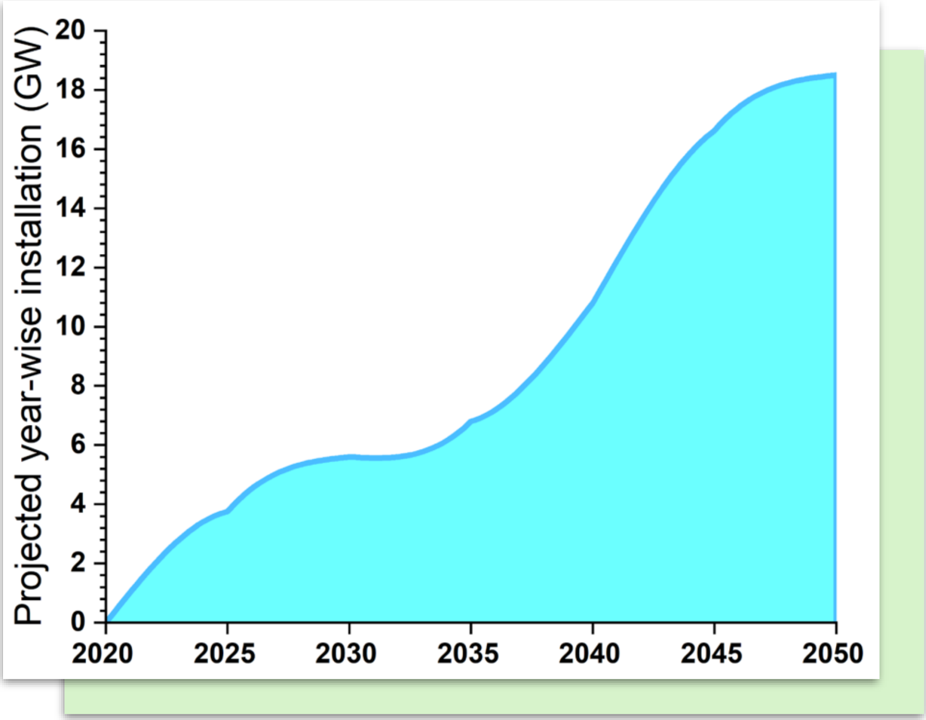


Fig: Proposed Year-wise installation plan

Proposed plan:
Ghana: 370 fold in 30 years

Solution for Electricity Crisis

Solar PV + Storage: Feasibility Analysis

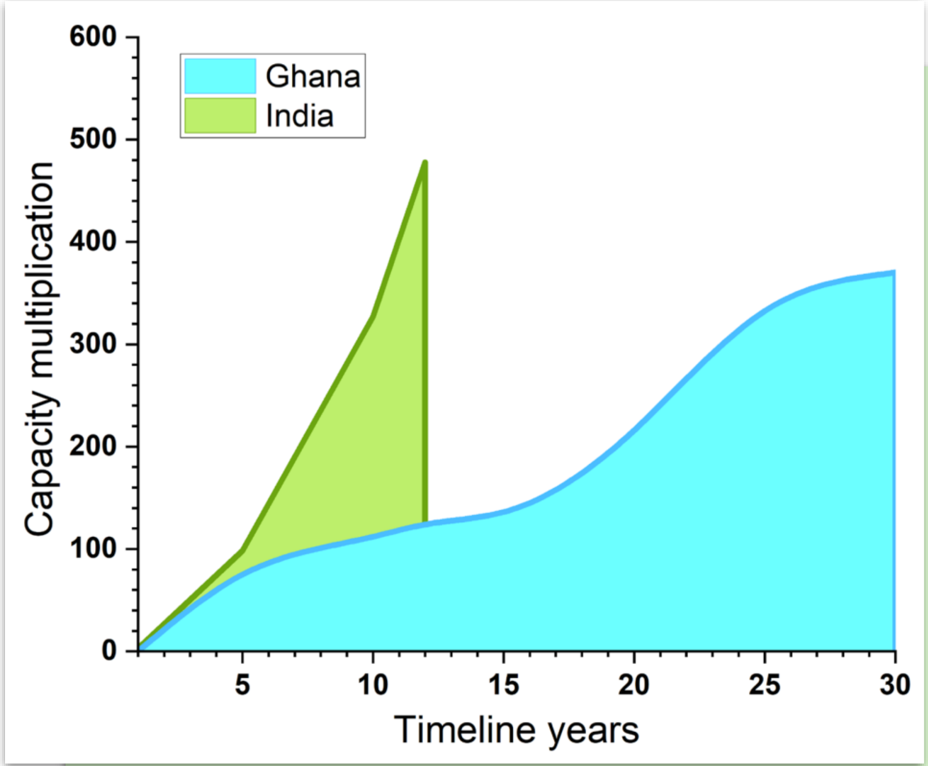


Fig: Comparative analysis on capacity multiplication

Proposed plan:
Ghana: 370 fold in 30 years

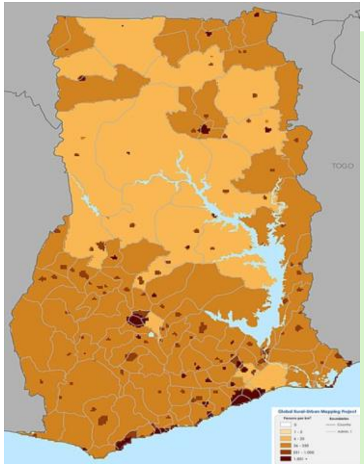
Actual data:
India: 500 fold in 12 years from 2010-22

Ref: Ministry of New and Renewable Energy, Government of India

Design

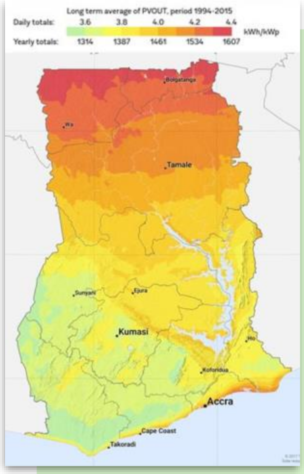
Solution for Electricity Crisis

Taping of Solar PV Potential



Ref: SEDAC, NASA

Fig: Population Density



Ref: Clean Technologies and Environmental Policy

Fig: Solar insolation

Ref: Global Energy Network Institute

Fig: Transmission Lines

	Northern & Central regions	Southern Region
Solar Insolation	Excellent	Average
Population density	Less	High
Interpretation	1. Availability of empty land with great solar potential. 2. Long transmission lines needed to bring electricity to southern region.	1. Average potential. 2. Benefitted with readily available gridlines

Executive
Summary

Problem Overview

- ❖ Ghana at a glance
- ❖ Energy Poverty in Ghana
  - Cooking fuel crisis
  - Unreliable & unaffordable electricity

Clean cooking fuel

- ❖ LPG and Biogas
- ❖ Technical & feasibility analysis
- ❖ Implementation approach & Timeline

Electricity: Affordable, accessible & reliable

- ❖ Solar PV + Battery storage
- ❖ Technical & feasibility analysis
- ❖ Implementation approach & Timeline

Finance

- ❖ Invest-Recoup-Reinvest model
- ❖ PPP model for electricity
- ❖ Cash-flow chart for investment

Environmental & social impact

- ❖ Reduction in carbon emission
- ❖ Carbon credit market exploration
- ❖ SDG analysis
- ❖ Policy recommendations