Switch Energy Case Competition 2023

Synergy Team-270

Country Pair
Kenya-Bangladesh

Home Country
Azerbaijan

Mentor: **Kamel Bou Hamdan**
Institution: Baku Higher Oil School
Team Members: Medina Ziyadkhanova
Narmin Nusalova
Sevinj Mollayeva

Kenya

Population: 52 million (2023)

Urban Population: 16 million (29%)

Rural Population: 36 million (71%)

GDP per Capita: 2269 US$

Minimum Wage: 102 US$

Inflation Rate: 6.8% (Sep-2023)

Area: 582,646 km²

Nº Tribes: 40+

Nº Languages: 70

HDI Ranking: 152nd

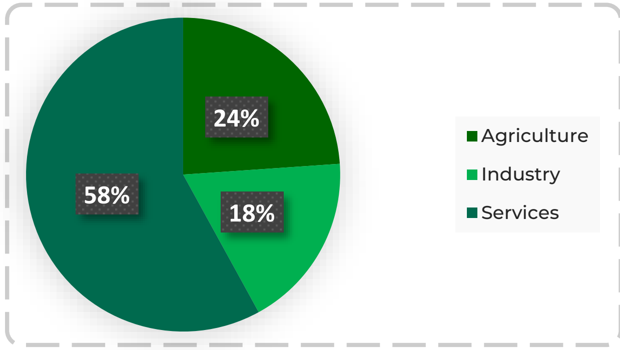
Life Expectancy: 67 years (2023)

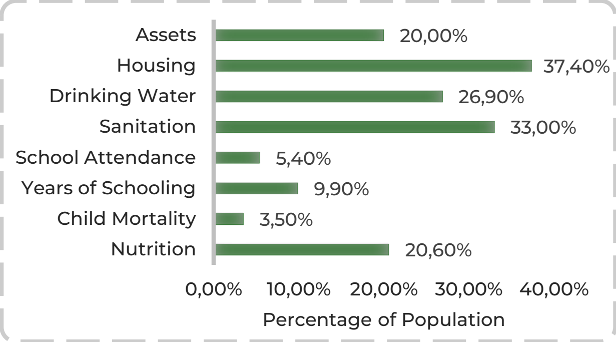
Death Rate: 5.34 per 1000

CO_2 Emissions: 0.37 metric ton per capita

Electricity Access: Urban-97% Rural-62%

Clean Cooking Fuel Access: 24%





Bangladesh

Population: 172 million (2023)

Urban Population: 67 million (39%)

Rural Population: 105 million (61%)

GDP per Capita: 2469 US$

Minimum Wage: 74 US$

Inflation Rate: 8.6% (Sep-2023)

Area: 148,460 km²

Nº Ethnic Communities: 75

Nº Languages: 42

HDI Ranking: 129th

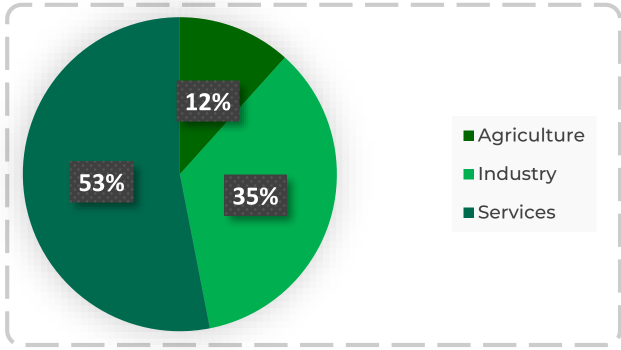
Life Expectancy: 73 years (2023)

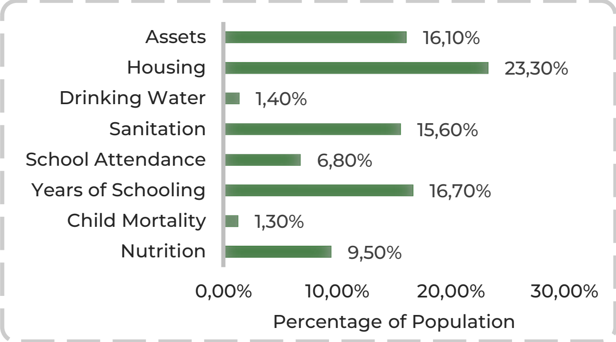
Death Rate: 5.5 per 1000

CO_2 Emissions: 0.51 metric ton per capita

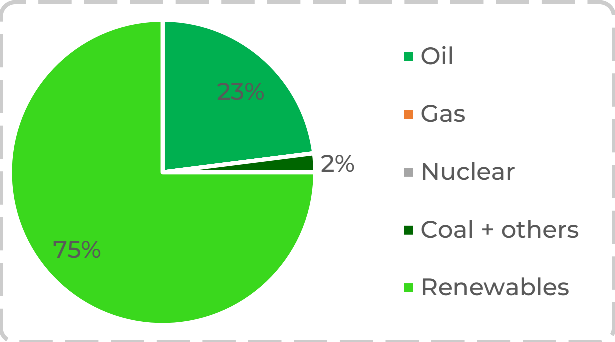
Electricity Access: Urban-100% Rural-100%

Clean Cooking Fuel Access: 28%

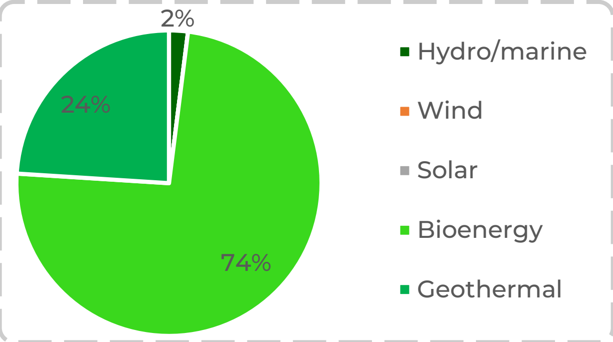




Kenya



Total Energy Supply



Renewable Energy Supply

1922
EAP&L was established, marking the start of Kenya's power sector.

2006
Energy Act 2006 was passed, furthering sector reform.

2018
Power consumption reaches 3,751 MW.

2030
The estimated system expansion cost is $41.4 billion.

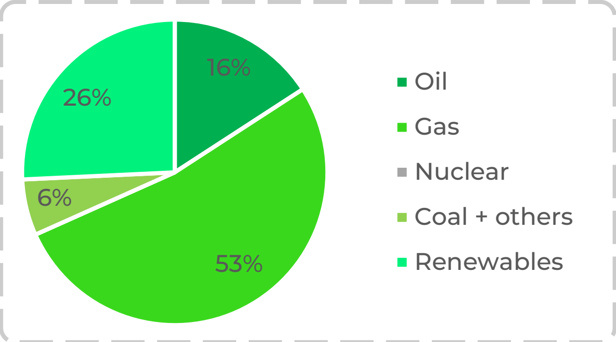
1954
KPC forms as a subsidiary of EAP&L.

2009
KenGen opens 5.1MW wind farm in Ngong.

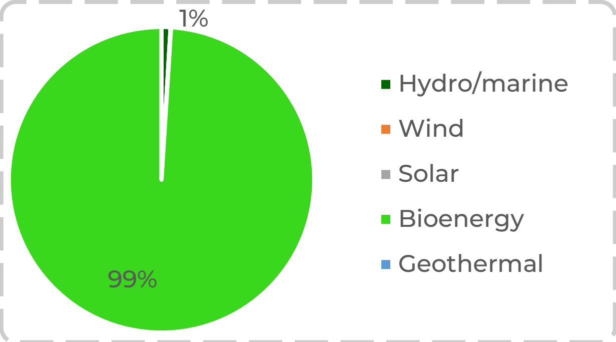
2022
Kenya plans a nuclear power program, aiming to have a nuclear plant with a generation capacity of 1,000 MW.

Energy Timeline

Bangladesh



Total Energy Supply



Renewable Energy Supply

1901
Electricity was introduced in Bangladesh under British rule.

2014
Nationwide blackout reveals issues with the power grid's infrastructure.

2018
The installed electricity generation capacity is 20,000 MW.

2041
Bangladesh aims to generate 17% of power from renewable sources.

2009-2012
Plans and investments to address load shedding and expand power generation.

2016
Potential for 3.6 GW of electricity from renewable sources, including wind.

2022
Severe blackouts due to natural gas shortages and reliance on it in the electricity sector.

Energy Timeline

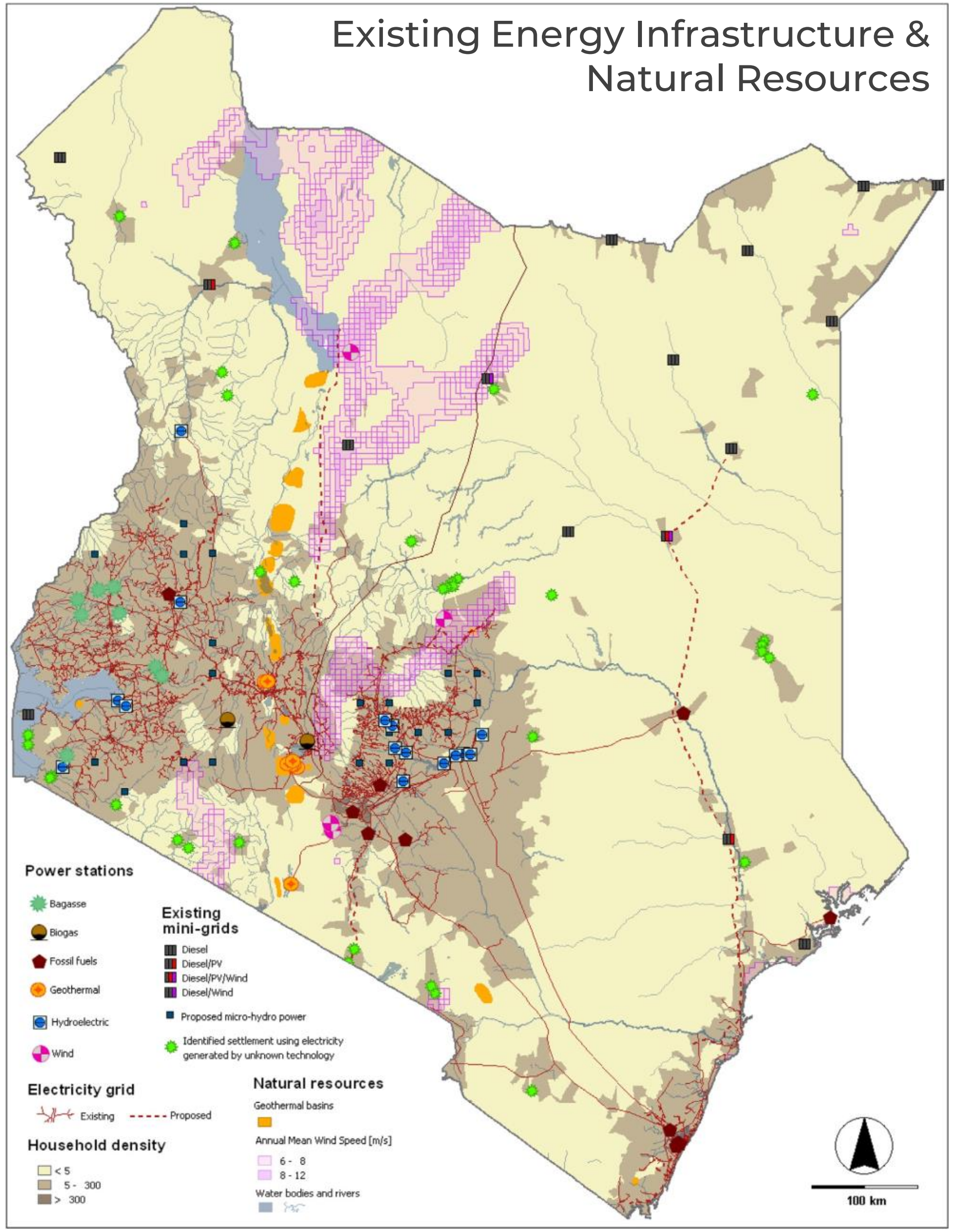
Executive Summary

Executive Summary

Problem Overview	Kenya: Current Energy State, Energy Poverty Factors, Cooking Fuel Crisis, Unaffordable-Inaccessible-Unreliable Energy Bangladesh: Current Energy State, Energy Poverty Factors, Cooking Fuel Crisis, Energy Crisis: Idle Plants, Outages, Soaring Prices
Comparative Analysis	Energy Poverty Factors, Conclusion and Takeaways Feasibility of Clean Cooking Fuels and Electrification Solution
Cooking Fuel Crisis	Success Indicators, Current Policies and Initiatives, Action Plan, Kenya Energy Transformation Office, Comparative Analysis of Cooking Fuel Sources, Biogas Digesters, Bioethanol and LPG as Transitioning Fuels, Projections, Implementation Timelines
Electricity Crisis	Current Scenario and Projections, Energy Barriers and Policies, Key Takeaways and Action Plan, Comparative Analysis of Renewable Energy Sources, Solar PV+Storage, Innovation: ENLIL Wind Turbines, Projections and Implementation Timelines
Financial Plan	Biogas: Assumptions and Financial Roadmap, Public Private Partnerships: Solar PV and Wind Turbines, Renewable Energy Sources: Assumptions and Financial Roadmap , Combined Financial Plan
RECs Monetization	Renewable Energy Certificates Definition, Implementation Timeline and Revenue, Utilization Ways of Generated Revenue
Impact Analysis	Impact Through 12 Sustainable Development Goals Impact On Various Sectors: Health Care, Gender Equality, Economic and Time Savings, Biodiversity
References	World Bank, IRENA, NREL, GGGE, Asian Development Bank, Our World in Data, Statista
Appendix	Cooking Fuel Region Classification in Kenya, Comparative Analysis: Fuel Sources and Stoves, Comparative Analysis of Biogas Digesters, Biogas Cost Analysis, Biogas Case Study, Solar and Wind Energy Potential in Kenya

Problem Overview
Kenya

Current Energy State

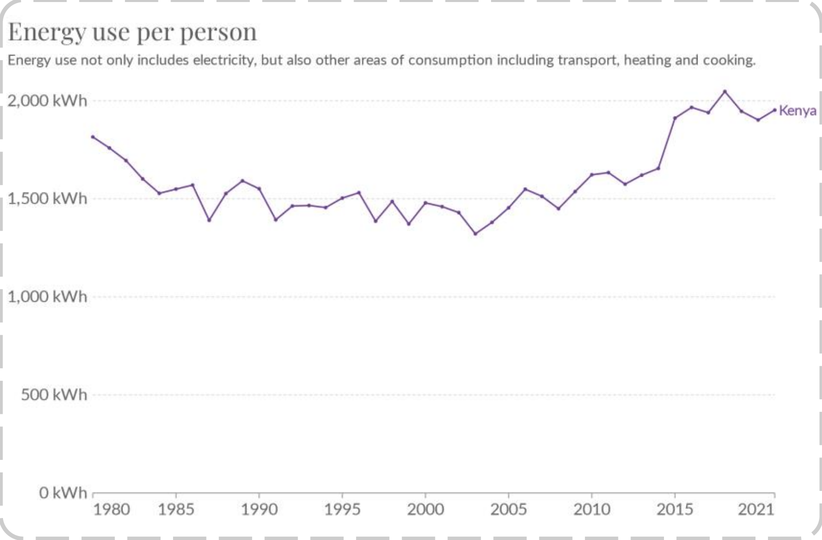


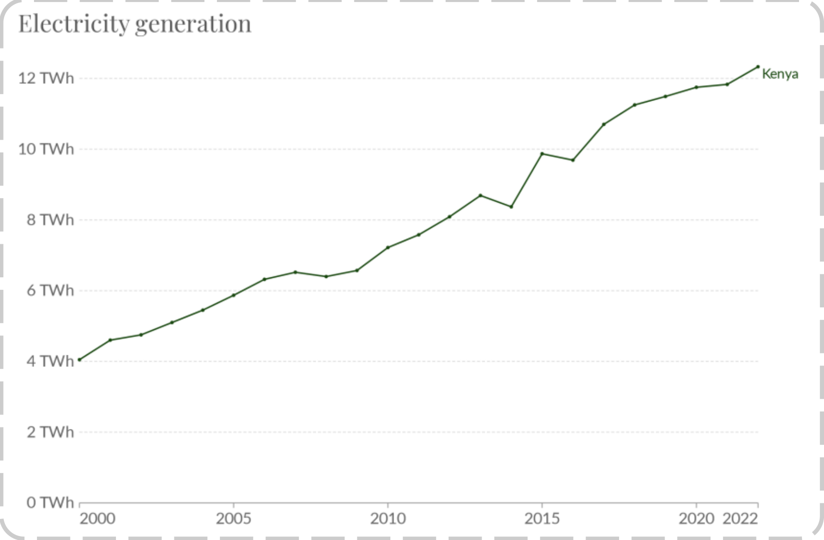
Source	Output	№
geothermal	948 MW	6
hydro	845 MW	24
oil	559 MW	7
wind	436 MW	3
solar	171 MW	9
diesel	87 MW	2
All	3,046 MW	51

51 power plants, 3,046 MW

Voltage	Length	Percentage
0 V – 9 kV	4 km	0.1%
10 kV – 24 kV	16 km	0.3%
25 kV – 51 kV	0 m	0.0%
52 kV – 131 kV	0 m	0.0%
132 kV – 219 kV	2,230 km	37.8%
220 kV – 329 kV	1,887 km	32.0%
330 kV – 549 kV	1,688 km	28.6%
550 kV –	0 m	0.0%
No voltage tagged	71 km	1.2%
Total	5,896 km	100.0%

5,896 km of power lines





Energy Poverty Factors

Accessibility

- 24% use LPG, but many in informal areas still use polluting fuels.
- Urban areas: 97% electricity access; rural Kenya: 62%

Affordability

Kenyan electricity bills surged by 19% in April 2023, rising from $0.17 to $0.21 USD per kWh.

Electricity, making up 14.6% of household spending, strained budgets, affecting housing and water expenses.

Environmental Impact

- A deficit in fuel wood supply results: deforestation, famine, drought land degradation, and desertification.
- Heavy reliance on hydropower resulting in loss of water capacity in places like Lake Turkana.

Safety

- In three years, 345 people were electrocuted due to unsafe practices and negligence.
- Annually, 23,000 Kenyan deaths are attributed to household air pollution from traditional cooking fuels.

Quality of Energy Services

- In 2023, Kenya Power receives 700,000 new smart meters to address consumer power issues.
- Energy quality improves through the adoption of energy-efficient LEDs (80% energy savings) for lighting.

Security

- In July 2023, Kenya's energy infrastructure, particularly Kenya Power, experienced significant disruptions and security concerns due to cyber-attacks, highlighting vulnerabilities in the sector..

Reliability

- A nationwide outage on August 25, 2023, significantly disrupted Kenya's power supply due to problems at Africa's largest wind farm, Lake Turkana Wind Power plant, and grid system issues.

Potential for Roadblocks

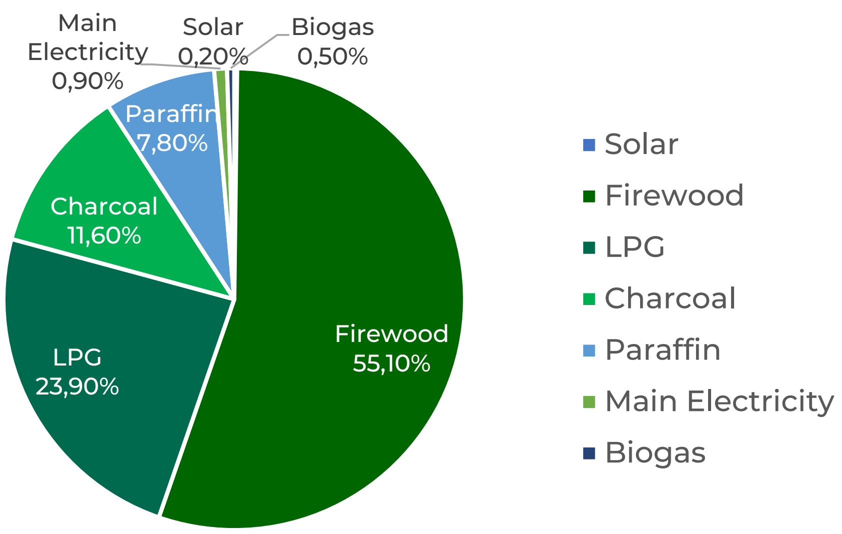
Banks in Kenya avoid investing in renewable energy due to cost concerns.

