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Unlocking Climate Finance to Accelerate Energy Access in Africa

Shell Foundation | The Rockefeller Foundation

Prepared by

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Produced by

CATALYST
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Backup genset research produced in association with

Schatz Energy Research Center

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RMI — Energy. Transformed.

Sustainable Energy for All

Backup genset research was based on previous work commissioned by

IFC | International Finance Corporation
World Bank Group

The Report is endorsed by key DRE industry associations

AMDA

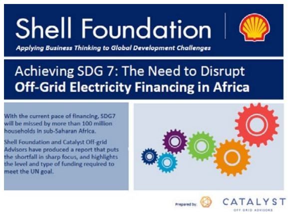
Clean Cooking Alliance

GOGLA

Table of Contents

Summary

This research demonstrates the business opportunity to unlock billions in climate finance and deliver on multiple SDG goals



- Our 2018 research demonstrated the financing opportunity to achieve universal household electrification in Africa (SDG 7) via off-grid solutions

- This research will show **off-grid solar's social dividends**, which cut across numerous SDGs[1]

- Alongside the **climate dividends** attributable to low-carbon SDG 7 scenarios
- It forecasts the **climate finance opportunity** associated with these low-carbon SDG 7 scenarios
- **Illustrating the multi-billion-dollar** climate finance opportunity associated with the low-carbon scenarios

[1] Forthcoming research will illustrate how DREs impact SDGs 1, 5, 8, and 10.

Research focus: predictive modeling illustrates Africa's low-carbon SDG 7 scenarios and the impact they will have on SDG 13

- **SDG 7:** Ensure access to affordable, reliable, sustainable and modern energy for all
- **SDG 13:** Take urgent action to combat climate change and its impacts

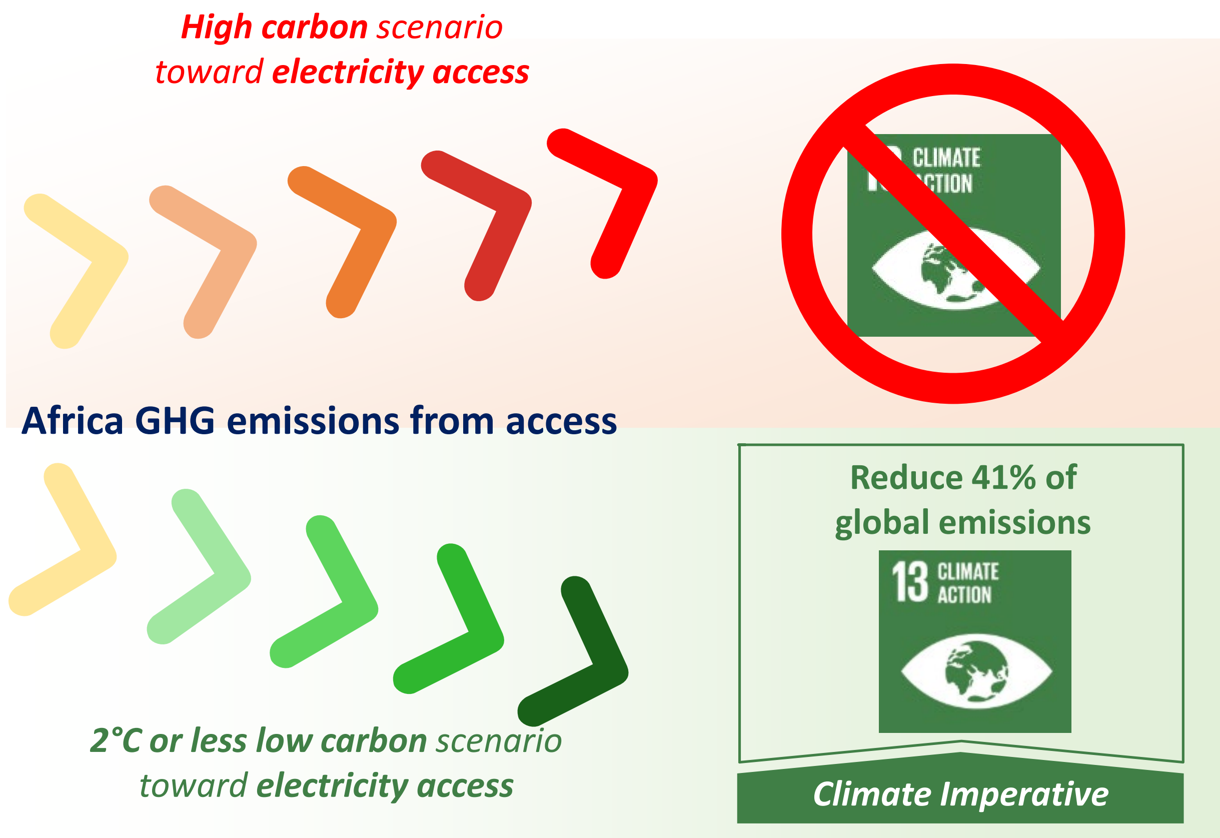
Universal access to **modern, reliable electricity** by 2030