Rural residents hesitate to connect to the grid due to fears of high electricity expenses.

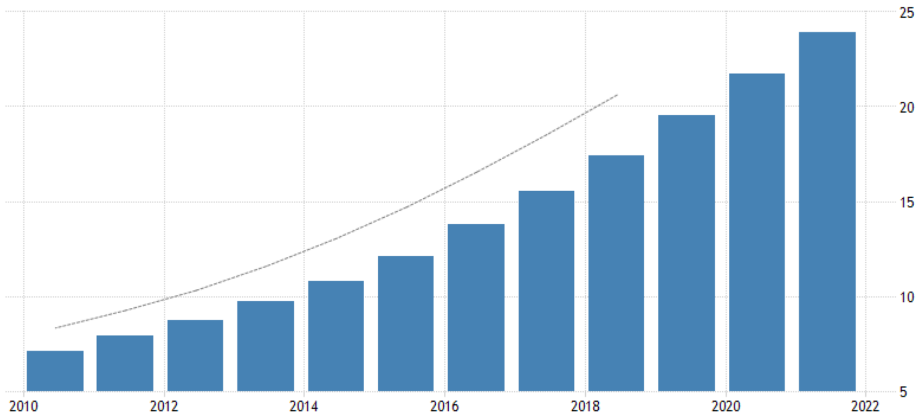
Corruption impedes energy efficiency efforts in Kenya.

Cooking Fuel Crisis

Household Cooking Energy Sources: Percentage Share



Access to Clean Fuels & Technologies for Cooking (% Of Population)



Challenges Hampering Transition to Clean Residential Cooking Sectors

Economic

High upfront costs and infrastructure limitations hinder cleaner cookstove adoption.

Political

Absence of a comprehensive strategy for safe and clean cooking despite existing policies.

Cultural

Cultural factors and fuel stacking can hinder the shift to cleaner cooking

Health Risks and Diseases Associated with BMF Use

Premature Death

21,500 annual premature deaths, with acute lower respiratory infections accounting for 26% of hospital deaths.

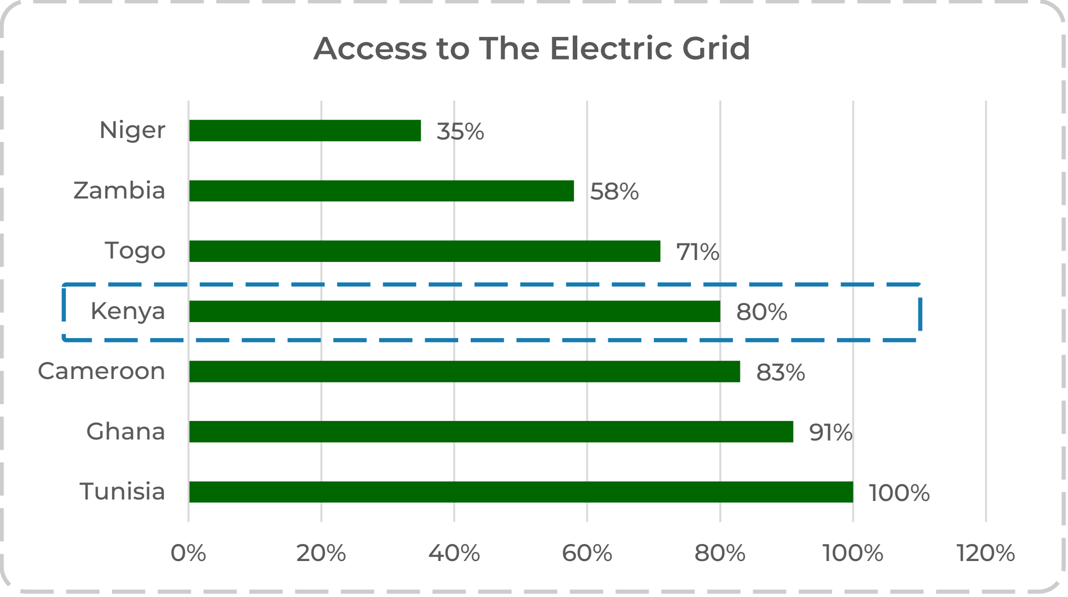
Women & Children

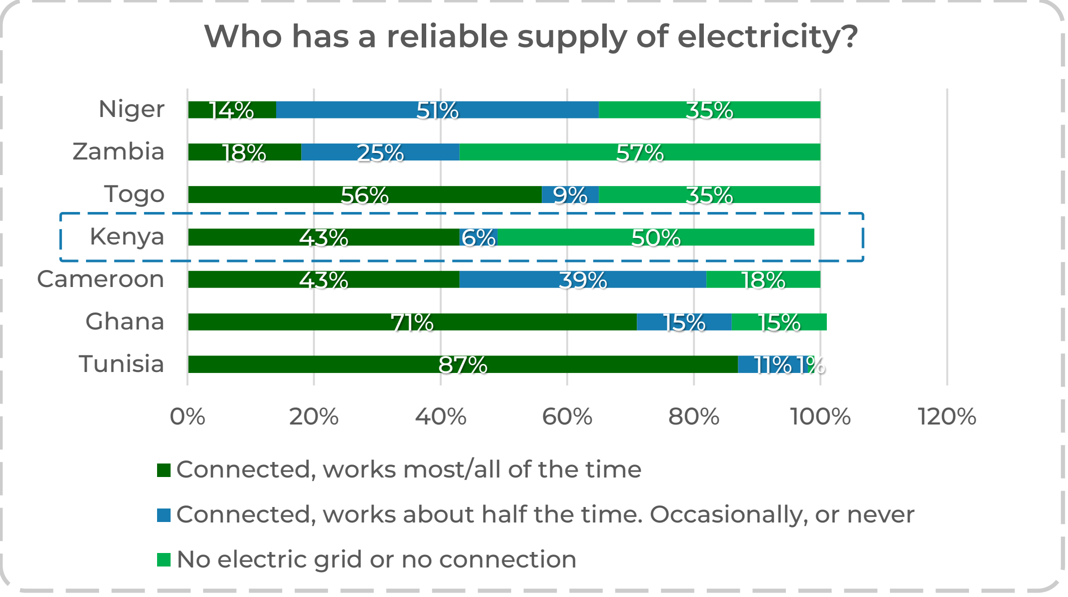
Indoor air pollution led to health issues in 92.0% of women & 95.4% of children, such as coughs, wheezing, fatigue, and headaches.

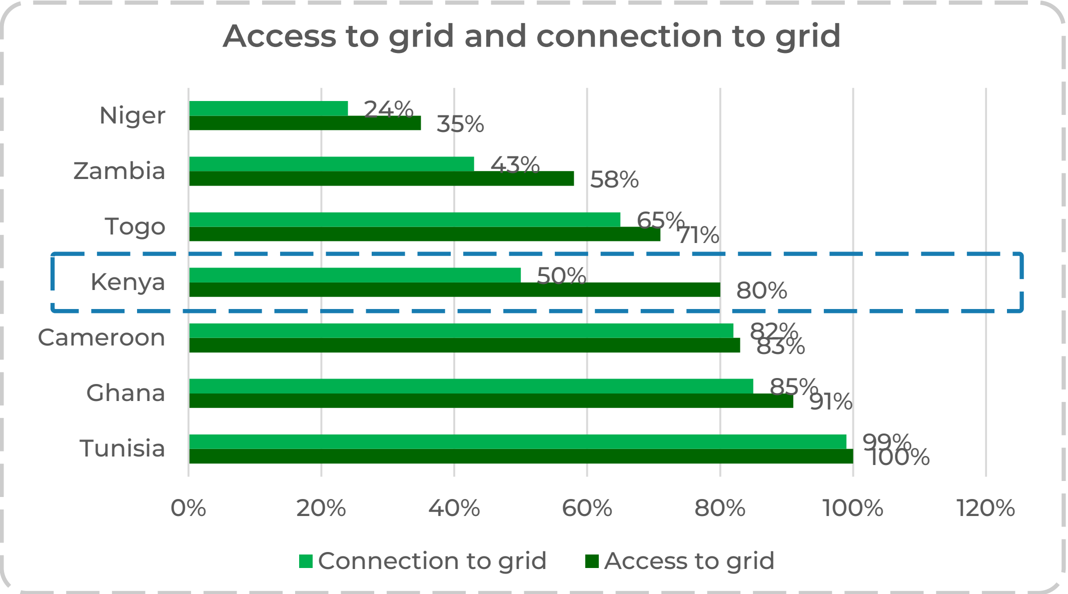
Health Issues

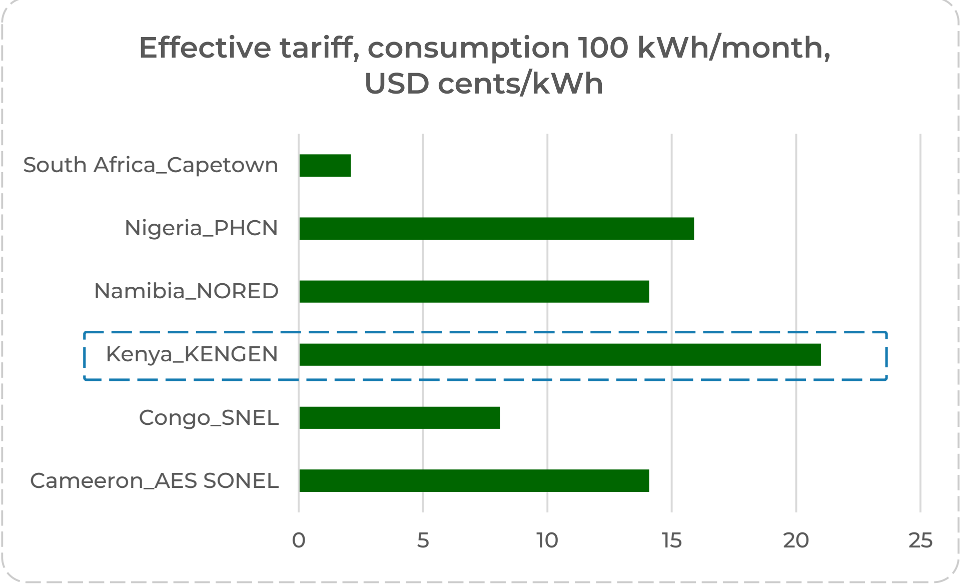
HAP from wood fuel in Kenya is associated with cardiac dysfunction and respiratory infections in children.

Unaffordable – Inaccessible - Unreliable Energy









T&D Losses
23.49%

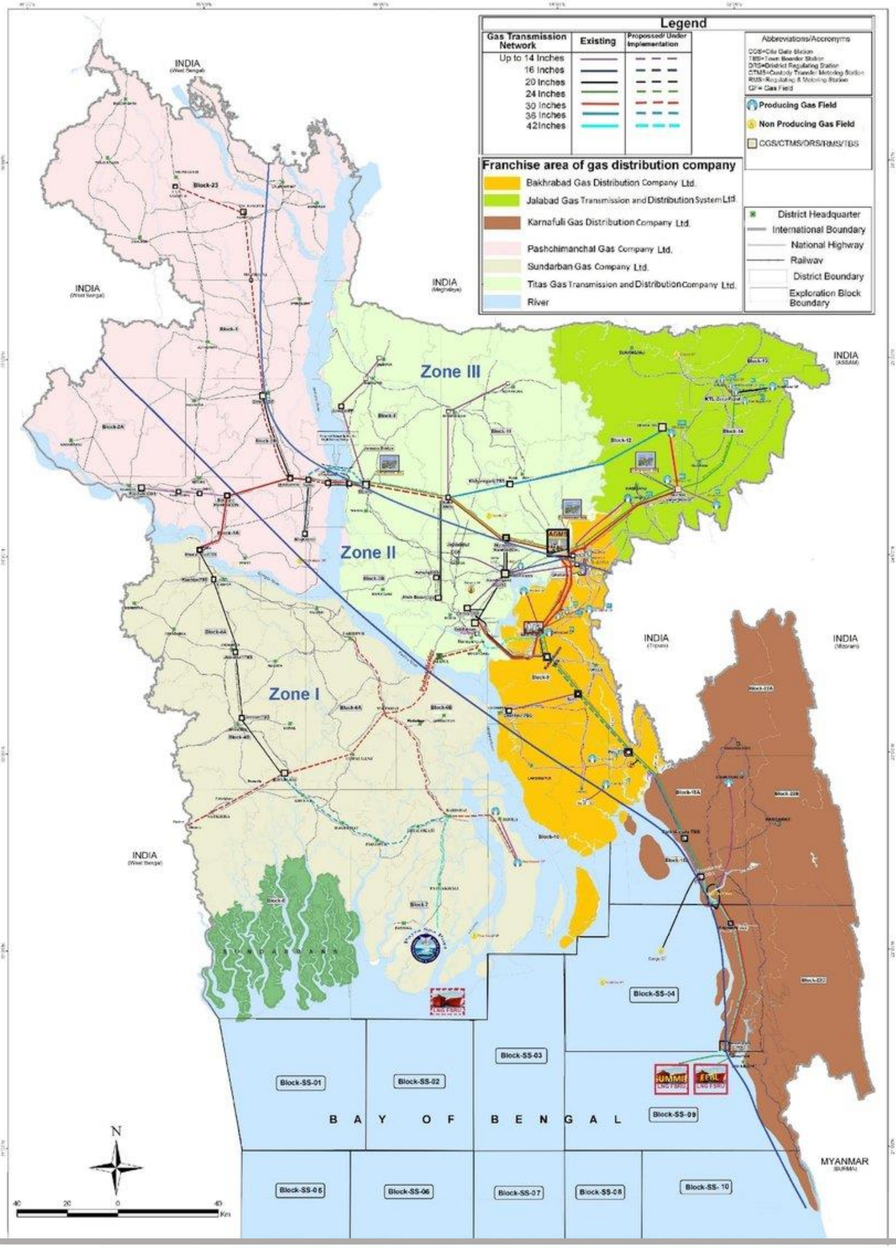
Urban
97%

Cost per kWh
$0.21 USD

Rural
62%

Problem Overview Bangladesh

Current Energy State



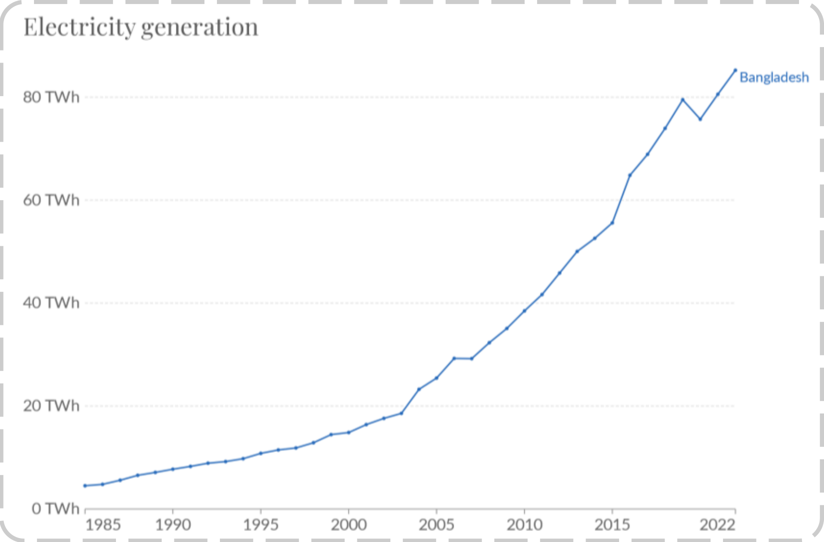
Existing Energy Infrastructure & Natural Resources

Source	Output	Count
gas	11,570 MW	53
oil	7,162 MW	65
coal	2,493 MW	4
solar	452 MW	16
hydro	230 MW	1
diesel	105 MW	1
wind		1
[unspecified]		15
All	22,012 MW	156

156 power plants, 22,012 MW

Voltage	Length	Percentage
0 V – 9 kV	0 m	0.0%
10 kV – 24 kV	153 m	0.0%
25 kV – 51 kV	3 km	0.0%
52 kV – 131 kV	0 m	0.0%
132 kV – 219 kV	4,159 km	58.2%
220 kV – 329 kV	1,844 km	25.8%
330 kV – 549 kV	869 km	12.2%
550 kV –	0 m	0.0%
No voltage tagged	269 km	3.8%
Total	7,144 km	100.0%

7,144 km of power lines



Energy Poverty Factors

Accessibility

- Clean cooking access in Bangladesh fell by over 1%, with 72% reliant on non-clean energy sources.
- Bangladesh uses only half of its 24,911MW installed electricity capacity due to policy flaws.

Affordability

- Bangladesh faces power cost challenges amidst a dollar crisis despite global price stability. Grid electricity comprises around 5% of household consumption (6.7% in urban, 3.4% in rural areas), sometimes exceeding the 5% affordability threshold.

Environmental Impact

- From 2001 to 2022, Bangladesh lost 228 kha of tree cover, equivalent to a 12% decrease in tree cover since 2000, and 124 Mt of CO_2e emissions.
- Deforestation for agricultural expansion also leads to habitat loss and biodiversity decline.

Safety

- Unsafe gas and power links heighten earthquake vulnerability, potentially exacerbating destruction.
- Titas Gas disconnected 602,884 illegal connections in Dhaka and Mymensingh divisions during 28,398 drives in the past 20 months.

Quality of Energy Services

- More than 5,000MW of gas-fired power plants are sitting idle across the country.
- Last year's electricity shortage highlighted domestic gas exploration neglect. A year later, limited drilling and insufficient budget allocation persist.

Security

- Bangladesh's primary sources of power production are coal, natural gas, and heating oil. The rising fuel imports and the substantial reliance on coal and gas to produce power raise questions about the security of the energy supply.

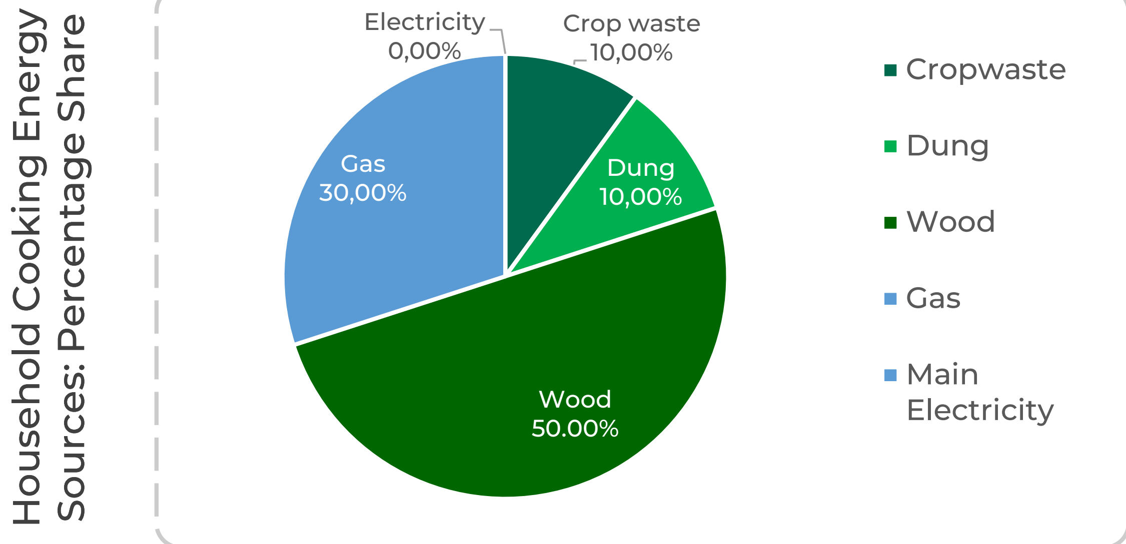
Reliability

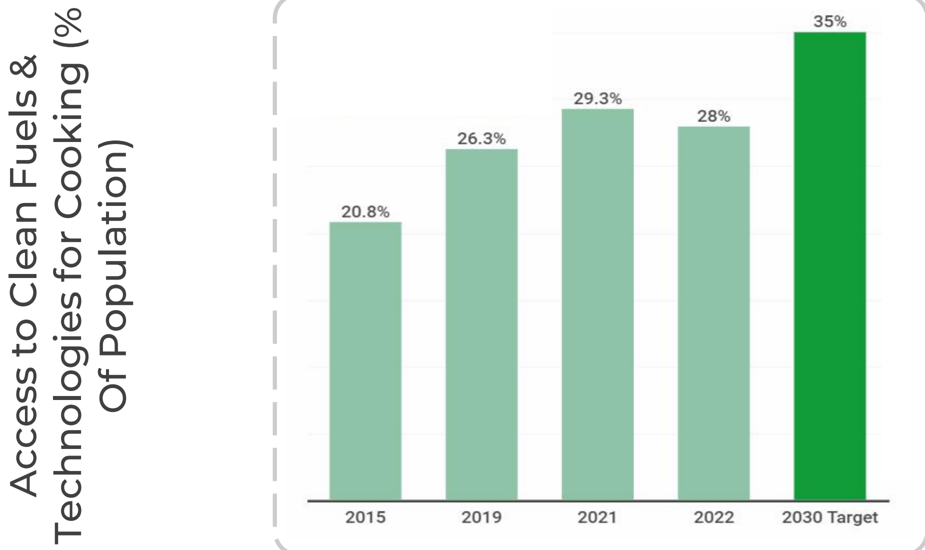
- Bangladesh experiences unreliable 12,000MW generation, causing frequent outages and spurring industries to add 3,000MW of captive power. Over 400 storm-related outages occur annually.