Social Imperative[1]

210 million households connected

7 AFFORDABLE AND CLEAN ENERGY

1 NO POVERTY | 5 GENDER EQUALITY | 8 DECENT WORK AND ECONOMIC GROWTH | 10 REDUCED INEQUALITIES



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[1] *Forthcoming research will illustrate how DREs impact SDGs 1, 5, 8, and 10.*

Africa's key energy trends and their climate impacts illustrate the scope of the SDG 7 and SDG 13 challenges

Electricity access

- **70%** of African households are unelectrified, meaning **200M** need to be connected to reach SDG 7
- Africa is falling behind the rest of the world on electricity access, hosting **69%** of the world's unelectrified households
- On top of that, Africa remains heavily dependent on fossil fuels, which accounts for **68%** of electricity generation

Unreliable grid access

- **Two-thirds** of African grids are considered unreliable, with enterprises experiencing an average of **10%** downtime, and **8%** revenue losses
- As a consequence, there are **~ 7 million** backup gensets deployed on the continent, equivalent to **120** coal power stations
- These gensets consume **US$13 billion/year** of fossil fuels

Clean cooking

- **82%** of Africa's population (890 million people) use solid fuels for primary cooking needs
- **600,000** Africans are killed annually from household air pollution, making it the 2nd largest health risk on the continent
- **600 Mt** CO_2 comes from solid cooking in Africa alone

Low-carbon scenarios accelerate Africa's achievement of SDG 7 and SDG 13 via 3 pillars

Predictive modeling forecasts three scenarios for each thematic pillar: business-as-usual, high-carbon, and low-carbon, shows the avoided emissions between the latter two, and then provides the investment costs associated with the low-carbon scenario

Pillar 1

Electricity access
Providing first-time electricity access

What will it take to provide first time electricity access in Africa via a low-carbon trajectory that avoids millions of tons of CO_2e emissions?

Pillar 2

Greening back-up generation
Solving the unreliable grid challenge

What's required to get enterprises and households to transition off back-up generators and onto decentralized renewable sources of power?

Pillar 3

Modern cooking access
Moving HH unto modern cooking solutions

What is a credible scenario to move a portion of African households onto modern cooking solutions?

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Africa's climate finance opportunity
Improving access, reducing emissions

What level of CO_2e emissions are avoided via each pillars' low-carbon scenario? What is the associated climate finance opportunity?