Potential for Roadblocks

- Weak financial institutions, negative balance of payments, downgraded credit ratings, corruption, and imperfect competition could hinder Bangladesh's renewable energy investments.

Cooking Fuel Crisis





Challenges Hampering Transition to Clean Residential Cooking Sectors

Economic

The Market is flooded by poor/low-quality electrical appliances causing distrust in products.

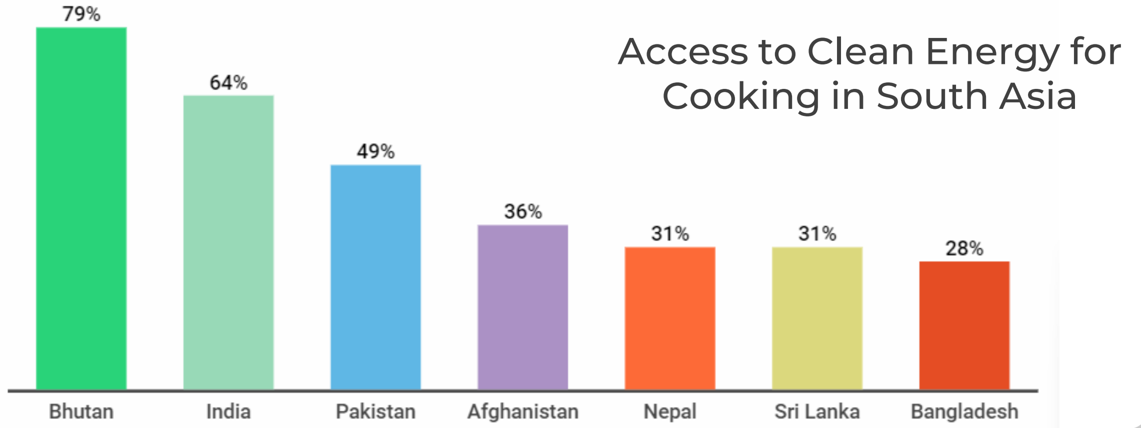
Political

The government KABITA program promotes ICS for free which negatively affects commercial viability of other technologies.

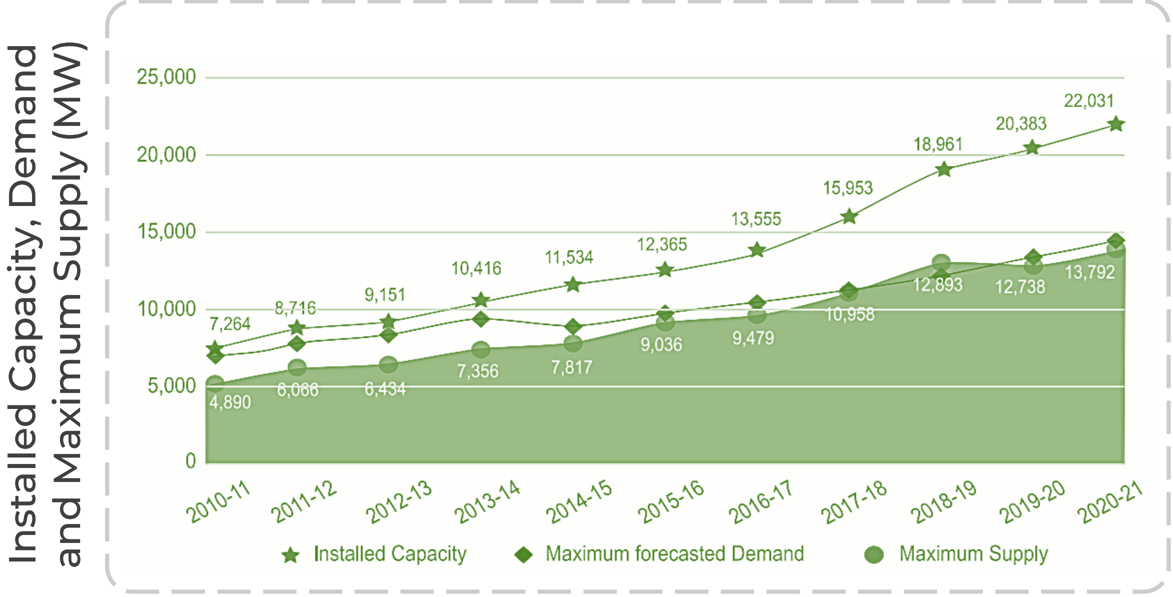
Cultural

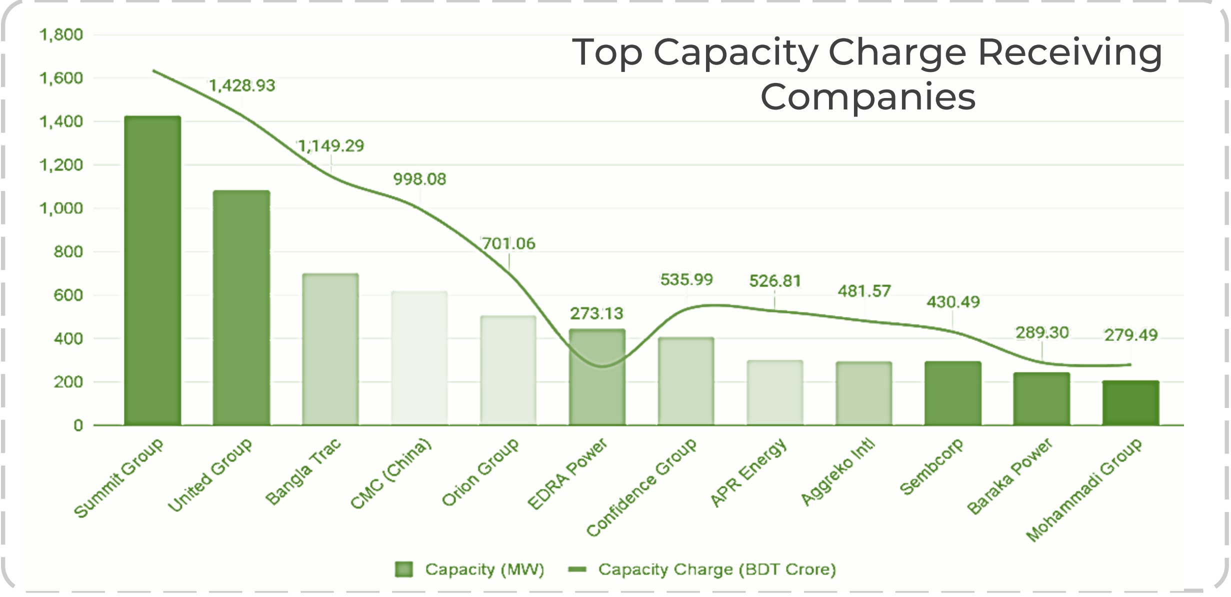
Cultural practices or habits that cannot be easily changed regardless of the availability of alternate options

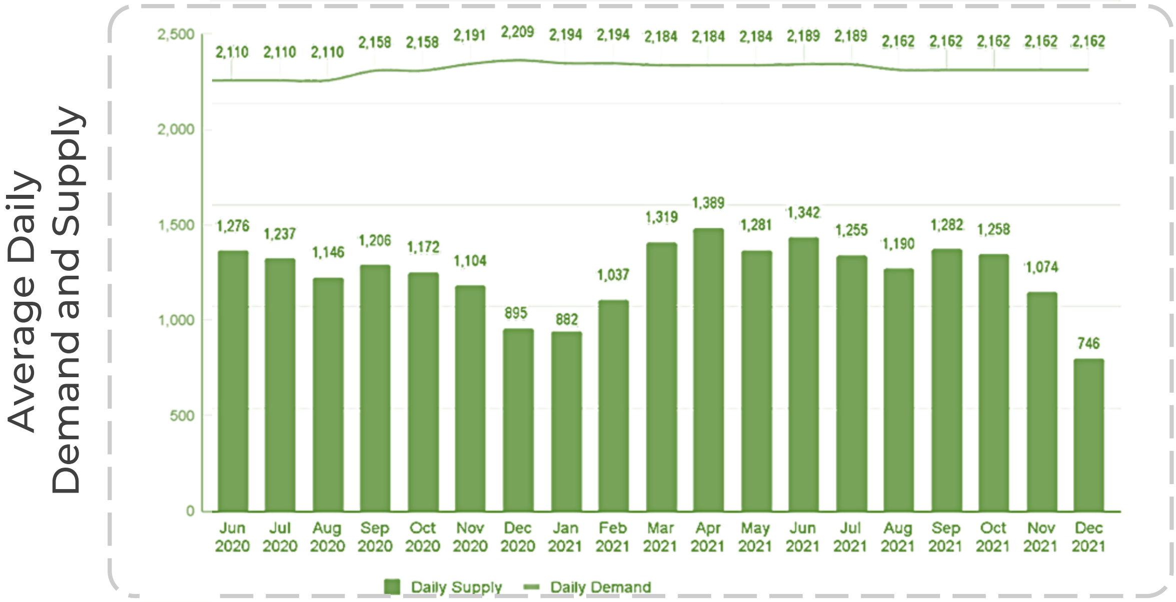
In Bangladesh, exposure to indoor air pollution results in nearly 107,000 deaths every year, mostly women and children, who also bear much of the burden of collecting firewood or other traditional fuels.

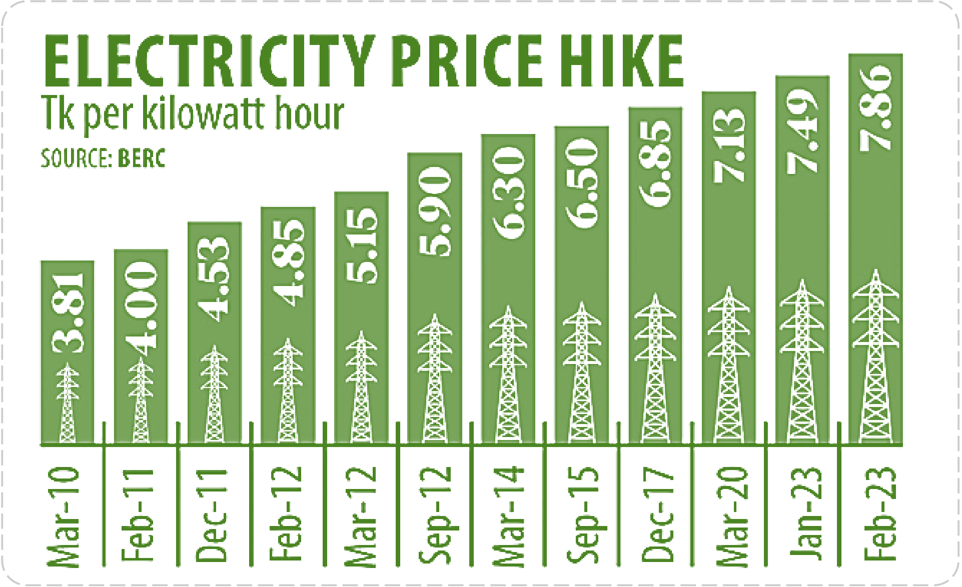


Energy Crisis: Idle Plants, Outages, Soaring Prices









T&D Losses
15%

Idle Plants
68

Surplus
40% more

No Electricity
10-12 hours

Comparative Analysis Problem Overview

Energy Poverty Factors

	Accessibility			Affordability		Reliability	Safety	
		Electricity					Annual Deaths	
	Clean Cooking Fuel %	Urban %	Rural %	Cost per kWh (USD)	Household Expenditure Share %	Longest Blackout (hours)	Indoor Air Pollution	Electrocution
Kenya	24	97	62	0.21	14.16	14	23000	149
Bangladesh	28	100	100	0.071	6.20	12	107000	5600

	Security		Quality of Services		Environmental Impact			Roadblocks			
					Land	Water	Air				
	Households with Illegal Connections	Attacks Caused Disruptions	Smart Meters	Idle Plants	Deforestation (kha)	Surface Level Decrease (%)	CO2 Emmissions (metric ton per capita)	Corruption	Low Investment Interest	Cultural Sensitivity	Lack of Comprehensive Transition Strategy
Kenya	500,000	✓	✓	NA	6.29	25	0.37	✓	✓	✓	✓
Bangladesh	NA	✓	✓	✓	228	NA	0.51	✓	✓	✓	✓

Conclusion and Takeaways

Access to Energy

Similarities

- Both Kenya and Bangladesh face challenges related to energy poverty and inadequate access to electricity in rural areas.
- In both countries, efforts have been made to expand access to energy, including through off-grid and mini-grid solutions to reach underserved populations.

Differences

- Kenya has made significant progress in increasing access to energy, particularly in rural areas, through initiatives like the Last Mile Connectivity Project, whereas Bangladesh has been working on expanding access more recently.
- Bangladesh has a higher electrification rate than Kenya, but still experiences disparities in access between urban and rural areas, whereas Kenya faces more significant access challenges in remote regions.

Renewable Energy

Similarities

- Both Kenya and Bangladesh are making efforts to promote renewable energy sources as an alternative to fossil fuels.
- Solar energy is gaining momentum in both countries as a renewable energy source, with numerous solar projects being developed.

Differences

- Kenya has a strong geothermal energy sector and is considered a leader in geothermal power in Africa, while Bangladesh has not yet tapped into significant geothermal resources.
- Bangladesh has shown interest in wind power projects and has invited bidders for projects totaling around 150MW, while Kenya has already established a substantial wind energy presence with projects like the Lake Turkana wind farm.

Energy Efficiency

Similarities

- Both Kenya and Bangladesh are working on improving energy efficiency to reduce energy wastage and enhance sustainability.
- Efforts to adopt energy-efficient technologies and practices are being promoted in various sectors of the economy in both countries.

Differences

- Kenya has made significant strides in improving energy efficiency, particularly in the transport sector, with the introduction of initiatives such as electric buses and the promotion of energy-efficient appliances. Bangladesh is in the early stages of implementing such initiatives.
- The industrial sector in Bangladesh faces challenges related to energy efficiency, and there is room for improvement in this regard, whereas Kenya has made progress in enhancing industrial energy efficiency.

Government Policies

Similarities

- Both Kenya and Bangladesh recognize the role of governmental policies in promoting renewable energy and sustainability.
- Both actively engage with international organizations and seek financing from institutions like the World Bank and the Asian Development Bank for their renewable energy projects.

Differences

- Kenya has canceled environmental licenses for coal-fired projects like the Lamu coal power project, signaling a shift away from coal. In contrast, Bangladesh is still considering coal power projects, including the Rampal coal-fired power plant.
- While both countries work to improve their renewable energy sectors, Kenya is more assertive in promoting its potential as a renewable energy leader in Africa, while Bangladesh is catching up with the rest of Asia.

Solution Methodology Cooking Fuel Crisis Kenya

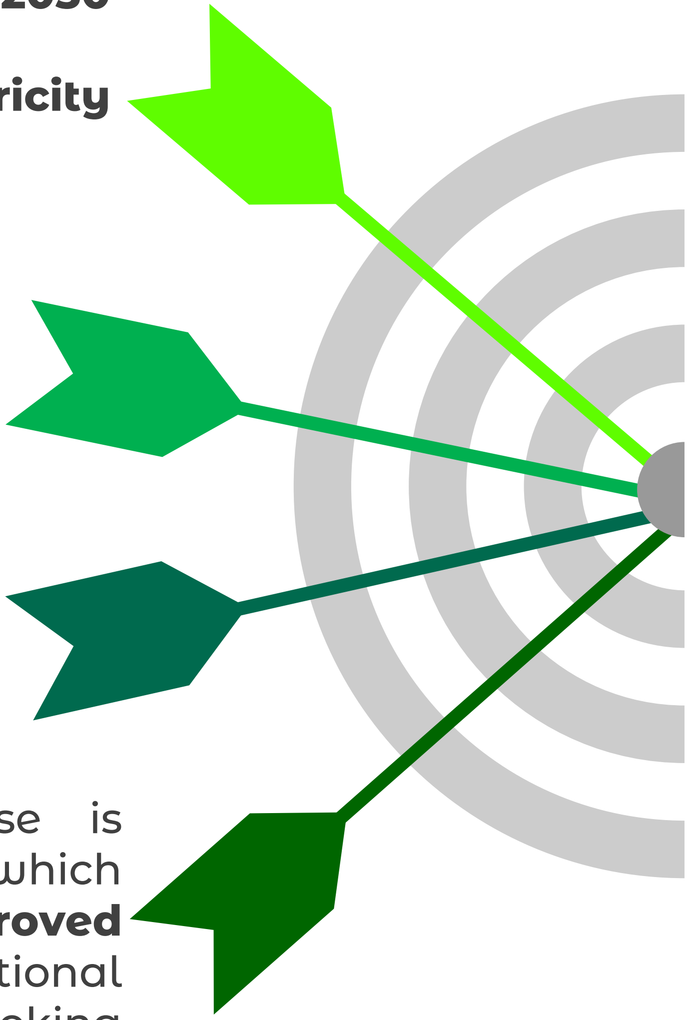
Success Indicators

- **100% electricity access** by **2050** (grid/off-grid)
- **100% renewable grid electricity** by **2050**

Focus on electrification (urban) and biogas (rural):
- **24% access to bioethanol cookstoves** by **2050**
- **42% access to biogas** and **bioethanol** by **2050**

In urban areas, LPG is a transitioning fuel:
- **34% access** by **2050**

Overall **solid biomass** use is **reduced** by **77%** by **2033** of which **100%** has **access** to **improved cookstoves** by **2033**. Traditional and solid biomass use for cooking is **phased out** by **2050**.



Based on regional best practices and top-down assumptions. (IEA, 2020b, Lambe, Nyambane & Bailis, 2020; Ministry of Energy, 2022a)

Targeted SDGs

Cooking Fuel: Current Initiatives and Policies

Forestry Laws, Policies, and Regulations

- **2016 Forest Conservation and Management Act:** Regulates unauthorized charcoal possession, calls for a national forest policy and strategy, and governs sustainable charcoal and fuelwood production.
- **2020 Draft National Forest Policy:** Drives governance reforms, focuses on restoring degraded forests, and tackles deforestation and governance challenges.

Energy Laws, Policies, and Regulations

- **2019 Energy Act:** Guides energy transition, establishes REREC, and devolves functions to County governments.
- **2019 Energy (LPG) Regulations:** Updates LPG rules for user safety.
- **2020-2027 National Bioenergy Strategy:** Promotes sustainable bioenergy and aims for clean cooking and modern bioenergy access.

Climate Laws, Policies, and Regulations

- **2018-2022 National Climate Change Action Plan (NCCAP):** Prioritizes clean cooking and sets targets for cleaner fuels and improved cookstove adoption by 2022.
- **2020 Updated NDC:** Aims for a 32% reduction in emissions relative to a business-as-usual scenario by 2030 to meet Paris Agreement goals.

Public Sector Laws, Policies, and Regulations

- **Kenya Off-grid Solar Access Project (KOSAP) (2017-2023):** A $150 million World Bank project targets providing electricity and clean cooking solutions to underserved areas by 2023, with a focus on private sector involvement.
- **Promotion of Climate-Friendly Cooking in Kenya (2020-2025):** Funded by the GCF and executed by GIZ with partners, it aims to promote improved cookstoves in rural areas and aligns with NDC goals.

Private Sector Laws, Policies, and Regulations

- **National Biomass Briquette Programme (2016-2022):** A multi-stakeholder initiative with Hivos, Greening Kenya Initiative, the African Centre for Technology, Practical Action, and the Kenyan government, promotes innovative briquette technologies and aims to increase the adoption of briquettes as a cleaner fuel through supply chain development.

Fiscal Policies Affecting The Cooking Sector

- **2018 Finance Act:** Increases kerosene excise duty, adds 8% VAT to petroleum products, and introduces an anti-adulteration levy to deter household kerosene use.
- **2020 Finance Bill:** Reapplies 16% VAT on LPG and clean cookstoves, undermining clean cooking promotion and raising costs for consumers.

Key Takeaways and Action Plan

Current policies prioritize modern cookstoves over clean cooking solutions. To align with Kenya's climate and development goals, recognizing the synergy between climate action and sustainable development in residential cooking is crucial for a sustainable future.

!

In Kenya, households use multiple cooking fuels, with rural areas relying on fuelwood, urban areas on LPG. To promote clean cooking, a supportive policy framework is crucial, considering socio-cultural and economic factors.

1

Establish a **permanent coordinating body** in a Ministry to unify policies and strategies for the cooking sector, ensuring alignment among stakeholders. Develop long-term plans for efficient resource utilization and monitoring progress.

2

Create a comprehensive, **long-term cooking sector transition strategy**, align with existing policies, analyze where needed, and emphasize mitigation potential and health benefits.

3

Emphasize clean cooking solutions for a long-term transition, with a **focus on LPG and improved biomass**. Address market and infrastructure challenges and explore **region-specific solutions** through feasibility studies, leveraging the Energy Act of 2019.

4

Integrate clean cooking to achieve climate and development targets, align with the Paris Agreement, and **raise awareness among stakeholders and the public**, emphasizing health benefits and using financial incentives alongside communication efforts.

5

Enhance **cooking sector data collection and analysis** to improve policy accuracy. Establish a **central coordination entity** for national-level **data management** and support county governments in data collection.

6

Accelerate cooking sector transformation with **innovative infrastructure**, leveraging existing networks, and fostering clean cooking solutions through **government-supported innovation**.

Kenya Energy Transformation Office (KETO)

KETO, operating as an **independent entity**, will oversee and coordinate the cooking sector and electrification initiatives in Kenya, ensuring alignment among stakeholders.

It **coordinates policies, strategies, and data among stakeholders**, supporting Kenya's sustainable development and climate targets.

It establishes clear ownership and responsibilities for the entire energy sector, fostering **a unified vision**.

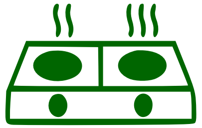
KETO **dissolves when electrification reaches 75%** and financial feasibility is proven, aligning with private sector expansion.

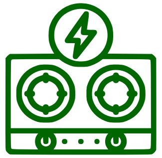
KETO sets up a **permanent planning process**, optimizing project execution and resource utilization.

Financing relies on **generated revenue**, **concessionary loans**, and **modest grants** to prevent budgetary strain.

Comparative Analysis: Cooking Fuel Sources and Stoves

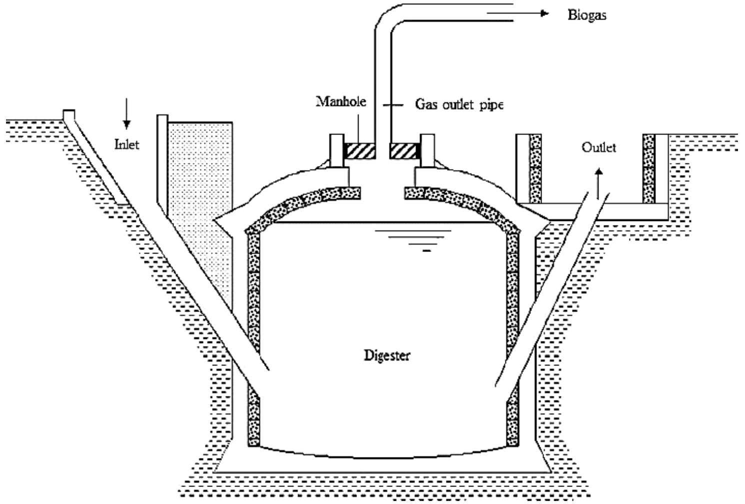
Advanced

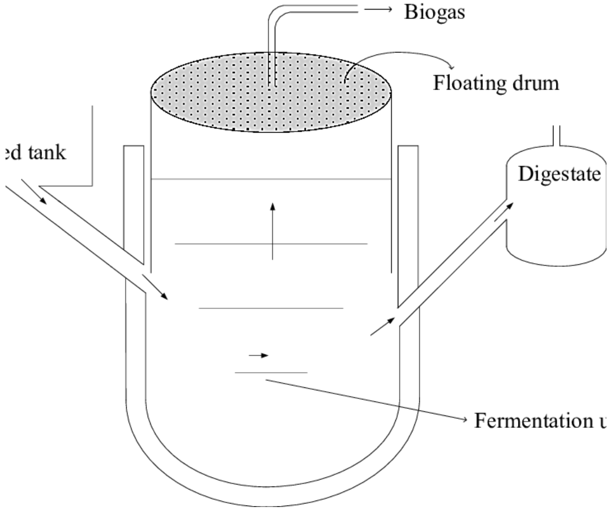



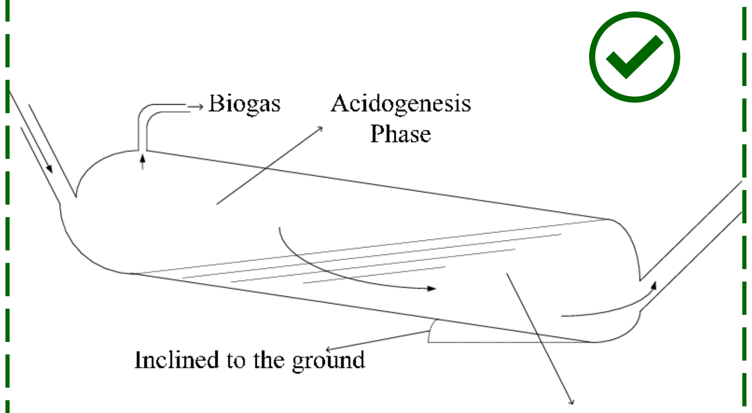



	Briquettes	Bio-Ethanol	LPG	Biogas	Electricity
Stove	**Kenya Ceramic Jiko**	**Bio-Ethanol Stove**	**LPG Stove**	**Basic Biogas Unit**	**Electric Stove**
Accessibility	Briquettes made from unused materials like bagasse, coffee and maize residues, or sawdust.	Denatured bio-ethanol for cooking is only available from a few emerging providers like KOKO Networks, Leocome, and Safi International.	In Nairobi, LPG is widely available, with 20% using it as their primary fuel and 40% having LPG stoves.	Farmers are encouraged to keep 2-4 cows to use their dung for biogas.	Limited availability; the residential grid is designed for lighting only, requiring substantial capital investment..
Cost of Stove	1000-1500 Ksh	Koko Bioethanol Stove: 1715 Ksh	3500-7000 Ksh	50000-70000 Ksh	3500-5000 Ksh
Cost of Fuel	1 Bag: 1500 Ksh	1 Liter: 70 Ksh	1 (Kg=Liter): 168-200 Ksh	0	Per Kwh: 31 Ksh
Efficiency	20%-50%	N/A	55%	N/A	80%
Health and Environmental Impact	Agricultural waste can worsen air pollution, but unused materials for briquettes offer a greener choice.	It contributes to the use of sugarcane waste disposal otherwise dumped in rivers.	LPG stoves emit 50 times less pollutants than biomass burning stoves.	None	It depends on the electricity sources.
Pollution	Low	Low	Low	Low	Low

Biogas: Comparative Analysis of Digesters







Fixed Dome Digester

ADVANTAGES

- ✓ Durable long lifetime
- ✓ No moving or rusting parts included
- ✓ Compact design, less land required
- ✓ Easy operation
- ✓ Long life span of 15-20 years
- ✓ Compact and well-insulated design
- ✓ Protected from temperature fluctuation

Floating Drum Digester

ADVANTAGES

- ✓ Stored gas volume is instantly recognizable
- ✓ Steady gas pressure
- ✓ Long lifetime of the digester (20 years)
- ✓ Simple operation
- ✓ Can be equipped with mixing devices
- ✓ Compact design, less land

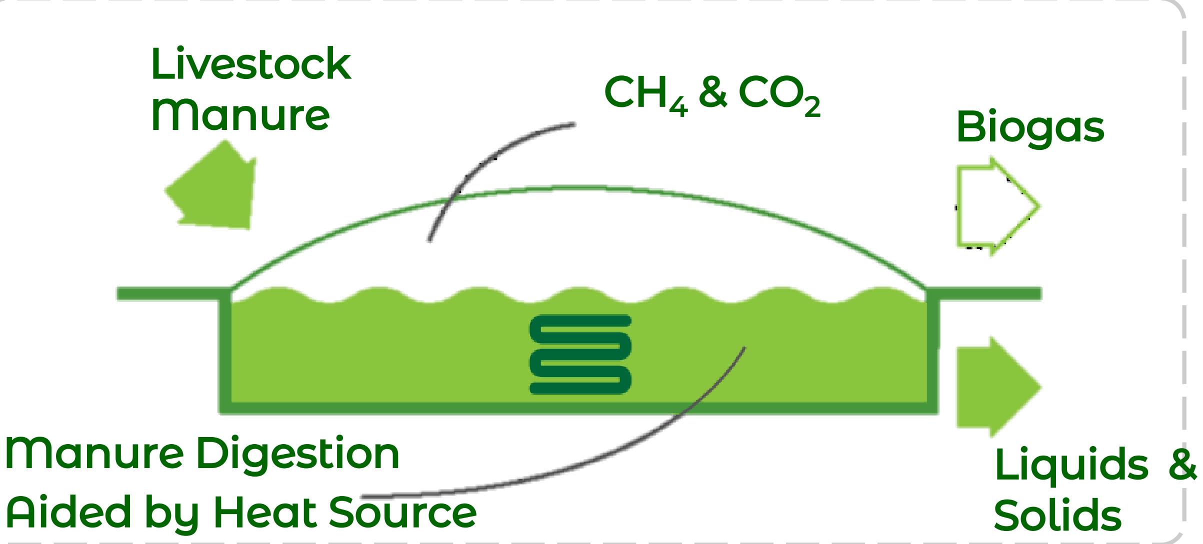
Plug Flow Digester

ADVANTAGES

- ✓ Low initial cost
- ✓ Light weight easy to transport
- ✓ No civil work needed
- ✓ Easy low-cost maintenance
- ✓ Less subject to temperature variation when equipped with greenhouse tunnel
- ✓ Efficient substrate fermentation
- ✓ Portable and expandable systems
- ✓ Easy to load, unblock and empty due to the open-ended tube
- ✓ Retention time 15 days

Biogas: Design of Plug Flow Digester Plant

- The utilization of tubular digesters in Kenya is driven by the opportunity cost of **not collecting firewood**, using animal waste for energy, and improving farm sanitation.
- Biogas digesters, including the plug flow type, have proven to be **effective year-round**, both in summer and winter.
- The system **has been successfully implemented** in Kenya as part of the Making Biogas Portable project, distributing 500 units.
- The economic and technical characteristics of the tubular biogas digester eliminate most barriers to biogas dissemination in rural areas of Kenya, making it **a practical design for rural settings**.



Components of Plug-Flow Digester

Flexi Biogas System

1. **Collection/Mix Tank:** Used for achieving a solids concentration between 11% and 14%.
2. **Plug-Flow Digester:** Heated, in-ground tank for biogas production, with options for cover types.
3. **Biogas Utilization System:** Converts recovered biogas into heat, hot water, cooling, or electricity.
4. **Solids Separator (Optional):** A mechanical separator between the digester outflow and effluent storage.
5. **Methane Recovery System:** Collects and directs biogas for utilization.
6. **Solid Cover:** Corrosion-resistant, minimal gas storage cover.
7. **Inflatable Cover:** Coated fabric cover with gas storage capabilities.
8. **Floating Cover:** Lies flat on the digester surface.

Biogas: Sources of Generation

Viability of Biogas

1.8 million rural farmers

6.7 million dairy cattle owned

74% of the farmers owned agricultural lands

Crop residues generate 1,313 million cubic meters of CH_4

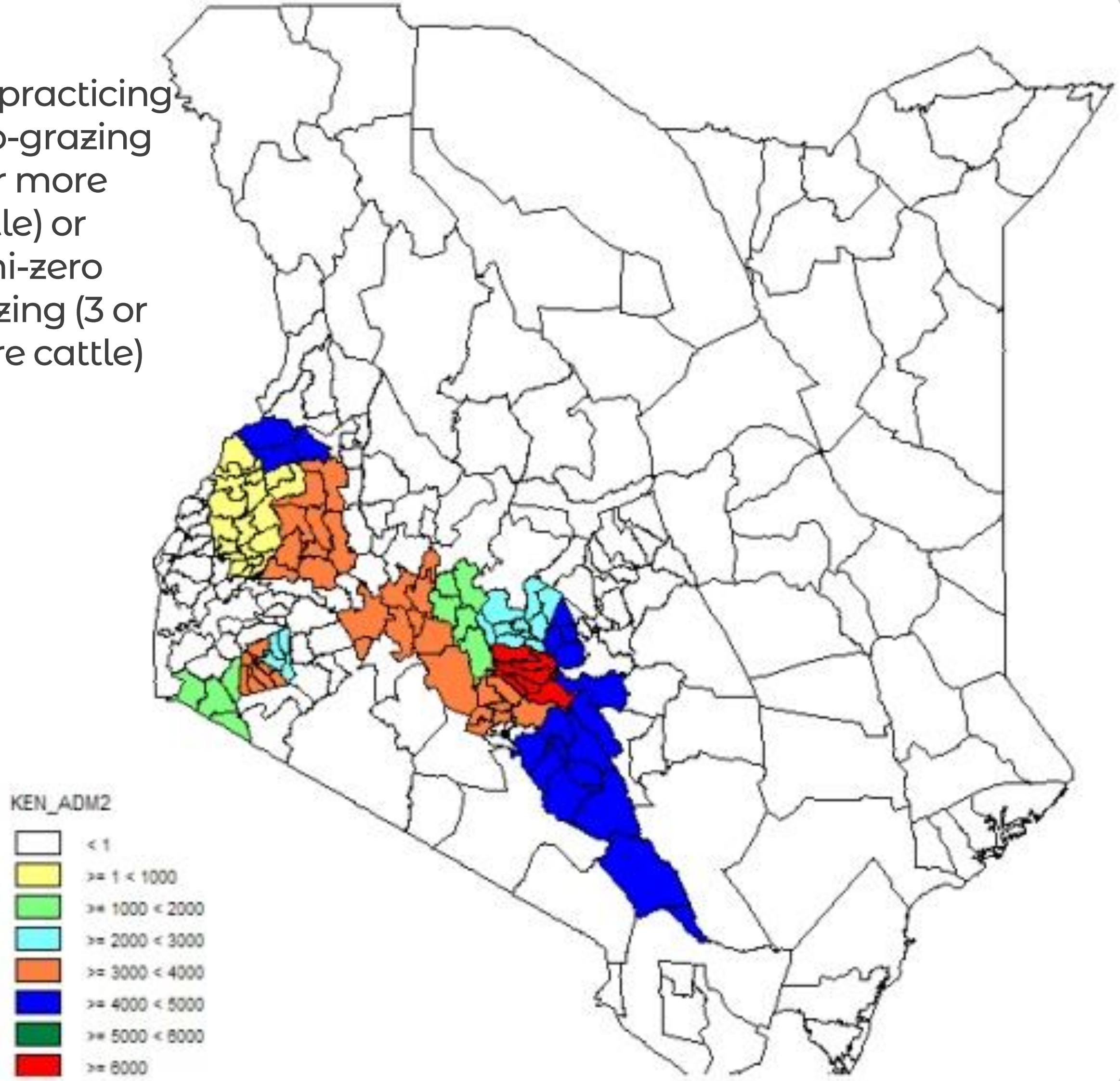
Equivalent to 73% of Kenya's Annual Energy Demand

Source	Energy Potential (GWh)
Pineapple	9.6 - 26.6
Municipal waste	80.6 - 512.6
Sisal	65.4 - 284.3
Pig	1.6 - 3.8
Milk	1.4 - 7.2
Meat	0.09 - 0.6

Table: Biogas Energy Potential in Kenya

Source	Energy Potential (GWh)
Chicken	5.8 - 24.7
Tea	2.7- 7.8
Cut flowers	2.4 - 7.6
Sugar	18.6 - 42.8
Coffee	12.6 -147.6
Distillery	1.8 - 14.9

HH practicing zero-grazing (2 or more cattle) or semi-zero grazing (3 or more cattle)



Transitioning Fuels: LPG & Bio-Ethanol

Kenya already has a fairly well-developed value chain and distribution network for modern energy options such as LPG, especially in urban and peri-urban areas.

!

LPG cost/liter
US$1.7-1.75

LPG Stove cost
US$30

Bio-ethanol Production

Sugar Feedstocks (e.g., sugar cane)	Edible sugar + molasses	**Bio-ethanol** made from molasses byproduct or syrup
Starch Feedstocks (e.g., maize, grains)	Syrup	Denatured technical alcohol used for cooking is the cheapest option.
Cellulosic Feedstocks (e.g., waste residues)	Syrup	

Cost-effective: Lower upfront costs compared to LPG, with similar ongoing fuel expenses despite VAT.

Affordable: **$45** for a 2-burner and **$30** for a 1-burner (KOKO) stove. **$0.85** per liter of Bioethanol including VAT and tax.

Clean and sustainable: Bio-ethanol burns cleanly with low particulate emissions, and can be sustainably produced.

Innovation: Distribution by Boda-Boda Delivery System

1.8 million Kenyan boda boda drivers offer versatile and widespread transport. This transforms LPG distribution, enhancing accessibility, affordability, and promoting clean cooking.

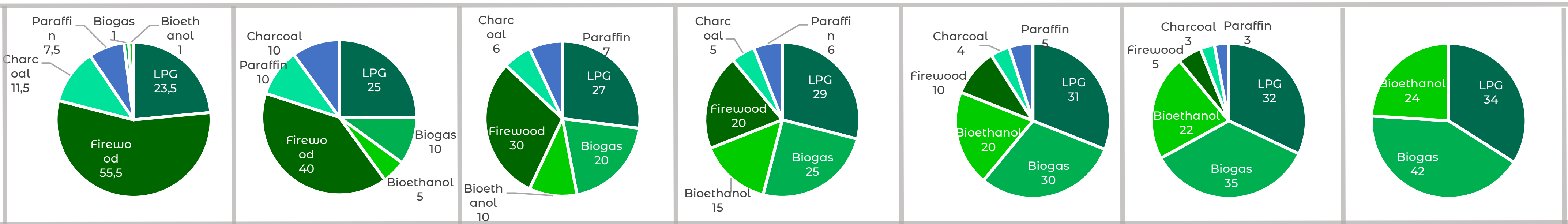
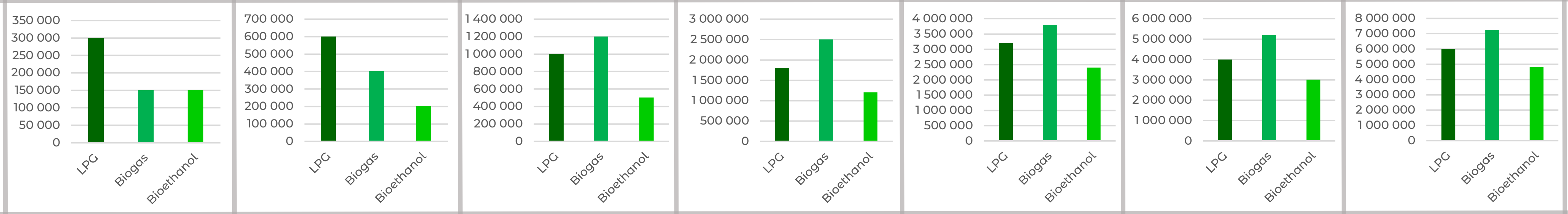
Refilling Stations: LPG hubs. **Distribution Points:** Cylinder transfers. **Village Retail Outlets:** Last-mile delivery. **Consumer Accessibility:** Convenient LPG access.