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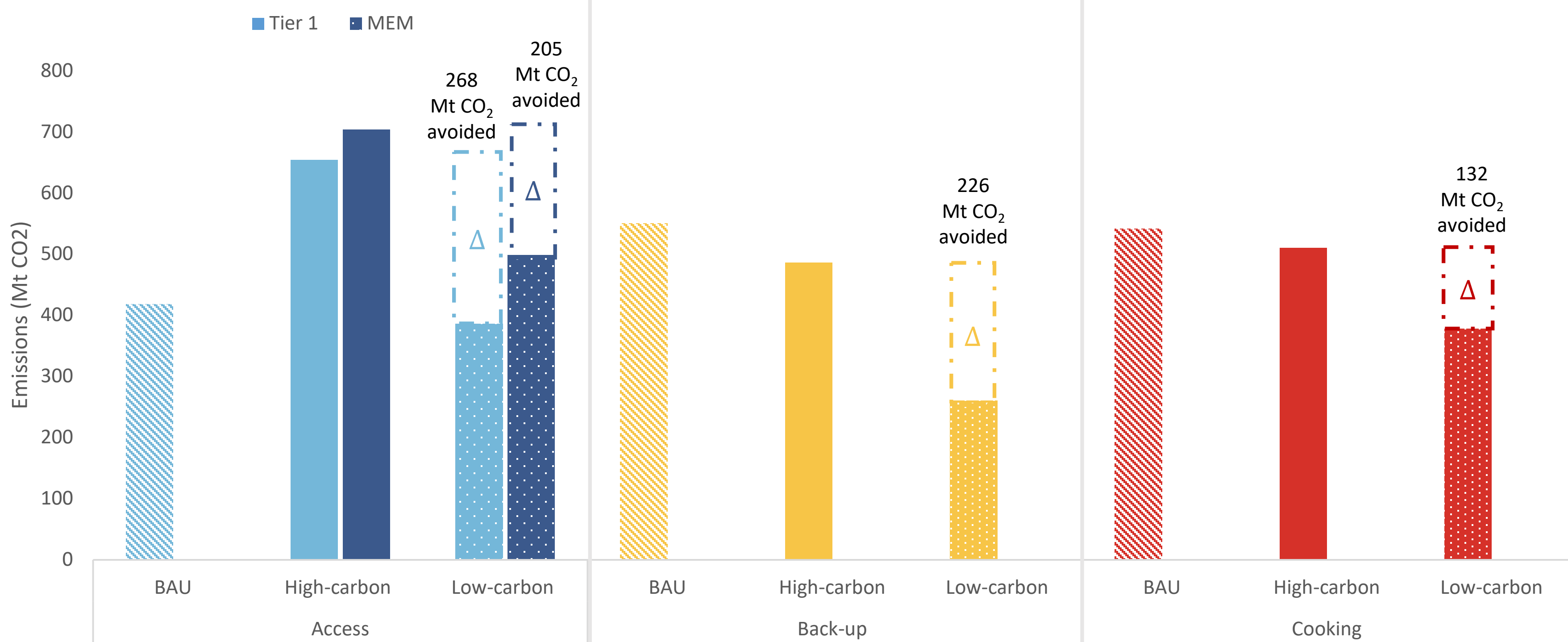
These scenarios avoid 563-626 million tons of CO_2 , deliver significant SDG 7 impacts, and unlock a substantial climate finance opportunity

Emissions from plausible low-carbon scenarios are benchmarked against equally plausible high-carbon counterfactuals; the difference between the two constitutes the avoided emissions



		Access		Back-up	Cooking
Impact		130 million households get first time access		9.2 million gensets retired	37 million households using clean fuels
Financing opportunity		$20.7B (Tier 1)	$67.1B (MEM)	$134.4B	$7.5B

TOTAL: $162.6B (Tier 1), $209B (MEM)

Source: *Catalyst predictive model outputs*

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[1] The Tier 1 scenario sees expansion of all access technologies (grid, mini-grid, and OGS of various sizes) but the majority of low- and lower-middle income households get access via Tier 1 OGS technologies. The Modern Energy Minimum (MEM) scenario targets per capita annual consumption of 130 kWh by 2030 and thus more households need mini-grid connections and Tier 2 and 3 OGS systems as a result.

Summarizing each pillar's social and climate impacts, and the associated climate finance needs of each low-carbon scenario

	BAU[1] @ 2030	impact	technology mix	avoided emissions	financing opportunity
Pillar 1: Electricity Access					
Tier 1	• 69% household (HH) access rate	• 100% HH access • **186 million** new HH connections	• 43% Off-grid • 2% Mini-grid • 55% Grid	268.1 Mt CO_2	$20.7 billion
MEM			• 35% Off-grid • 10% Mini-grid • 55% Grid	205 Mt CO_2	$67.1 billion
Pillar 2: Greening Back-up Generators					
Back-up gensets	• Gensets that reach end-life are replaced w/fossil-gensets	• **9.2 million** back-up gensets displaced w/ DRE	• Each year, 50% of end-life gensets replaced w/DREs	226.4 Mt CO_2	$134.4 billion
Pillar 3: Improved Cooking					
Clean Cooking	• 39 million HHs continue to cook with charcoal	• **39 million** HHs transition to cook with modern fuels	• 60% LPG • 22% electricity • 11% ethanol • 7% pellets	131.7 Mt CO_2	$7.5 billion

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Source: Catalyst predictive model outputs

[1] *"Business-as-usual" (BAU) illustrates historical trends extrapolated forward to 2030*

Africa's low-carbon access scenarios: huge impact, significant avoided CO_2 emissions, large climate finance opportunity

A **low-carbon scenario** contributes massively toward **universal access and improved cooking**

132 million
new connections from **off-grid** technologies delivered

9.2 million
gensets used by enterprises and households **displaced**

39 million
new households would **cook with modern fuels**

A **low-carbon scenario** benchmarked against a high-carbon scenario **yields**

Up to 626 million
tons of **avoided CO_2e emissions** over the next decade, *approximately equivalent to the annual emissions of 160 coal-fired power plants*

A **low-carbon scenario** requires substantial volumes of **new capital**

US$200+ billion
climate finance opportunity

And creates an imperative to rally climate-first investors who can mobilize commercial and concessional capital to deliver on SDG7

Climate finance must be mobilized at scale to support energy access; several types of institutions need to be brought to the table to change this

Public Organizations		Private Organizations	
Bilateral DFIs	Single country owns institution and directs finance flows	**Corporations**	Project developers and corporate actors
Multilateral Regional DFIs	Multiple shareholder countries and directs finance flows	**Family Offices**	Philanthropic and/or commercial financing
Climate Funds	National or multinational climate funds	**Private Equity / VC**	Entities that invest in private companies, or that engage in buyouts of public companies
		Investment Banks / Institutional Investors	Company or organization that invests money on behalf of others or providers of debt and equity

Three calls to action to climate-first investors to help catalyze the SDG7-climate finance nexus

1 Finance existing energy access enterprises

via existing vehicles (e.g. CrossBoundary Energy Access Facility, Energy Access Ventures, Facility for Energy Inclusion) to quickly scale impact and get Africa on the low-carbon SDG7 trajectory.

2 Support new, innovative mechanisms

to monetize social & environmental impact of DRE enterprises, such as Universal Electricity Facility, Distributed Renewable Energy Certificates, and Digital Carbon Credits.

3 Help define the next wave of investment opportunities

that leverage the co-benefits of the SDG7-SDG13 nexus & **roll out new solutions to unlock climate funding for the DRE sector.**

$200+ Billion

Climate Finance Catalysed

Linking SDG7 to SDG 13

"Light is a human right"[1]: electrification is a crucial social imperative

SUSTAINABLE DEVELOPMENT GOAL 7

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

Yet, **789 million people** still lack **access** to modern electricity in the world

and SDG 7 is integrally linked other global social imperatives

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[1] *Leonel Zinsou, former Prime Minister of Benin, announcing the country's Light for All campaign; United Nations Sustainable Development Goals. Connecting the sustainable development goals by their energy inter-linkages, David L McCollum et al 2018 Environ. Res. Lett.*

At the same time, combatting climate change is a top global priority

SUSTAINABLE DEVELOPMENT GOAL 13

Take urgent action to combat climate change and its impacts*

Economic, Social Costs

- **$3 trillion**: disaster-related economic loss
- **1.3 million lives** claimed by climate-related disasters

Limiting Global Warming

- **2°C or less**: global warming must not exceed this level
- **Decarbonizing** the **electricity sector** a top priority
  - Via mitigation measures

Climate Finance

- **$540 billion:** total climate finance flows in 2018
- **$1.6-3.8T** in climate financing would be needed annually to reach a 1.5° C scenario