Efficient: Reduces wait times. **Affordable:** Lowers transport costs. **Wide Access:** Reaches remote areas. **Empowering:** Creates jobs, enhances lives. **Cleaner:** Promotes sustainable LPG

Scalable: Expands clean cooking access. **Economic Boost:** Fuels local economies. **Policy Support:** Backs clean energy goals. **Higher Adoption:** Enhances quality of life.

Urban Storage	Packaging	Distribution	Retail	User Experience	Payments & tracking
Distributed storage in customize tanks at existing petrol stations	Zero recurring packaging costs as fuel is distributed in bulk form.	Small retrofitted fuel tankers for last-mile delivery, slashing logistics costs.	Fuel ATMs inside shops with low fuel industry margins for shopkeepers .	Safely dock reusable, valve-controlled canister with ATM & stove. No spillage, no plastic waste.	100% digital payments, automated inventory management.

Projections Timeline: Biogas-LPG-Bioethanol

	2023	2028	2033	2038	2043	2048	2050
Fuel Mix (in percentage)							
Stoves Distribution (Type-Number)							
Raw Material Potential (million kg/year)	30000	33100	36665	40907	45955	51963	59112
Expected addition in generation (million m³/year)	1600	1800	2050	2362	2753	3241	3851
Employment (million)	0.07	0.13	0.20	0.28	0.37	0.48	0.60

Implementation Timeline

(2023-2024): Setting the Foundation

1. Establish the Kenya Energy Transformation Office (KETO) as an independent entity to oversee and coordinate cooking sector and electrification initiatives.
2. KETO begins planning and implementation, optimizing project execution and resource utilization.
3. Seek funding through generated revenue, concessionary loans, and modest grants to prevent budgetary strain.

(2025-2026): Pilot Phase for LPG in Urban Areas

1. Launch a pilot program for LPG distribution in urban areas. Boda bodas play a significant role in LPG delivery.
2. Train boda boda drivers in safe LPG handling and distribution.
3. Start importing LPG equipment and engines needed for distribution.
4. Implement LPG awareness programs in urban centers.

(2027-2029): Expanding LPG and Introducing Bioethanol

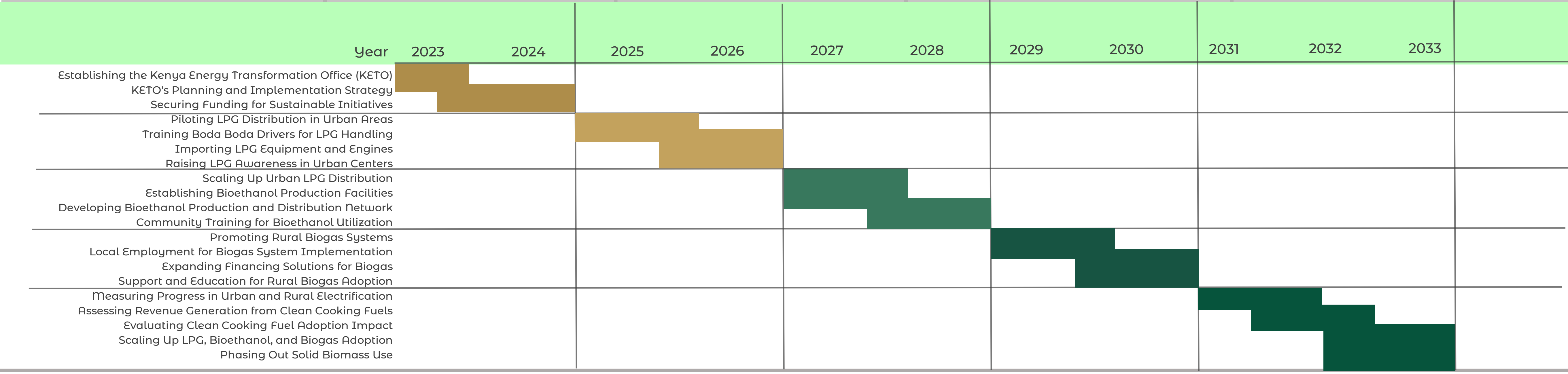
1. Scale up LPG distribution using boda bodas to reach more urban households.
2. Establish bioethanol production facilities using feedstocks like sugarcane, maize, and cassava.
3. Develop a network of bioethanol production and distribution centers.
4. Train local communities in the production and use of bioethanol for cooking.

(2030-2032): Biogas Expansion in Rural Areas

1. Promote biogas systems in rural areas using agricultural and organic waste as feedstock.
2. Employ locals to implement biogas systems with electric engines.
3. Expand financing solutions for villages upon the completion of biogas systems.
4. Continue support and education on biogas utilization for cooking, lighting, and electricity generation in rural communities.

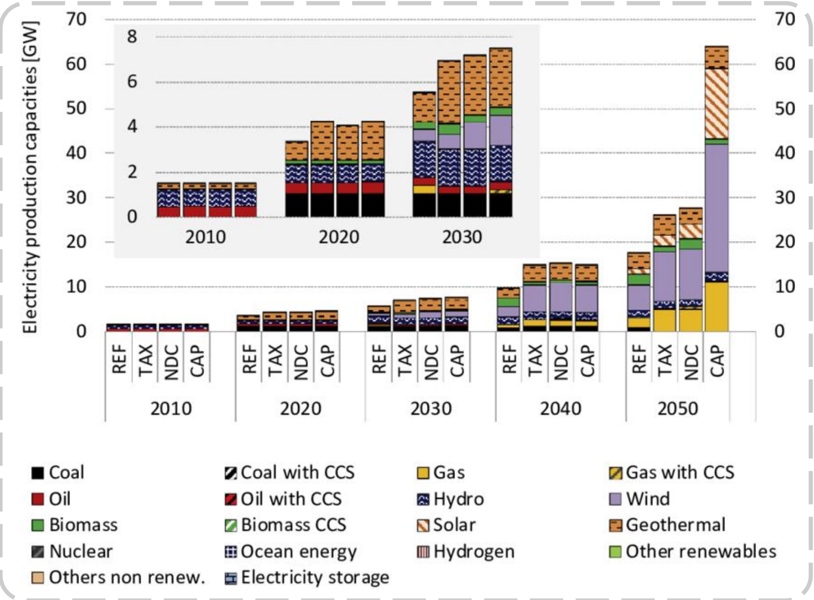
Year 2033: Achievement and Expansion

1. Measure progress towards electrification goals in urban and rural areas.
2. Assess revenue generation through the sale of LPG, bioethanol, and biogas.
3. Evaluate the impact on clean cooking fuel adoption.
4. Continue scaling up LPG, bioethanol, and biogas adoption in both urban and rural areas.
5. Implement policies to phase out the use of solid biomass for cooking.

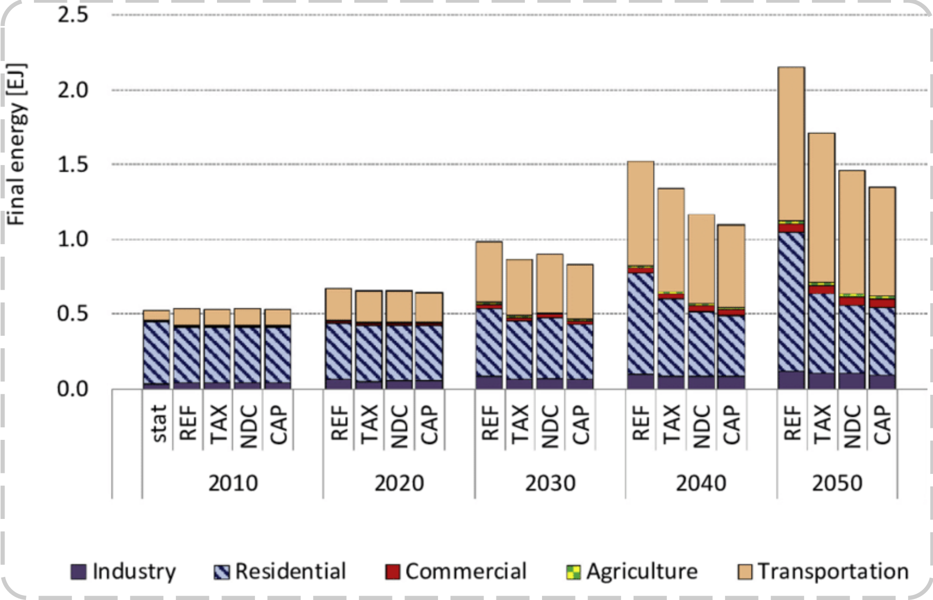


Solution Methodology Electricity Crisis Kenya

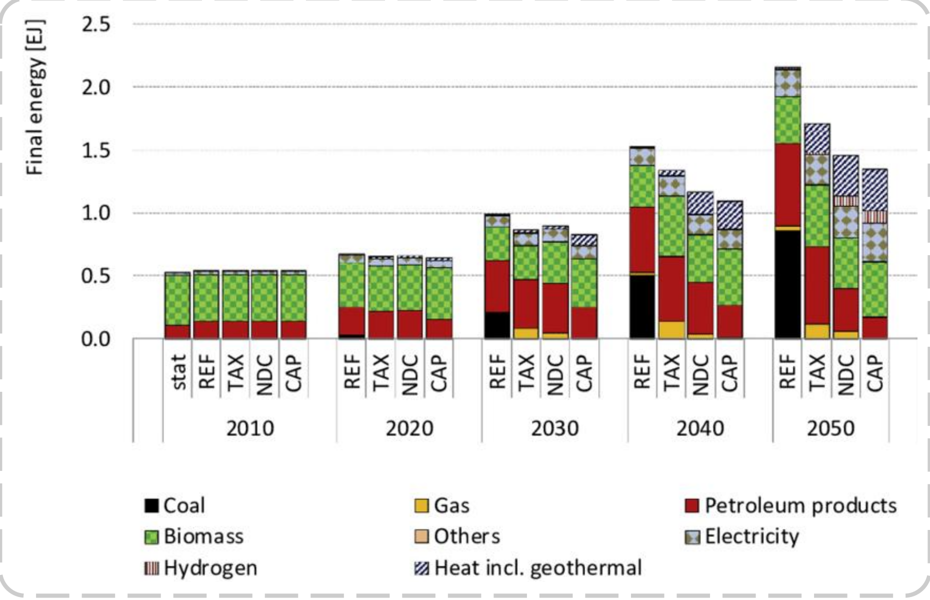
Current Scenario and Projections



Electricity production capacity projections per technology until 2050, Inset: zoom-in on the capacity mix until 2030.



Final energy consumption projections per sector in Kenya until 2050



Final energy consumption projections per carrier in Kenya until 2050

- **Reference (REF):** No GHG emission reduction or renewable energy deployment policies have been enacted or proposed after 2010.
- **High carbon price (TAX):** A global carbon market exists with exogenously assigned CO2 prices, increasing from $50/tCO2e in 2020 to $162/tCO2e in 2050.
- **Paris commitment (NDC):** A 20% emission reduction is achieved in Kenya in 2030, compared to the REF scenario, without considering LULUCF. The maximum allowed emissions level remains constant in subsequent years until 2050. In the rest of the world, a cap-and-trade system is in place with a global target for 2050 to reduce GHG emissions by 20% compared to 2010.
- **Carbon cap (CAP):** A cap-and-trade system is in place with a target to reduce global GHG emissions in 2050 by 30% compared to 2010; CO2 prices are determined endogenously, and the target is also separately achieved in Africa.

IMPORT

The top exports of Kenya are Tea ($1.2B), Cut Flowers ($766M), Coffee ($262M), Refined Petroleum ($247M), and Titanium Ore ($194M), exporting mostly to Uganda ($831M).

EXPORT

The top imports of Kenya are Refined Petroleum ($3.53B), Palm Oil ($1.26B), Packaged Medicaments ($554M), Cars ($549M), and Hot-Rolled Iron ($508M), importing mostly from China ($5.81B)

Energy Barriers and Policies

Key Policies

1. **The Kenya Energy Act** of 2019 consolidates energy laws, outlines the roles of 11 energy sector entities, supports community development through royalty allocations and rural electrification, and enforces licensee requirements while promoting renewable energy and reducing electricity bills through net-metering.
2. **Kenya's 2018-2022 Climate Change Action Plan** prioritizes low-carbon, climate-resilient development, focusing on water, energy efficiency, and renewable electricity. Initiatives include solar panel installation, energy efficiency programs, and sustainable transportation.

7 Barriers That Policies Address

1. **Financial Accessibility:** The Kenya Energy Act provides funds for communities affected by geothermal extraction and establishes the Rural Electrification Program Fund. No specific projects are outlined.
2. **Cost Recovery and Affordability:** The Kenya Energy Act encourages energy efficiency, while the NCCAP emphasizes public transport expansion and electric vehicles.
3. **Grid Management and Expansion:** The Kenya Energy Act sets up 11 energy sector entities, clarifies electricity discontinuation, and focuses on comprehensive grid management. The NCCAP promotes renewable energy and loss reduction.
4. **Policy Uncertainty, Political Priorities, and Development Policies:** Both policies prioritize sustainability and renewable energy. Clear political goals are established, but community-based efforts are not addressed.
5. **Electricity Reliability:** Neither policy provides strong mechanisms for improving reliability.
6. **Illegal Connections:** The Kenya Energy Act addresses illegal connections with strict standards but lacks integration programs. The NCCAP does not mention illegal connections.
7. **Development of Renewable Energy Resources:** Both policies support renewable energy through entities and financial incentives in the Kenya Energy Act, and goals and projects in the NCCAP.

BARRIER TO ELECTRIFICATION	STRENGTH OF POLICY RESPONSE	CURRENT POLICY MECHANISMS USED TO ADDRESS BARRIER
Financial accessibility	Weak	Funding for rural electrification & geothermal impact relief.
Cost recovery, energy usage, & affordability	Moderate	Mandate meters, energy efficiency plan, and public transit electrification.
Grid management & expansion	Moderate	Establish 11 energy sector regulators, clarify shutdown reimbursements, and seek 2.406 MW of renewable capacity.
Policy uncertainty, political priorities & development policies	Moderate	Prioritize sustainability with policies like feed-in tariffs, GHG reduction goals, and establish regulatory agencies.
Electricity reliability	Weak	Boosting efficiency by cutting losses, penalizing illegal shutdowns.
Illegal connections	Weak	Enforcing strict requirements for licensed electricity distributors and electricians, with punitive measures against illegal connections.
Development of renewable energy resources	Strong	Renewables plan, tariffs, net metering, agencies, 2.406 MW goal, green bonds..

Key Takeaways and Action Plan

1 Financial Accessibility

- Expand consumer financing options for electricity connections, particularly for rural and inner-urban poor populations.
- Implement targeted financial assistance programs to identify and support those in greatest need.
- Collaborate with financial institutions to offer low-interest loans and payment plans for connection fees.

2 Cost Recovery, Energy Usage, & Affordability

- Develop household-level initiatives to encourage electricity usage, such as promoting energy-efficient appliances and educating consumers on cost-saving practices.
- Incentivize energy-efficient public transportation & electric vehicle.
- Increase electricity consumption at the household level.

3 Grid Management & Expansion

- Enhance regulatory oversight to ensure energy sector entities meet key objectives.
- Modernize the grid infrastructure for efficiency and revenue loss reduction.
- Promote collaboration between government, utilities, and local communities for efficient grid expansion and management.

4 Policy Uncertainty, Political Priorities & Development Policies

- Prioritize transparent policy and regulation.
- Define clear rules for mini-grids and solar systems.
- Involve local communities in equitable, eco-friendly energy projects.

5 Electricity Reliability

- Upgrade grid infrastructure to minimize outages.
- Create a comprehensive strategy to enhance electricity supply reliability, covering maintenance and outage response.
- Offer incentives for backup power system adoption by businesses and households.

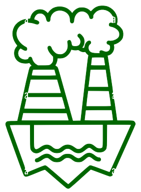
6 Illegal Connections

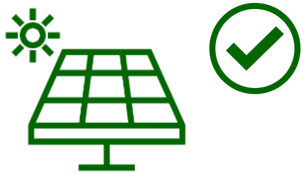
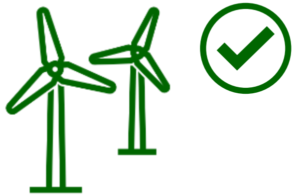
- Work with law enforcement to dismantle illegal energy cartels.
- Run public campaigns against illegal connections and promote safety.
- Adopt a community-based approach to integrate illegal connections safely into the grid.

7 Development of Renewable Energy Resources

- Sustain feed-in tariffs and net-metering for renewables.
- Set generation targets and create regulatory bodies.
- Invest in R&D for diverse, sustainable energy tech.

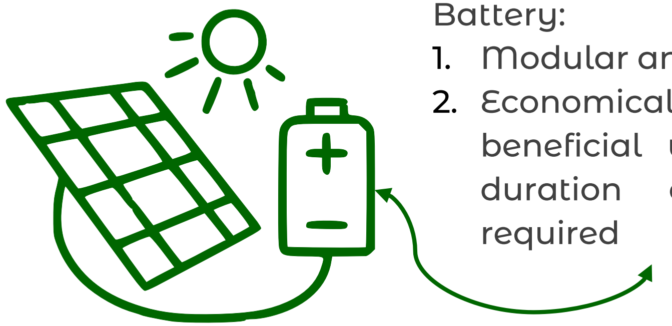
Comparative Analysis: Renewable Sources



	Geothermal	Hydropower	Solar PV	Wind Energy
Potential	7-10,000 MW	3,000MW	4-6kWh/m2 (per day)	73% of the country with 6m/s or higher
Installed Capacity	828.04 MW	826.23 MW	52.0 MW	336.05 MW
Feasibility	Kenya's substantial geothermal potential (7,000-10,000 MW) in the Rift Valley offers a greener future.	High installation costs ($2,500 per kW) discourage hydropower development.	Kenya has significant solar potential (4-6 kWh/m2 daily insolation).	Kenya's topography offers high-wind regions in the northwest and along the Rift Valley edges.
	With 828.04 MW currently, geothermal is a promising energy source for Kenya's future.	Inadequate data and local capacity hinder small hydro exploitation.	Government initiatives focus on solar electrification for rural schools and healthcare facilities.	Approximately 25% of Kenya's land area supports wind energy for grid-connected and off-grid applications.
	The geothermal Development Company (GDC) drives Kenya toward a geothermal-powered future.	Climate change risks affect hydropower reliability.	Stringent energy regulations and The Feed-in-Tariff Policy ensure quality solar PV installations.	Land access and transmission pose Challenges in wind energy development.
	Past geothermal projects displaced indigenous communities, raising concerns.	Underutilization of Kenya's small hydro potential.	The country aims for a solar potential of nearly 15,000 MW, promoting ongoing projects and investments.	Marsabit and Turkana have high-wind areas with speeds exceeding 9 m/s at 50 meters, ideal for wind projects.
	Inadequate consultation and transparency may violate legal requirements.	Rising oil prices boost the appeal of hydropower sites.	Kenya's Vision 2030 emphasizes clean, reliable energy for industrialization, boosting solar power and component manufacturing.	Wind resource maps confirm sufficient wind energy potential across a quarter of Kenya's territory.
	The Maasai community's freshwater source is at risk from geothermal drilling.	Government conducts feasibility studies for potential hydropower sites.	Current solar capacity exceeds 100 MW, with more projects underway, highlighting investment opportunities.	Recent installations indicate a growing interest in wind energy.