7 AFFORDABLE AND CLEAN ENERGY

Via **Mitigation** to address causes of climate change

Via **Adaptation** to address impacts of climate change

Sources: United Nations Sustainable Development Goals, SDG 13; CPI Global Climate Finance: An Updated View 2019; World Bank State and Trends of Carbon Pricing 2019

Electricity consumption is a significant contributor to global CO_2 emissions, which leads to the energy-climate nexus

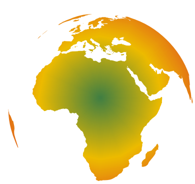
2018 GHG emissions related to electricity and heat

Global Trends

- Accounted for **42% of** total energy-related **CO_2 emissions**
- **Coal combustion** responsible for **44% of global energy-related CO_2 emissions**

Africa Trends

- If **Africa**[1], India emissions reach EU levels (~7/tCO_2), global emissions will increase by 33% **(13/GtCO_2)**

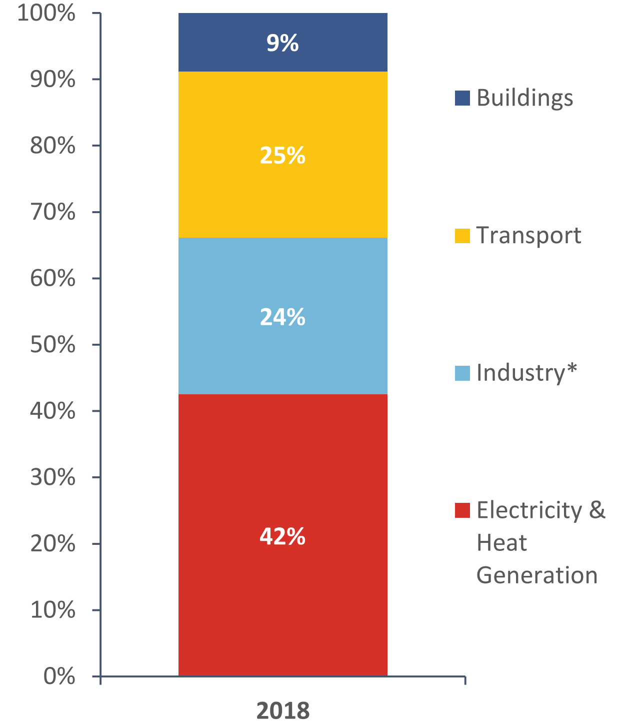


Paris Agreement

- Limiting global warming to **under 2°C** requires **deep decarbonization** in **electricity sector**

PARIS2015
UN CLIMATE CHANGE CONFERENCE
COP21·CMP11

Global energy-related CO_2 emissions by sector (total ~33.5/gtCO_2)



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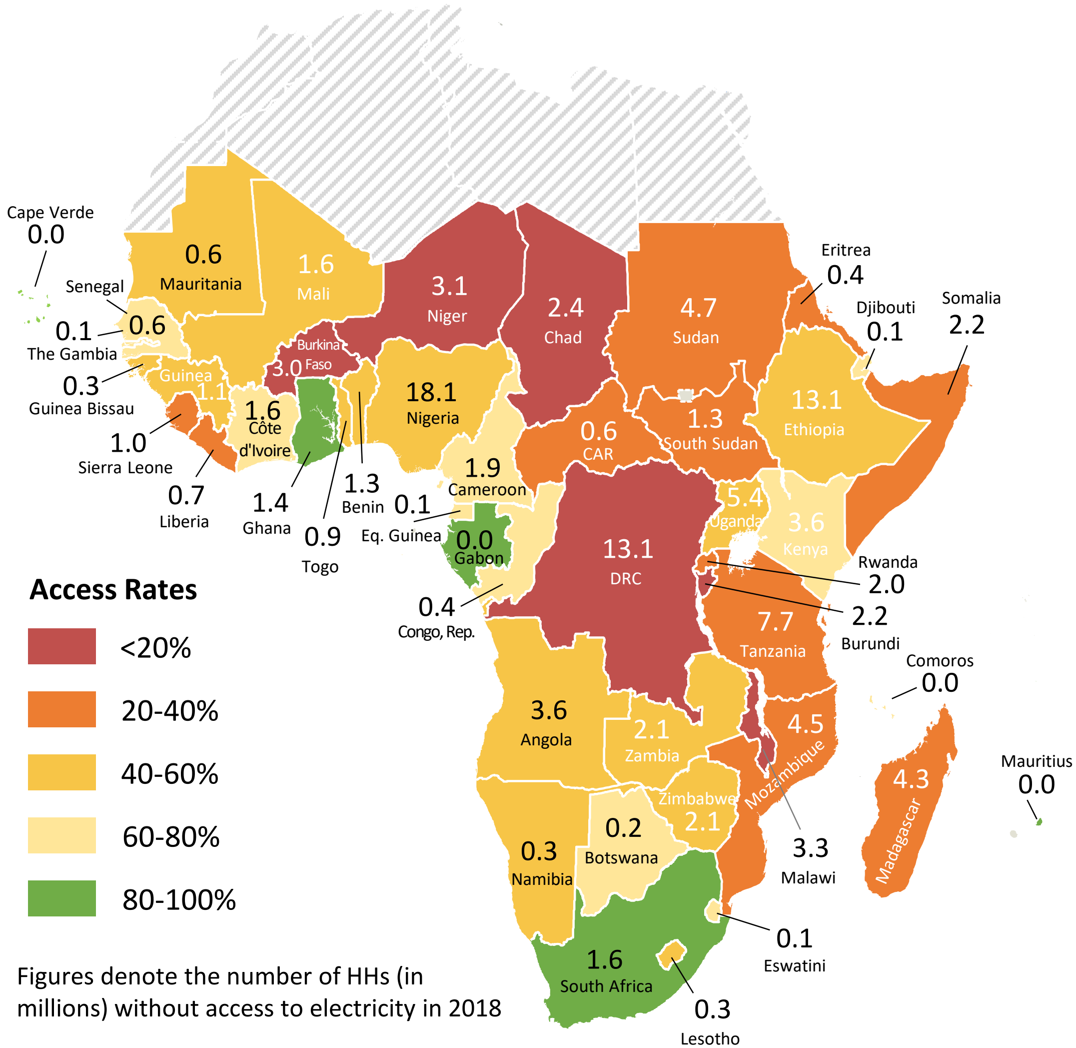
Source: IEA CO_2 Emissions from Fuel Combustion 2020 (publicly available); [1] Industry figures also include emissions resulting from energy industry use of energy for own operations

Why Africa's electricity access deficit matters

Africa[1] faces a massive electricity access deficit



Figures denote the number of HHs (in millions) without access to electricity in 2018

~70 percent
of households **that are unelectrified** are found in sub-Saharan Africa

~110 million
African households lack access to modern electricity services in 2020

200 million
households will need to be connected by 2030 to meet **SDG 7** given current demographic trends