Solar PV + Storage

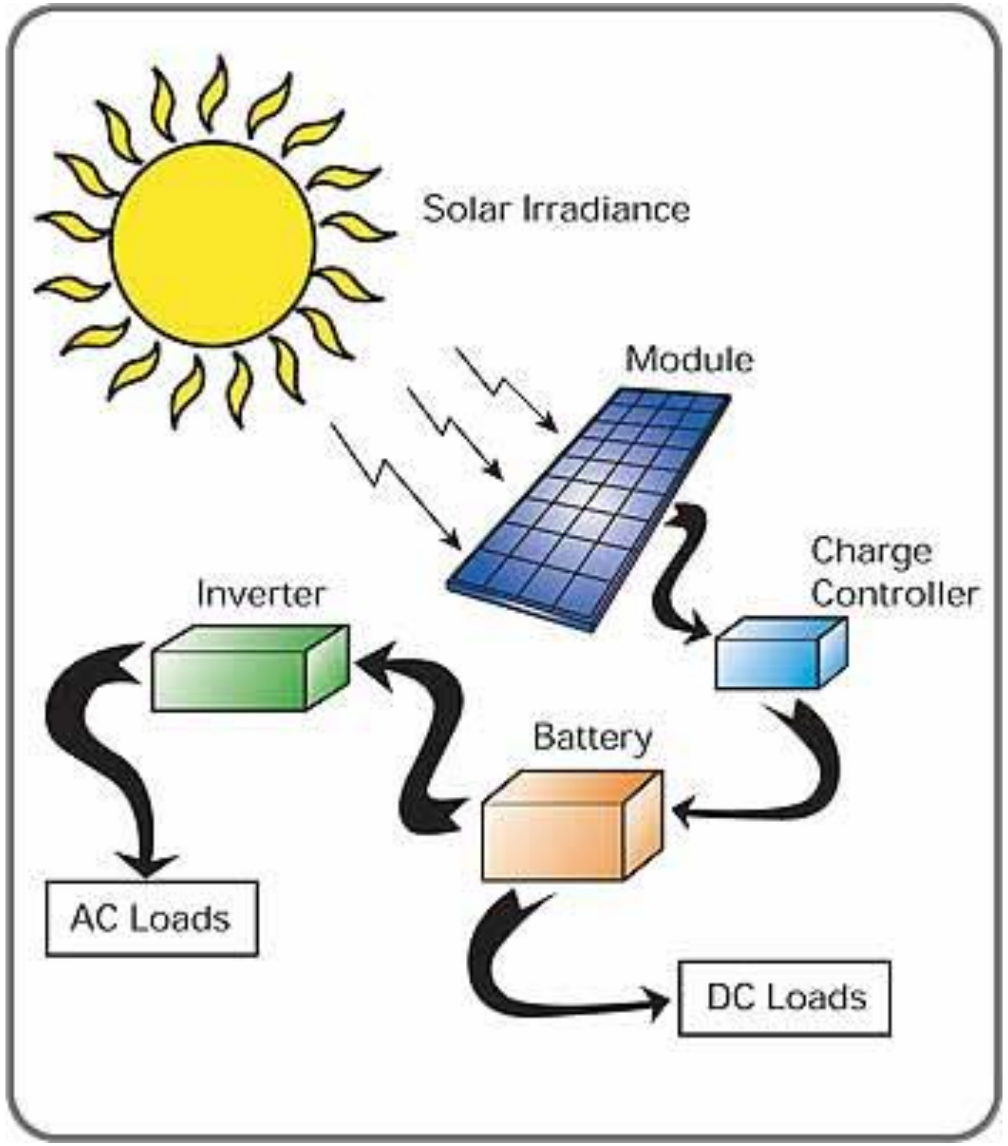


Battery:
1. Modular and compact
2. Economically beneficial when short duration of storage required

When solar electricity is stored, it serves as insurance for energy availability after sunset, providing grid operators with a reliable source.

Proposed Solution:

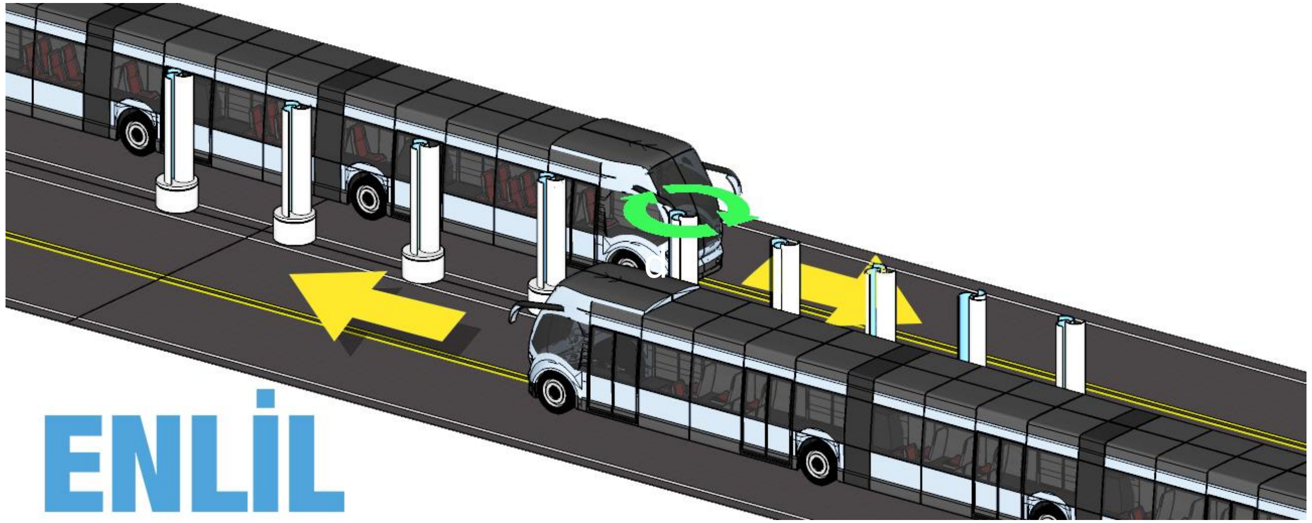
- Continue to utilize existing **geothermal and hydropower** plants without adding additional capacity.
- All new capacity installations will be dedicated to renewable energy sources, specifically **solar and wind**.
- By 2030, aim for a 17-19% contribution of solar PV and wind energy to the electricity mix each. By 2050, strive to increase this percentage share to 30% for both sources.
- **Phase out the use of biomass**, reducing it to 34% by 2033 and further down to 1% by 2050.
- **Organically increase** the percentage share of hydropower and geothermal to 8% and 30%, respectively, by 2033.



Innovation: ENLIL Wind Turbines

ENLIL, a smart vertical axis wind turbine, harnesses wind energy from vehicles on highways and railways, improving safety and reducing wildlife disruption. It also powers highway lights and signs, with an impressive 98% lower climate impact while generating **2kWh** of energy and **having a storage battery**.

This innovation offers localized energy consumption, cost-effective distribution, and adaptability to various climates, making it a solution for environmental and energy challenges, particularly in off-grid residential areas. **ENLIL** is the result of international collaborations, addressing both economic and environmental concerns with its versatile "**plug and play**" design.



Feasibility and Advantages in Kenya

Enhanced Energy Access: ENLIL offers off-grid areas in Kenya reliable energy access, fostering economic development and improved living conditions.

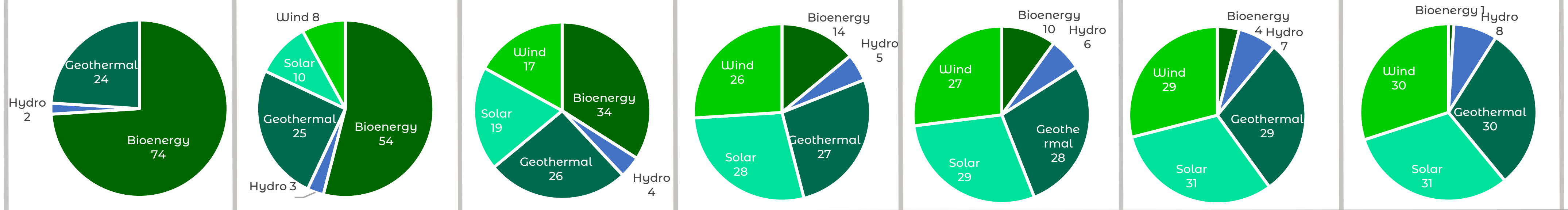
Economic Opportunities: The project creates job prospects and reduces transmission losses, potentially lowering energy costs for consumers and businesses.

Climate-Resilient Infrastructure: ENLIL's adaptability to various climates ensures consistent energy generation, enhancing infrastructure reliability in Kenya.

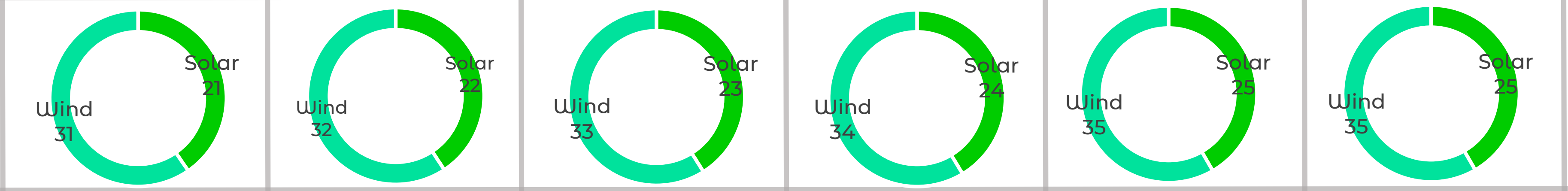
Lower Carbon Emissions: ENLIL's 98% lower climate impact supports Kenya's environmental sustainability goals to reducing carbon emissions.

Projections Timeline: Solar PV & Wind Turbine

Energy Mix (in percentage)



Capacity Factor (in percentage)



	2023	2028	2033	2038	2043	2048	2050
Units of Generation (TWh) – Solar	0.025	3.9	5.1	7.4	9.3	11.9	12
Units of Generation (TWh) – Wind	0.130	3	5.5	8.7	11	12.3	13.2
Solar PV and Wind Turbine Installation (MW) – Solar	52	7620	9500	13208	15915	19656	19800
Solar PV and Wind Turbine Installation (MW) – Wind	336	4070	7160	10930	13400	14500	16000
LCOE (US$/kWh)	0.21	0.18	0.15	0.11	0.07	0.05	0.04
Employment (million)		0.20	0.28	0.35	0.60	0.66	0.75

Implementation Timeline

Phase 1: Establishing a Unified Vision and Task Force (2023-2025)

1. Year 2023-2024: Establish the Kenyan Energy Transition Organization (KETO) as an independent entity responsible for coordinating the entire energy sector in Kenya. Ensure clear ownership and responsibilities for the sector, aligning with national sustainable development and climate targets.
2. Year 2024-2025: Set up a permanent planning process under KETO to optimize project execution and resource utilization. Develop a comprehensive energy transition strategy in collaboration with stakeholders, including private sector companies, NGOs, and international donors..

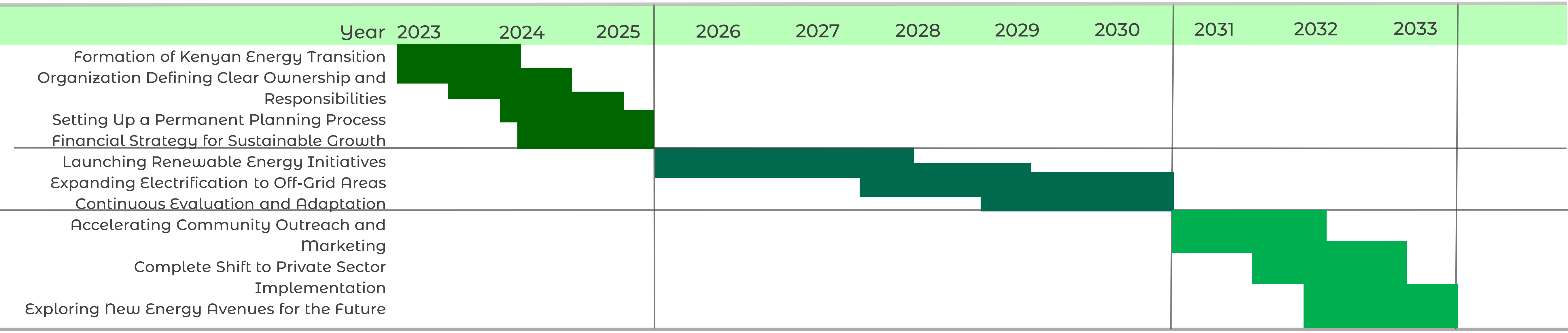
Phase 2: Initial Electrification and Renewable Energy Projects (2025-2030)

1. Year 2025-2026: Begin implementing renewable energy projects, including solar PV with storage batteries and ENLIL turbines. Initial focus on powering public infrastructure such as highway lamps and signs, and select community centers.
2. Year 2027-2028: Expand renewable energy projects to off-grid residential areas, targeting a specific number of households. Leverage partnerships with private sector businesses to increase adoption.
3. Year 2029-2030: Continue electrification efforts, with an emphasis on economic feasibility and transitioning toward private sector involvement. Reevaluate and revise targets based on audit reports.

Phase 3: Full Transition to Private Sector and Future Expansion (2030-2033)

1. Year 2030-2031: Accelerate community outreach and electrification marketing, promoting a shift to the private sector for distribution and implementation.
2. Year 2031-2032: Complete the transfer of implementation to the private sector, ensuring widespread access to renewable energy technologies.
3. Year 2032-2033: Explore the potential distribution of electric cooking stoves to households and promote the growth of a healthy renewables private sector.

Stakeholders: Kenyan Government, Kenyan Energy Transition Organization (KETO), Private Sector Energy Companies, International Donors (World Bank, IMF), Non-Governmental Organizations (NGOs), National Renewable Energy Laboratory (NREL), Local Communities



Financial Plan
Cooking Fuel Crisis
Kenya

Biogas: Assumptions and Financial Roadmap

Assumptions

- Number of People per Household: 5
- Biogas Required per Household: 1.5-2 m^3/day
- Selling Price to Consumer: US$ 0.030/m^3
- O&M cost (% fixed capital cost): 4
- Inflation (%): 2

Fixed Capital Cost for 1 m^3 of Biogas Plant (US$)

2023	2028	2033	2038	2043	2048	2050
100	115	135	162	200	250	290

Year	Government Allocation (in millions of USD)	Year	Government Allocation (in millions of USD)
1	$10	6	$12
2	$2	7	$5
3	$15	8	$0 (assumed revenue generation)
4	$3	9	$0 (assumed financial self-sufficiency)
5	$10	10	$5

Roadmap

2023

2024 — Allocate approximately $10 million to set up biogas plants in strategic locations across Kenya. These plants will serve as the foundation for biogas production.

2025 — Invest $2 million in training local communities, technicians, and operators for efficient biogas plant management and maintenance.

2026 — Allocate $15 million to expand the biogas plant network, increasing capacity and production.

2027 — Invest $3 million in awareness campaigns to encourage households, farms, and businesses to adopt biogas as an alternative energy source.

2028 — Dedicate $10 million to support community-based biogas projects. This includes subsidies for household biogas systems and supporting local initiatives.

2029 — Allocate $12 million to expand biogas adoption in rural areas, targeting farms and households without access to conventional energy sources.

2030 — Collaborate with private sector companies to invest $5 million in scaling biogas production, distribution, and adoption.

2031 — At this stage, anticipate $8 million in biogas sales revenue. Strive for financial self-sufficiency, directing $8 million toward ongoing operations and expansion.

2032 — Invest $5 million in expanding the biogas network, targeting more remote and underserved areas.

Financial Plan Electricity Crisis Kenya

Public Private Partnership Model: Solar PV & Wind Turbine

Advantages of PPP vs. Purely Public Financing

- **Risk Sharing:** PPPs distribute financial risks between the public and private sectors, reducing the burden on the government. If a project faces unforeseen issues or cost overruns, both parties share the responsibility.
- **Efficiency and Innovation:** Private sector involvement often brings greater efficiency and innovation to project execution. Companies have a profit incentive to optimize operations and reduce costs.
- **On-Time and On-Budget Delivery:** PPPs tend to have better records of completing projects on time and within budget due to private sector accountability.

Advantages of PPP vs. Grant Financing

- **Cost Recovery:** PPPs can generate revenue through user fees, making them self-sustainable in the long term. Grant financing may not achieve this level of financial independence.
- **Scale:** PPPs can typically undertake larger and more complex projects compared to grant financing, which often focuses on smaller initiatives.
- **Stakeholder Engagement:** PPPs encourage private sector engagement and expertise, bringing a wider range of skills and knowledge to the project.

Advantages of PPP vs. Public-Private Joint Ventures

- **Risk Distribution:** PPPs have more defined risk-sharing mechanisms, providing clear guidelines for risk allocation. Joint ventures might face ambiguity in responsibilities.
- **Contractual Structure:** PPPs use robust and detailed contracts that outline each party's responsibilities and obligations, reducing the likelihood of disputes.
- **Accountability:** PPPs often involve performance-based payment structures, ensuring that the private sector delivers results or risks financial penalties.

Advantages of PPP vs. Public-Private Equity Models

- **Reduced Capital Outlay:** PPPs often require lower upfront government capital investment, making them more attractive for governments with limited budgets.
- **Infrastructure Ownership:** Governments often retain ownership or control of the infrastructure in PPPs, ensuring public interests are preserved.
- **Transfer of Expertise:** PPPs allow governments to benefit from the private sector's expertise in project development, operation, and maintenance.

Solar & Wind Energy: Assumptions and Financial Roadmap

Assumptions

- Solar PV Fixed Cost (Million US$/MW): 0.5
- ENLIL Turbine Fixed Cost (Million US$/MW): 0.35
- Sunshine Days: 200
- Sunshine Hour: 8
- O&M cost (% fixed capital cost): 10

LCOE of Electricity Over The Years						
2023	2028	2033	2038	2043	2048	2050
0.21	0.18	0.15	0.11	0.07	0.05	0.04

Year	Government Contribution	Year	Government Contribution
1	25%	6	20%
2	25%	7	18%
3	22%	8	16%
4	22%	9	15%
5	20%	10	15%

Roadmap

- 2023
- 2024: Allocate $20 million for the initial setup of Solar PV systems.
- 2025: Invest $10 million for the deployment of ENLIL Wind Turbines.
- 2026: Dedicate $18 million to expand the Solar PV infrastructure.
- 2027: Allocate $12 million for expanding the ENLIL Turbine network.
- 2028: Invest $15 million in optimizing and upgrading the Solar PV systems.
- 2029: Allocate $10 million for improving the efficiency and performance of ENLIL Turbines.
- 2030: Expect to generate revenue through power sales, allocating $5 million for reinvestment.
- 2031: Continue to allocate $5 million for reinvestment in power generation. Invest $5 million in expanding the Solar PV and ENLIL Turbine infrastructure.
- 2032: By year 10, aim to reach financial self-sufficiency, where revenue covers operational costs and further expansion..

Final Budget Break-Up

Combined Financial Plan

Financial Plans Takeaways:

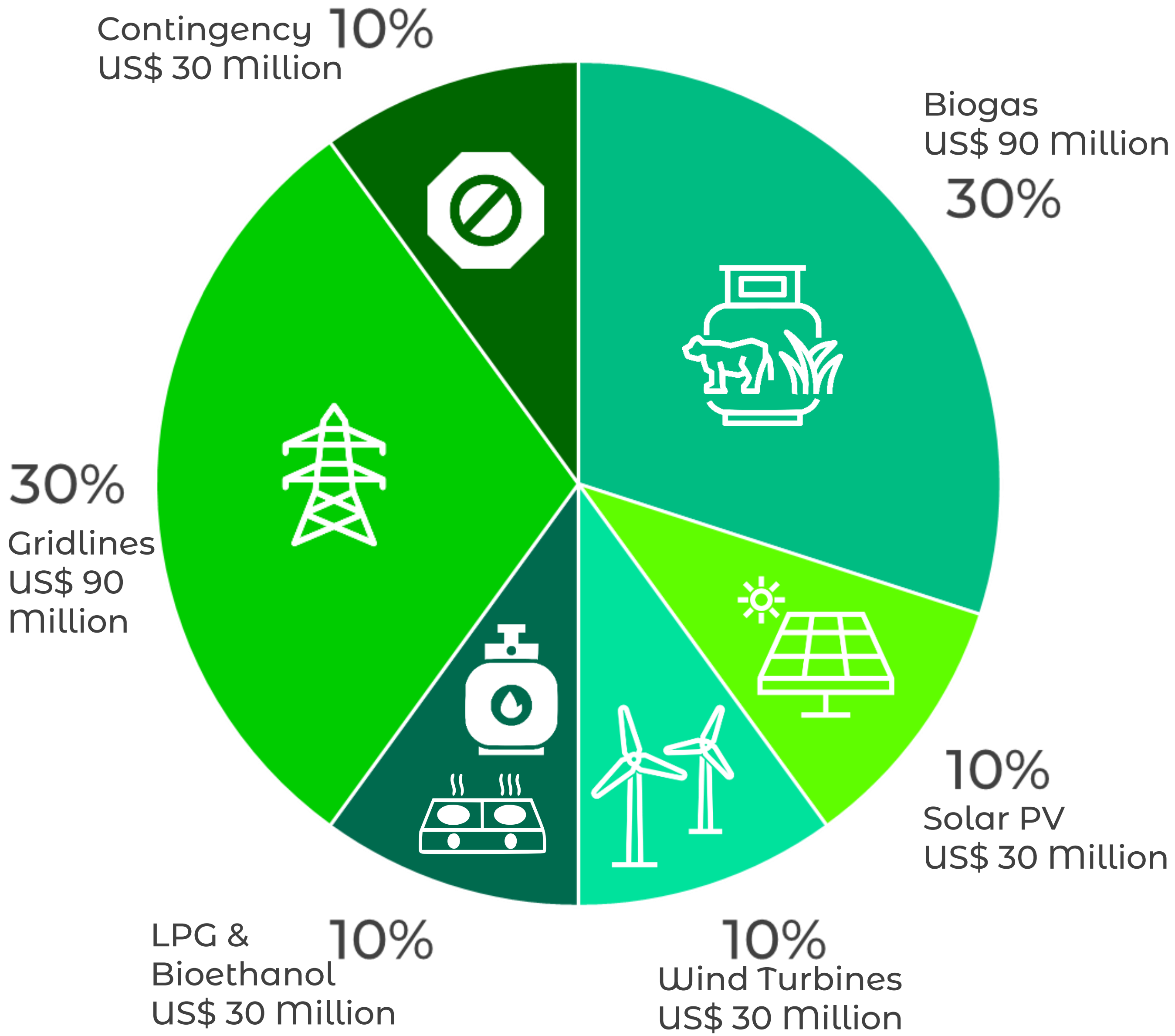
Solar PV and ENLIL Wind Turbines:

- Investment: $30 million (Years 1-2)
- Reinvestment: $5 million (Year 7)
- Recouped: Expects revenue generation in Year 7

Biogas:

- Investment: $12 million (Years 1-2)
- Reinvestment: $5 million (Year 10)
- Recouped: Aims for $8 million income in Year

Total Budget: 300,000 Million US$



Funding: Total Budget Distribution

Monetization: Renewable Energy Certificates

Renewable Energy Certificates

Definition: Renewable Energy Certificates (RECs), also known as Renewable Energy Credits or by other names like Tradable Renewable Certificates (TRCs) and Green Tags, are **tradable, non-tangible certifications** that represent ownership of **one MWh** of electricity generated from a renewable source. RECs are a powerful tool in promoting the adoption of renewable energy, as they can be **traded in the commercial market for profit.**

According to a Facts and Factors report, the global renewable energy certificate market reached **$13.65 billion** in 2021 and is expected to surge to approximately **$111 billion** by **2030**, reflecting a CAGR of about 27.22% from 2022 to 2030.

Top 10 Companies Purchasing RECs

amazon

verizon

McDonald's

Google

Meta

EVRAZ

gm general motors

NUCOR

Nestle

LOWE'S

Implementation Timeline & Revenue

2023-2028: Establishing the Foundation:

1. **2023-2024:** Establish REC regulatory framework, develop a national registry, promote renewables with incentives, and raise REC awareness.
2. **2025-2026:** Implement grid integration, forge international partnerships, and commence domestic and international REC sales.
3. **2027-2028:** Evaluate progress, fine-tune regulations, sustain support for renewables, emphasize job creation, target 5% energy generation as RECs by 2028.

2029-2033: Scaling Up and Generating Revenue

1. **2029-2030:** Expand rural electrification and promote green energy. Encourage business investment in renewables to boost REC supply.
2. **2031-2032:** Collaborate with international partners for market expansion and aim for 10% of energy generation as RECs by the end of 2032.
3. **2033:** Assess progress and make necessary REC program adjustments. Target 20% of energy generation as RECs by year-end 2033. Calculate cumulative revenue from REC sales, accounting for market growth and pricing trends.

2034-2050: Expanding the Impact

1. **2034-2040:** Enhance grid integration for increased renewable energy capacity. Promote job creation and invest in renewable energy projects. Aim to reach a milestone of 50% of total energy generation sold as RECs by the close of 2040.
2. **2041 to 2050:** Continue to expand REC sales and improve energy access programs. Set a long-term objective of achieving 70% of total energy generation sold as RECs by the end of 2050.

1. **Starting Point:** We'll start with an assumed annual revenue figure for 2023 based on the information provided, which mentions that the global REC market size was valued at $9.3 billion in 2020.
2. **Annual Growth Rate:** We'll assume a constant annual growth rate based on the projected CAGR of 27.2% from 2021 to 2030.
3. **Market Share:** We'll assume Kenya captures a small percentage of the global market, which will grow proportionally over time.
4. **REC Price:** We'll assume an average REC price of $1 per REC for simplicity.
5. **No Consideration of Market Fluctuations:** This estimate does not consider market fluctuations, policy changes, or any unexpected factors that may affect the REC market.

Assumptions

2023
$93 million (1% of global market)

2028
$118.4 million

2033
$150.6 million

2038
$191.2 million

2043
$242.5 million

2048
$389.3 million

2050
$493.9 million

Annual Growth (27.2%)

Utilization of Revenue From RECs

1 Rural Electrification & Energy Access

- **Mini-Grids:** Establish mini-grids and off-grid solutions in remote areas to provide reliable electricity to off-grid communities.
- **Last-Mile Connectivity:** Extend the grid's reach to the last mile, ensuring that even the most isolated villages have access to clean energy.

2 Renewable Energy Projects & Infrastructure

- **Solar and Wind Farms:** Invest in large-scale solar and wind farms, increasing clean energy generation.
- **Hydroelectric Facilities:** Develop hydroelectric power plants harnessing the potential of local water resources.

3 Job Creation & Workforce Development

- **Skilled Workforce:** Train and educate workers in renewable energy technologies, creating job opportunities in installation, maintenance, and operation.
- **Manufacturing and Supply Chain:** Promote local manufacturing of renewable energy components, fostering employment in the supply chain.

4 Grid Modernization & Enhancement

- **Smart Grid Technologies:** Implement smart grid solutions to optimize energy distribution and manage intermittent renewable energy sources effectively.
- **Energy Storage:** Invest in energy storage systems to balance supply and demand, improving grid stability.

5 Environmental Conservation & Sustainability

- **Reforestation Projects:** Support reforestation efforts to sequester carbon and enhance local biodiversity.
- **Waste Management:** Implement sustainable waste management practices to reduce environmental impact.

6 Education, Training, & Awareness

- **Vocational Training:** Establish vocational training programs to equip individuals with the skills needed for jobs in the renewable energy sector.
- **Public Awareness Campaigns:** Conduct awareness campaigns to educate communities about the benefits of renewable energy and encourage sustainable practices.

7 Energy Efficiency & Conservation

- **Building Retrofits:** Retrofit public buildings and private homes for energy efficiency, reducing energy consumption.
- **Transportation Initiatives:** Promote energy-efficient transportation methods, including public transit and electric vehicles.

8 Research & Innovation

- **Clean Energy Research Centers:** Support research centers focused on developing cutting-edge clean energy technologies.
- **Start-up Incubators:** Foster innovation by funding start-up incubators that encourage entrepreneurs to create solutions for the renewable energy sector.

Impact Analysis

Impact Through SDGs & Various Sectors

1 NO POVERTY
Promoting renewable energy and biogas access reduces poverty and improves livelihoods.

2 ZERO HUNGER
Enhanced energy access boosts food production and distribution, enhancing food security.

3 GOOD HEALTH AND WELL-BEING
Renewable energy supports health services, especially in rural areas.

4 QUALITY EDUCATION
Reliable energy enhances education access, fostering better learning environments.

5 GENDER EQUALITY
Improved energy access empowers women in various aspects of their lives.

7 AFFORDABLE AND CLEAN ENERGY
The plan promotes clean energy sources, aligning with this goal.

8 DECENT WORK AND ECONOMIC GROWTH
Infrastructure development creates jobs and spurs economic growth..

9 INDUSTRY, INNOVATION AND INFRASTRUCTURE
The plan enhances infrastructure, encourages innovation, and supports sustainable industries.

10 REDUCED INEQUALITIES
Enhanced energy access reduces inequalities, benefiting marginalized communities.

11 SUSTAINABLE CITIES AND COMMUNITIES
Renewable energy contributes to sustainable urban development.

12 RESPONSIBLE CONSUMPTION AND PRODUCTION
The plan encourages responsible energy practices.

13 CLIMATE ACTION
Promoting clean energy and reducing emissions supports climate action.

Sector Wise Impact

Health
Transitioning to clean cooking improves human health by reducing indoor air pollution, lowering the risk of respiratory diseases.

Biodiversity
High biomass energy use pressures indigenous forests, requiring sustainable forest management.

Fuel Savings
Cleaner fuels reduce household expenditures, potentially decreasing costs by 20%-50% by 2030 and 40%-60% by 2050.

Jobs
The clean cooking sector offers job opportunities, especially with enhanced compensation and retention efforts.

Time Savings
Clean cooking solutions save time on fuel collection and cooking, benefiting women who spend less time collecting fuel.

Gender Equality
Clean cooking empowers women by reducing their domestic workload.

Comparative Analysis Kenya-Bangladesh Solution

Feasibility : Clean Cooking Fuels Solution

Independent Entity Establishment
Creating such an entity is viable in Bangladesh with existing examples like SREDA.

Funding Through Revenue, Grants, Loans
Securing funds through these means is achievable in Bangladesh.

LPG Distribution Via Boda Bodas:
Using motorcycles for LPG is practical in Bangladesh, where they're common.

Bioethanol Production And Distribution
Establishing bioethanol production using local feedstocks is doable in Bangladesh.

Biogas Systems In Rural Areas
Promoting biogas systems with agricultural waste is workable in Bangladesh.

Phasing Out Solid Biomass For Cooking
Phasing out solid biomass is achievable in Bangladesh, like in Kenya.

Cost-effective, Affordable Solutions
Implementing such solutions is possible in Bangladesh, considering income levels.

Clean, Sustainable Fuels
Introducing clean fuels like bioethanol is possible in Bangladesh.

What May Not Work

LPG Distribution
While using boda bodas for LPG distribution may work in some urban areas of Bangladesh, it may face challenges in densely populated cities like Dhaka, where traffic congestion is a major issue. Alternative distribution methods may be needed.

Biogas Implementation
The success of biogas systems in Kenya may not directly translate to Bangladesh, as local farming practices and waste management differ. Customized education and outreach programs would be necessary.

Economic Conditions
Bangladesh has a different economic landscape than Kenya, and the affordability of certain solutions might need to be further tailored to local income levels.

Regulatory Framework
Government policies and regulations in Bangladesh may differ from those in Kenya, which could impact the ease of implementation. Local regulatory alignment would be essential.

Feasibility : Electrification Solution

Independent Entity Establishment

Creating such an entity is viable in Bangladesh with existing examples like SREDA.

Project Optimization

Implementing a permanent planning process for optimization is feasible.

Renewable Energy Projects

Implementing solar PV and wind projects is viable.

Off-Grid Expansion

Expanding to off-grid areas is feasible, addressing rural electrification needs..

Private Sector Transition

Transitioning to the private sector aligns with ongoing initiatives.

Community Outreach

Community outreach for private sector promotion is feasible.

Private Sector Implementation

Transferring implementation to the private sector is feasible, aligning with public-private partnerships.

Electric Cooking Stoves

Distribution is feasible but requires consideration of local cooking habits.

What May Not Work

Solar and Wind Energy Transition

In Kenya, solar and wind may be major renewable sources, but in Bangladesh, these sources are less prominent, making the transition more complex and potentially less cost-effective.

Biomass Phase-Out

In Bangladesh, many households rely on biomass, such as crop residues and wood, for cooking and heating. Transitioning away from these traditional sources may require alternative solutions tailored to local practices.

ENLIL's Wind Energy Integration

Bangladesh's road network often experiences high congestion, and road conditions can be challenging, making the utilization of wind energy from vehicles less practical in this context.

Biogas and Biomass Variability:

In Bangladesh, the availability of organic waste for biogas production and the reliance on specific cooking habits may require customized approaches to achieve similar outcomes.

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Appendix

Cooking Fuel: Region Classification

Region 1 Central

This region is characterized by fertile terrain with coffee cultivation, and by mountains and forested highlands. Space heating is required only during the winter in the highlands.

Main Fuels Used

Wood/ Agriresidues, Charcoal

Region 2 Coast

This region lies on the Indian Ocean. The main urban center is Mombasa, the 2nd Kenyan city. While firewood and charcoal are prevalent in rural areas, kerosene is widely used in the cities.

Main Fuels Used

Wood/ Agriresidues, Charcoal

Region 3 & 5 East/North Eastern

These regions are arid, hot lands populated mainly by Somali people. Wood is the cooking fuel for almost 90% of people.

Main Fuels Used

Wood/ Agriresidues, Charcoal

Region 4 Nairobi

In Nairobi, 1.8% use firewood, 10.5% use charcoal, 63% use kerosene, and 20% use LPG, showing disparities between moderately-poor and extremely poor residents in fuel choices.

Main Fuels Used

Wood/ Agriresidues, Charcoal

Region 6 & 8 Nyanza and West

Centered around Lake Victoria, this region grapples with Malaria and uses smoke to deter mosquitoes. Clean fuels, especially LPG, are subsidized in Kisumu, where less than 3% of households use kerosene.

Main Fuels Used

Wood/ Agriresidues, Charcoal, LPG

Region 7 Rift Valley

In the Rift Valley, a vital economic region with around 7 million people, the fertile highlands primarily use wood (70%) and charcoal (20%) for cooking, with only 7% using kerosene, mostly in urban areas.

Main Fuels Used

Wood/ Agriresidues, Charcoal, LPG

1a-Nyandarua
1b-Nyeri
1c-Kirinyaga
1d-Murang'a
1e-Kiambu

2a-Mombasa (city)
2b-Kwale
2c-Kilifi
2d-Tana River
2e-Lamu
2f-TaitaTaveta

3a-Marsabit
3b-Isiolo
3c-Meru
3d-Tharaka-Nithi
3e-Embu
3f-Kitui
3g-Machakos
3h-Makueni

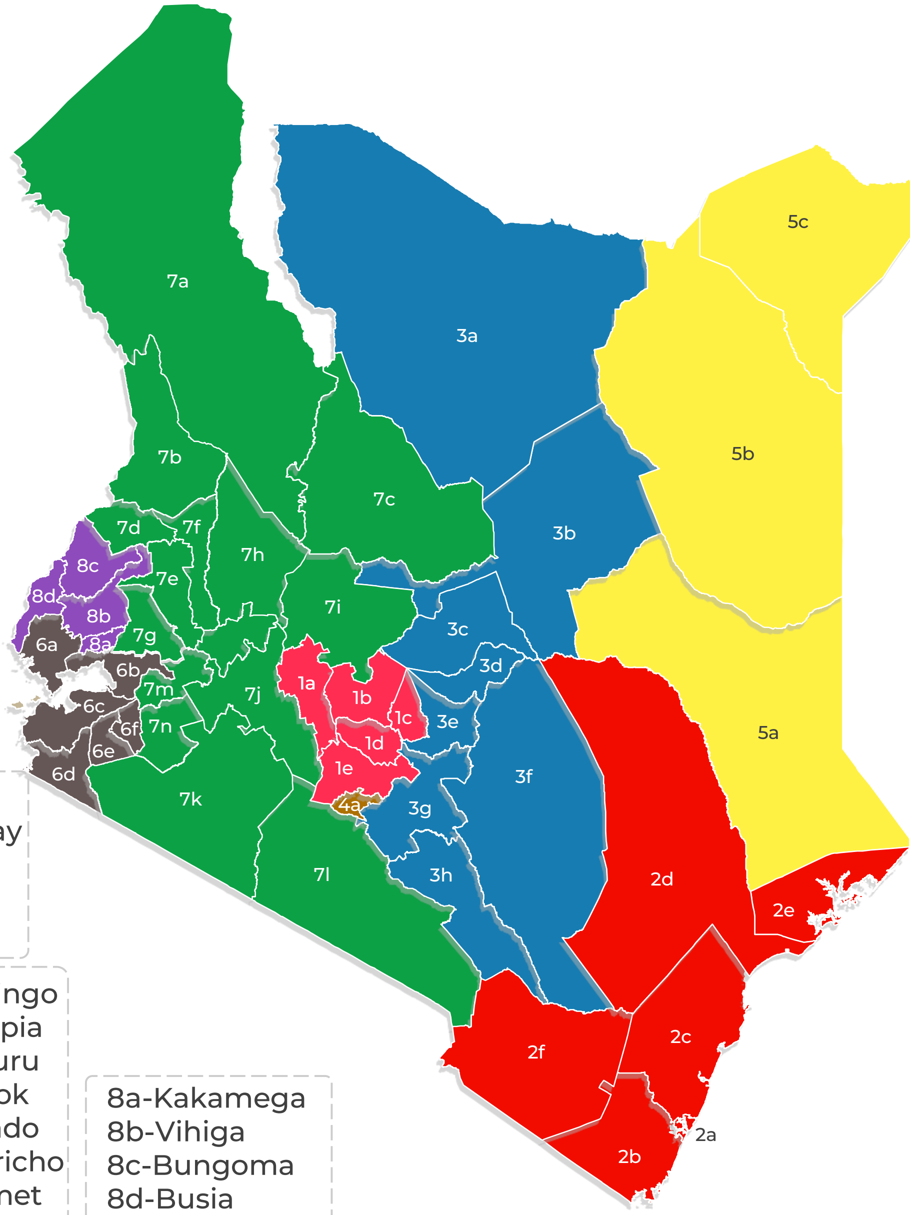
4a-Nairobi City
5a-Garissa
5b-Wajir
5c-Mandera
6a-Siaya

6b-Kisumu
6c-Homa Bay
6d-Migori
6e-Kisii
6f-Nyamira

7a-Turkana
7b-West Pokot
7c-Samburu
7d-Trans-Nzoia
7e-Uasin-Gishu
7f-Elgeyo-Marakwet
7g-Nandi

7h-Baringo
7i-Laikipia
7j-Nakuru
7k-Narok
7l-Kajiado
7m-Kericho
7n-Bomet

8a-Kakamega
8b-Vihiga
8c-Bungoma
8d-Busia

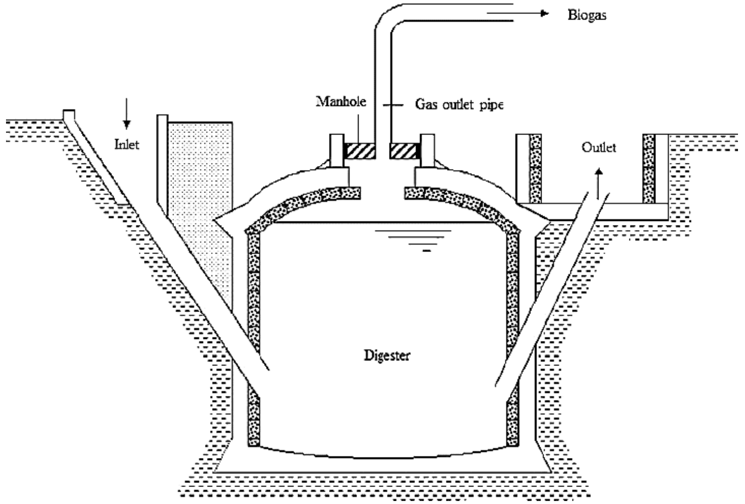


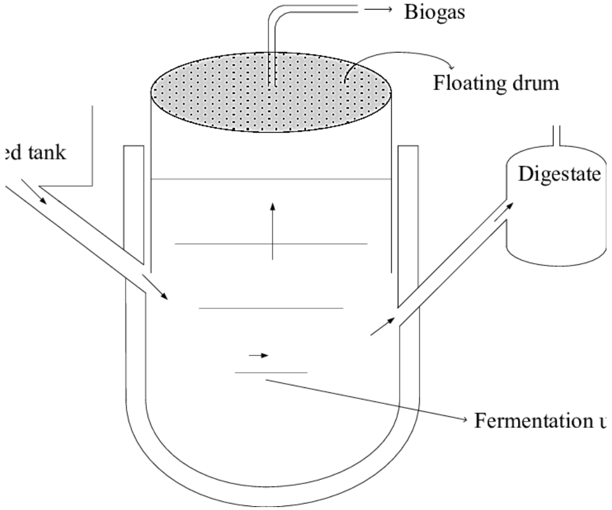
Comparative Analysis: Cooking Fuel Sources and Stoves