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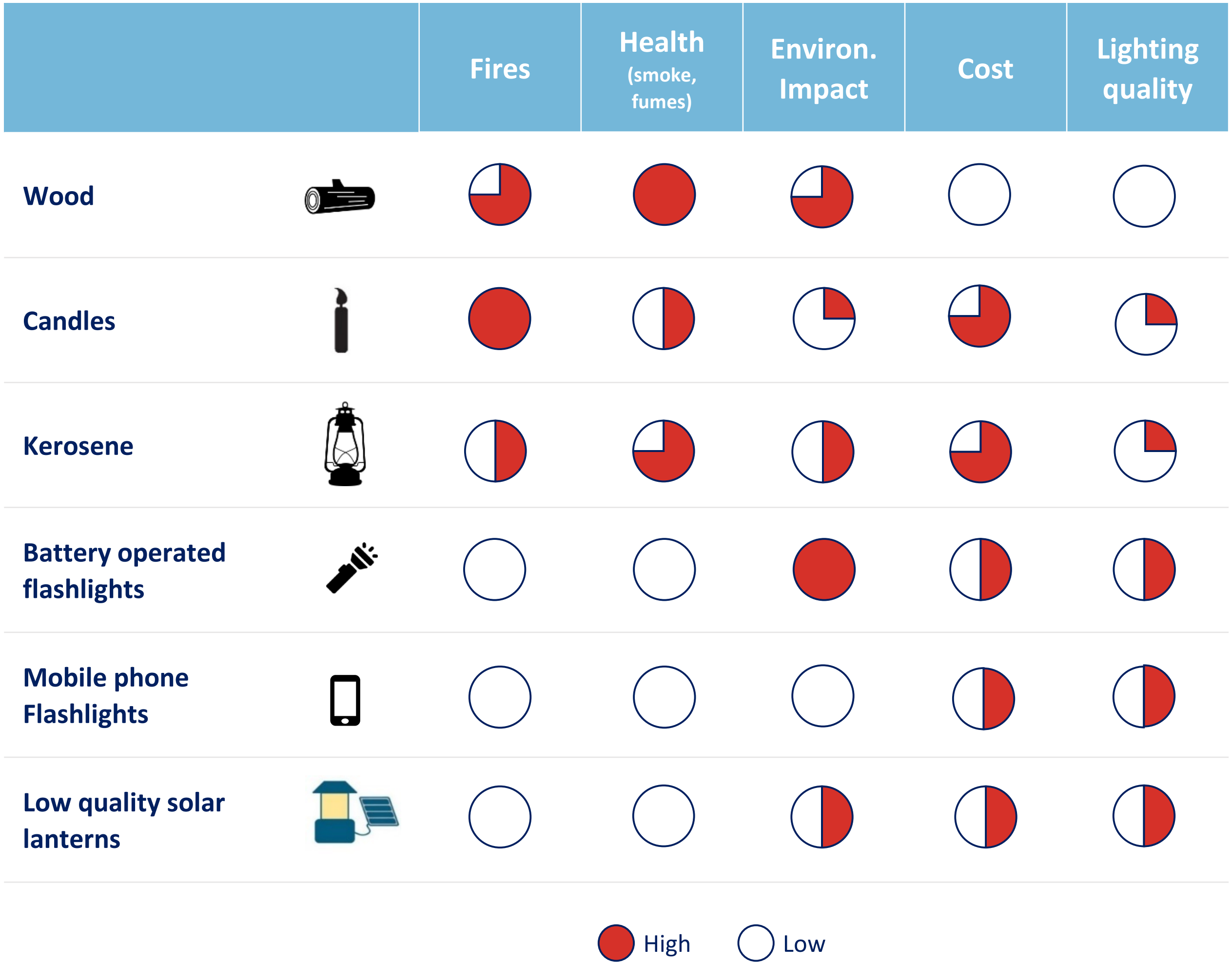
Source: 2020 Tracking SDG 7 – The Energy Progress Report; 1: In this report, Africa refers to Sub-Saharan Africa

These 110 million unelectrified households make do with stopgap solutions for basic lighting