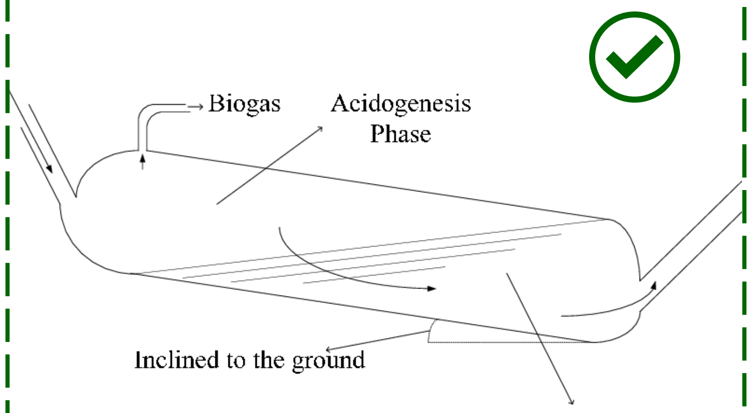
Traditional | Transitional

	Wood Fuel			Charcoal		Kerosene
Stove	**Three Stone Fire**	**Firewood Jiko Kisasa**	**Rocket Mud Stove**	**Three Stone Fire**	**Kenya Ceramic Jiko**	**Kerosene Wick**
Accessibility	Abundant and largely free in rural areas for collectors, although 20-30% of rural households purchase at least some of their firewood.			Widely available in urban Kenya, for example, charcoal is accessible within 50-150 meters of most homes in Nairobi.		Widely available throughout mass-market neighborhoods at hyper-local distribution points, such as the 1500+ points in Nairobi alone.
Cost of Stove	0	250-500 Ksh	250-500 Ksh	0	500-1000 Ksh	350-1000 Ksh
Cost of Fuel	Small bundle: 1,500 Ksh			1 Kilogram: 1600 Ksh		1 Liter: 200 Ksh
Efficiency	20%	28%	20%-28%	12%	20%-50%	35%
Health and Environmental Impact	Firewood has adverse health effects (lung and heart problems, cancer risks) and environmental consequences (significant greenhouse gas emissions, high per capita consumption).			Charcoal reduces respiratory deaths but is less clean than transitional fuels.. Converting wood to charcoal is inefficient, emitting 450-500g CO2 per kg. 3.3-10 kg firewood needed for 1 kg charcoal with 30 MJ/kg energy content.		Kerosene stoves emit fine particulate matter, posing health risks, including tuberculosis. They also release CO, NOx, and SO2, contributing to air pollution and carrying fire and explosion hazards.
Pollution	High	High-Moderate	High-Moderate	High	High-Moderate	Moderate

Biogas: Comparative Analysis of Digesters







Fixed Dome Digester

DISADVANTAGES

- ✓ Medium to high initial cost
- ✓ Difficult to identify leaks
- ✓ Irreparable/ difficult to maintain cracks
- ✓ Fluctuating gas pressure
- ✓ Skilled labor needed for construction
- ✓ Masonry is prone to porosity and cracks
- ✓ Long retention days, 45 days for KENBIM
- ✓ No indication of gas volume
- ✓ Heavy construction materials, and high transportation cost

Floating Drum Digester

DISADVANTAGES

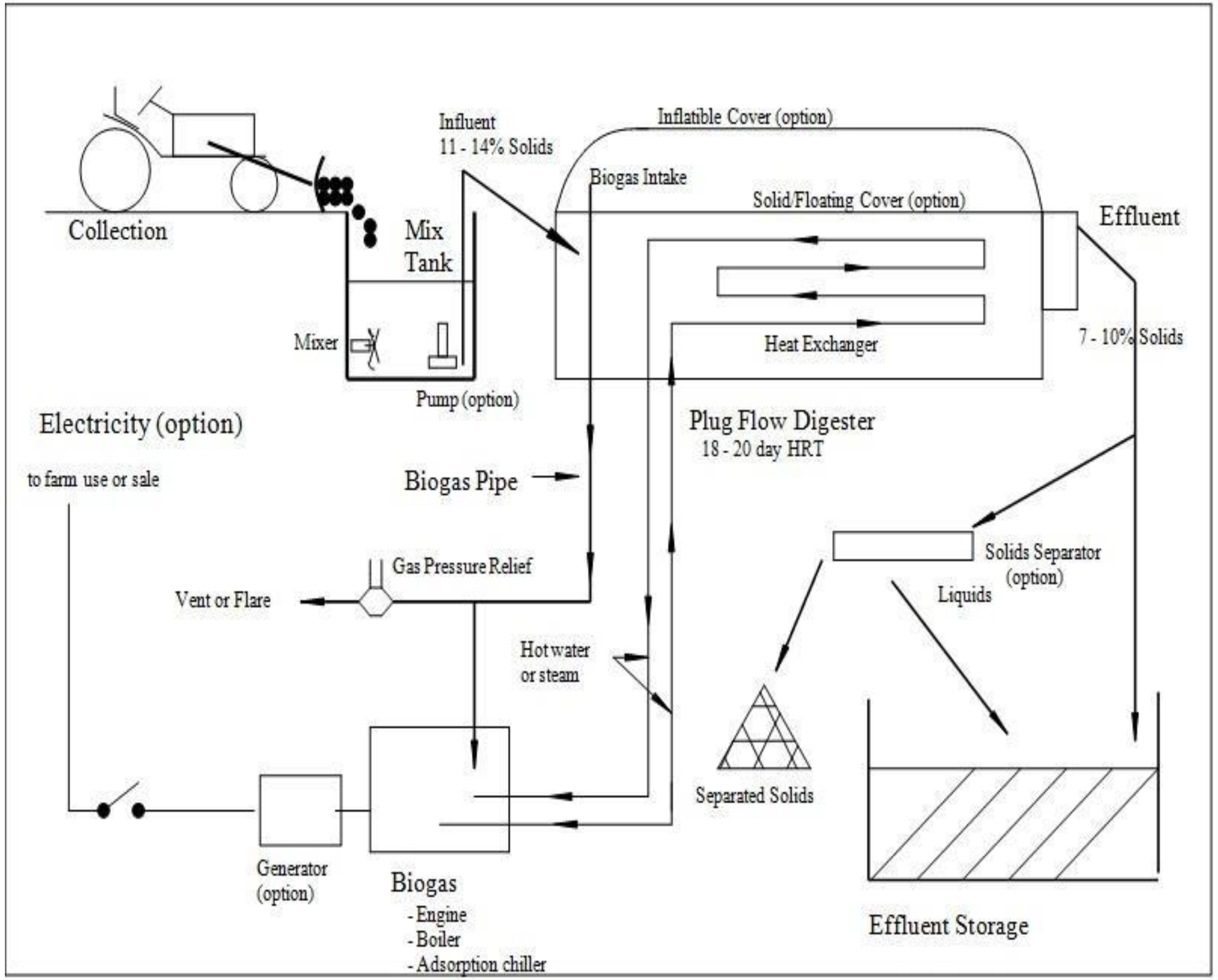
- ✓ High initial cost
- ✓ Steel drum is expensive and maintenance-intensive
- ✓ Short lifetime of the steel drum (5 years)
- ✓ Construction is labor intensive
- ✓ Heavy construction materials, and high transportation cost

Plug Flow Digester

DISADVANTAGES

- ✓ Short life of greenhouse tunnel
- ✓ High susceptibility to damage
- ✓ Low gas pressure needs regular control by adding weights.
- ✓ End-of-life disposal procedure unknown

Biogas: Utilization with Plug Flow Digester



Design Criteria and Sizing the Plug-Flow Digester

- **Location:** Within a 91-meter radius of the mix tank.
- **Mix Tank:** Round, square, or rectangular with a pump for manure transfer.
- **Hydraulic Retention Time (HRT):** Typically 15-20 days for optimal methane yield.
- **Dimensions:** Depth between 2.4-4.9 meters, width:depth ratio >1 and <2.5, length:width ratio 3.5-5.
- **Heat Exchanger:** Required for temperature control, with hot water heated by biogas or waste heat.
- **Operating Temperature:** Mesophilic range, around 37-40°C.
- **Insulation:** Surface insulation to minimize heat loss.
- **Construction Materials:** Lined trench or reinforced concrete/block tank.
- **Methane Recovery System:** Similar to complete mix digesters, with appropriate covers.

Operation and Maintenance of Plug-Flow Digesters

- **Mix Tank Operation:** Collect manure daily or every other day. Adjust total solids mixture with dilution water if necessary. Release mixed manure into the digester via a gravity gate or pump.
- **Mix Tank Maintenance:** Normal maintenance for pumps and mixers as per manufacturers' recommendations. Occasional cleaning to remove debris like sand, gravel, steel, and wood.
- **Plug-Flow Digester Operation:** Feed from the mix tank daily or every other day. Daily check of heating and mixing system operation.
- **Plug-Flow Digester Maintenance:** Daily temperature check. Weekly checks for effluent outlet and gas pressure relief. Lubricate the heat exchanger pump per the manufacturer's recommendations. Sludge removal every 8 to 10 years, if needed.

Biogas: Haubenschild Farms Case Study

When the digester was started, it was processing manure from about 425 dairy cows, which was about half of its total design capacity of 1000 cows. In 2000, Haubenschild Farms built a second free stall barn and has expanded to a current size of about 750 cows. Since startup in the fall of 1999, the biogas output of the digester steadily increased to about 65,000 cubic feet by May 2000. Currently, more biogas is being produced than can be used by the engine-generator, so it is hard to estimate exactly how much biogas is being produced. The Haubenschilds are considering adding generation capacity to utilize the excess biogas. Approximately 70,000 cubic feet/day of biogas is used by the engine generator; the rest is currently flared. With 425 cows, the biogas output per cow was almost twice projections – with 750 cows, the output per cow has come down somewhat to about 40 percent above projections. Haubenschild's cows are producing about 50 percent more manure per cow than the digester was engineered for, which somewhat explains the high biogas production per cow.

The sale of the electricity generated is an important benefit of the project. Before the digester was built, Haubenschild Farms entered into a power purchase contract proposed by the local electric cooperative, East Central Energy, who greeted the project with enthusiasm and offered Haubenschild Farms a very favorable contract. Since the expansion of the milking herd size from 425 to about 750 cows in the summer of 2000, the digester has been producing enough electricity to provide all the electric needs on-farm, plus enough surplus electricity to power about 75 additional homes.

Construction and operation of the Haubenschild Farms project has offered several key lessons for future digesters:

- Payback of 5 years on investment is possible
- A good time to install a digester is when changing or expanding operations
- Electric utility cooperation is important
- Active management is crucial for stable digester and engine operation
- Digester design and engineering expertise is key
- There are barriers to financing digester systems
- Cooperative agency participation reduces the barriers to a project's success
- Manure collection method and collection frequency are important.

Biogas: Cost Analysis

Volume of Biogas Digester (m^3)	Amount of Dung Fed Daily (kg)	Expected Gas Yield per Day (m^3)	Expected Energy Generated (kWh)	Cost of Energy Expected (USD)
2.15	26	1.57	9.42	1.54

Number of Cows Considered	Quantity of Cow Dung per Day (kg)	Volume of Biogas Digester (m^3)	Estimated Daily Cooking Demand (m^2/day)	Amount of Biogas per Day (m^3)	Amount of Electricity Generated (kWh)	Quantity of Cow Dung (kg/day)	Quantity of Water Added (L/day)
16	300	2.15	0.2	0.35	0.324	26	52

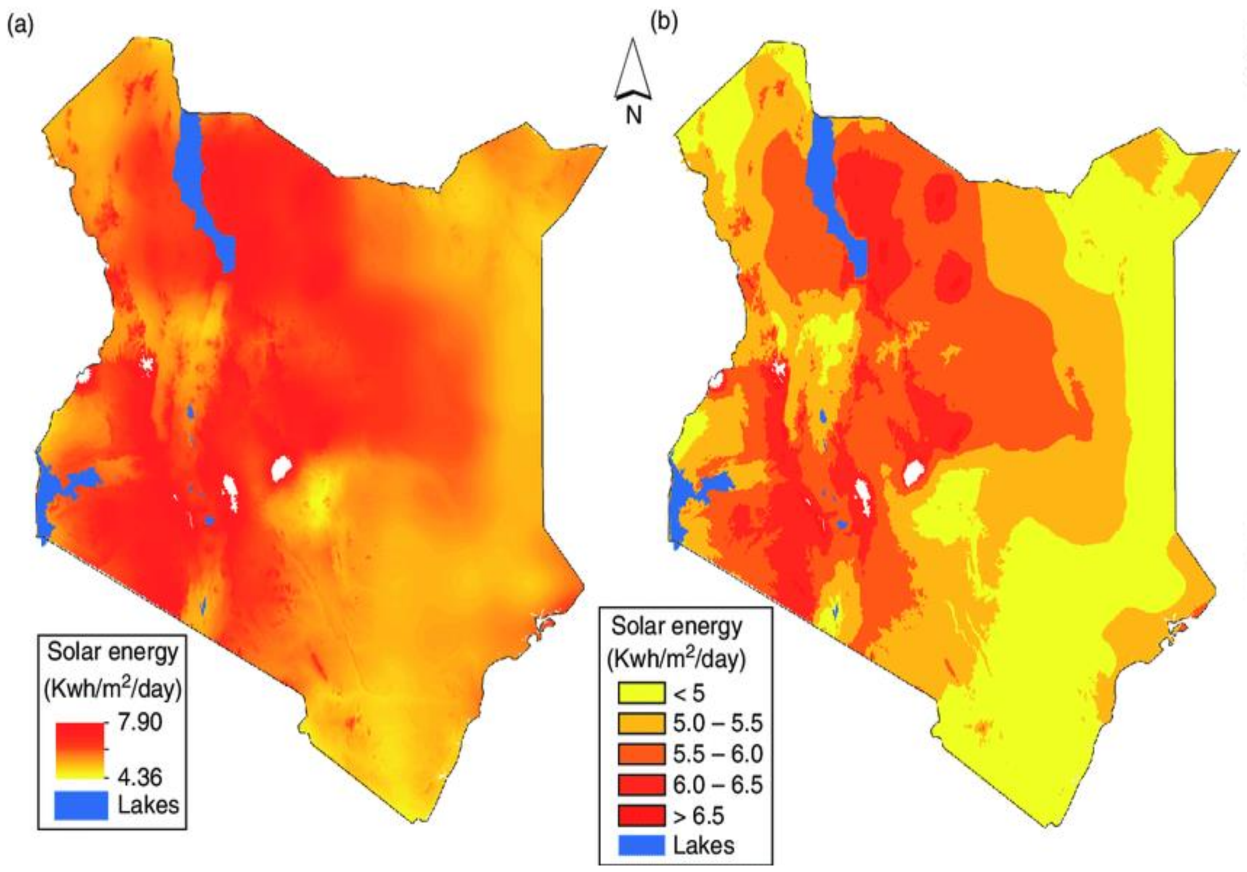
Table 6. Annual operating cost for the biogas digester.

Cost Components	Cost (USD)
Additional cost of waste (maize silage and inoculum etc.)	63.88
Cost of water	N/A
Cost of electricity	35.13
Cost of maintenance and repair	324.68
Total	**423.70**

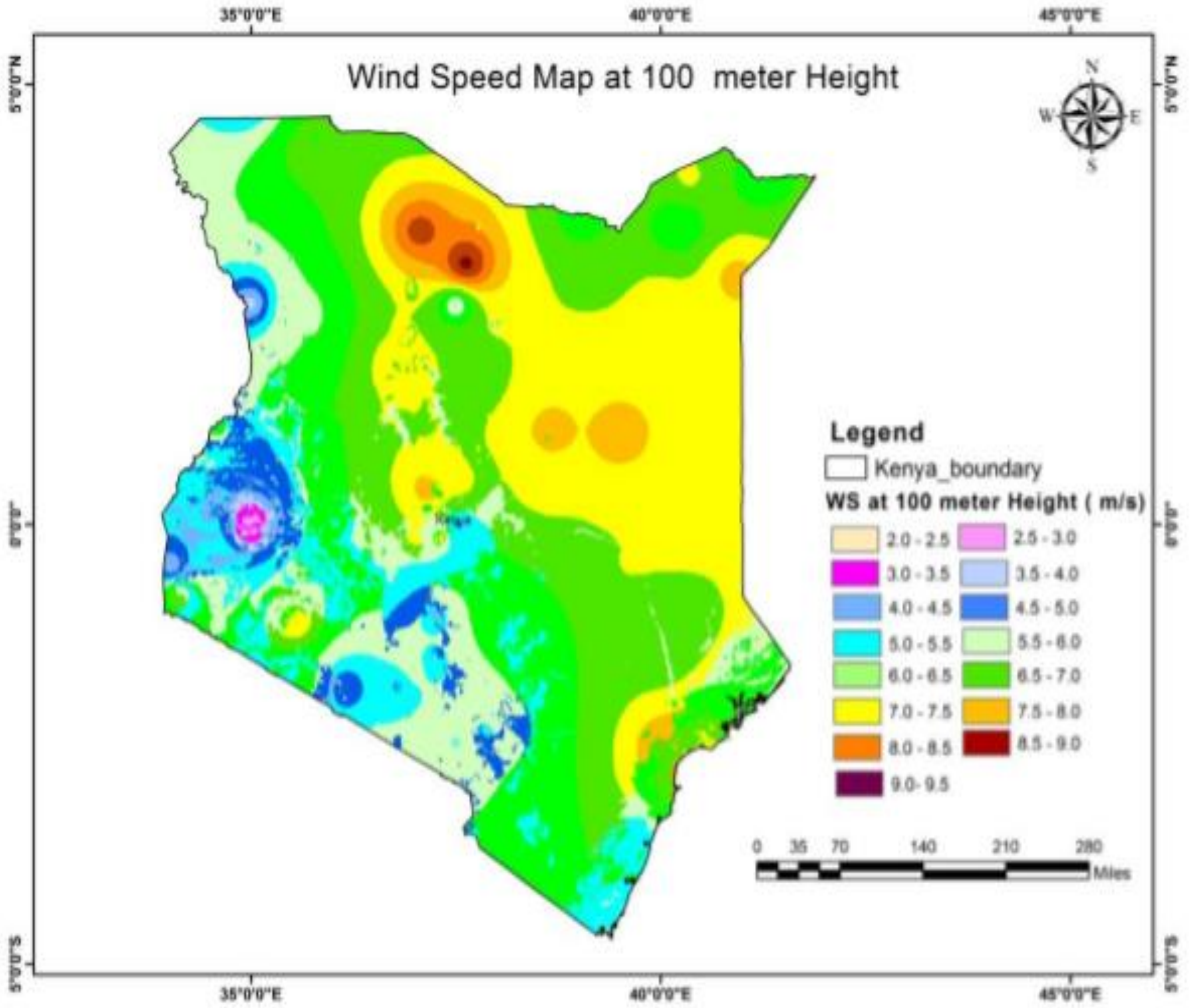
Table 7. Cost calculation of 2.15 m^3 biogas digester.

Parameters	Values	Units
Volume of biogas digester	2.15	m^3
Annual biogas production	140	m^3
LPG equivalent value of biogas	60	kg
Investment/fixed cost	1623.41	USD
Annual operating cost	423.70	USD

Solar and Wind Energy Potential in Kenya



Spatial variation of solar energy potential in Kenya at 100 x 100m spatial resolution. a) Continuous average solar energy potential in kwh/m 2 /day b) Classified average solar energy potential in kwh/m 2 /day.



Thank You!