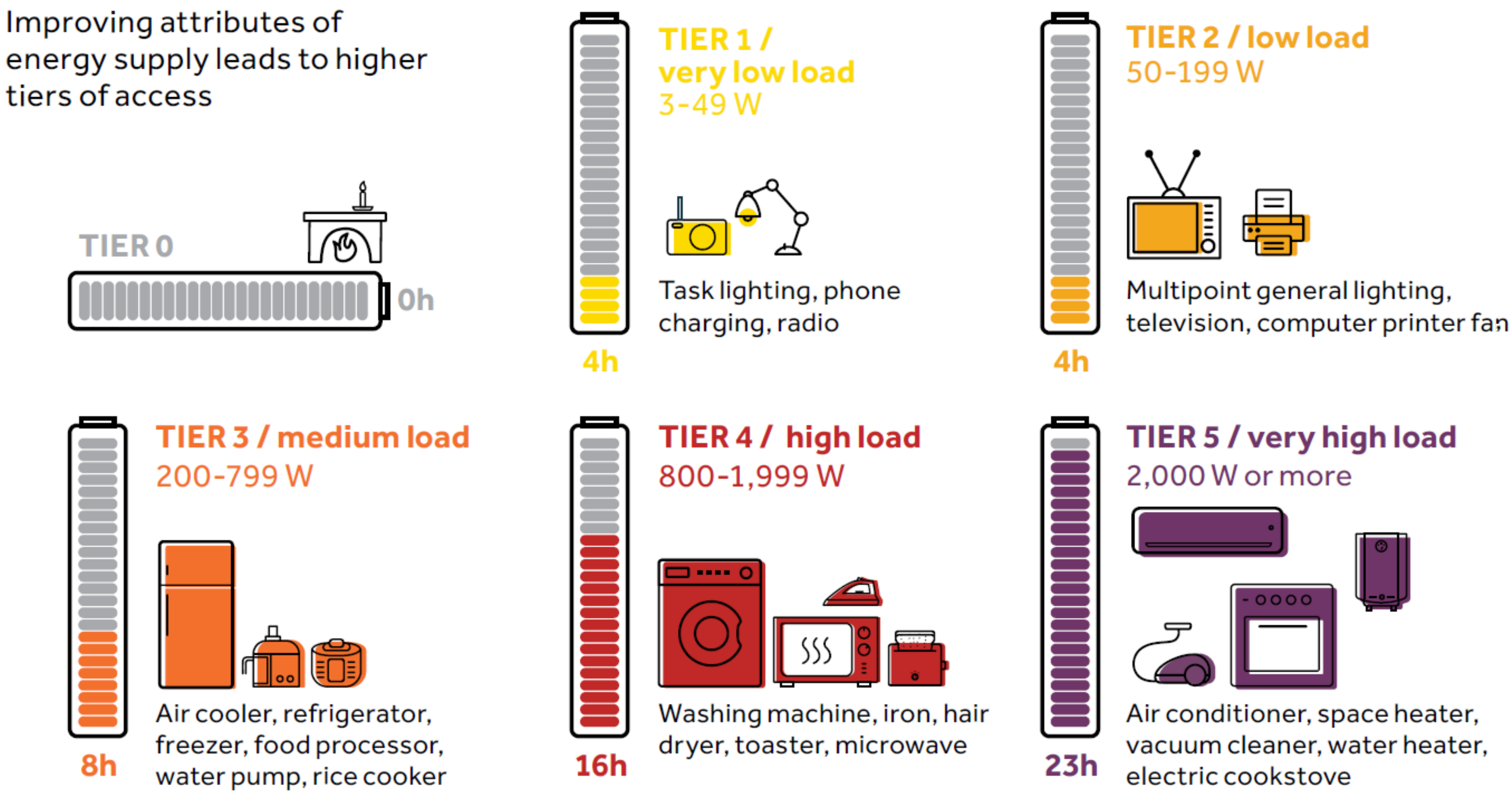


Stopgap solutions deliver **poor lighting**, and are often **dangerous** and **expensive**

Source: Authors' analysis

"Access" is no longer binary (whether a consumer is connected to an electricity grid): now based on "tiered" levels of service

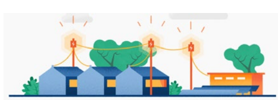
Multi-Tier Framework (MTF) definition: "the ability to avail energy that is adequate, available when needed, reliable, of good quality, convenient, affordable, legal, healthy and safe for all required energy services"



Source: Adapted from the MTF, World Bank 2019.

Source: World Bank Multi-Tier Framework for Measuring Energy Access; A Sure Path to Sustainable Solar (Solar Deployment Guidelines), ESMAP SMRI, September 2019

Tiered levels of service delivered via varying technologies, with many stakeholders considering Tier 1 as a minimum threshold

	Tier Level	Electricity Source	GHG Impact	Upfront Cost*	O&M Cost
Quality-verified solar lantern 	1 for <hh	Solar PV	○	◔	○
Small solar home system (SHS) 	1	Solar PV	○	◔	◔
Medium SHS	2	Solar PV	◔	◑	◔
Large SHS	3	Solar PV	◔	◕	◔
Mini-Grid 	2-4	Varies	◕	◕	◑
Grid 	5	Varies	◑	●	◕

● High ○ Low

Standalone, **mini-grid** & **grid** provide connectivity

Scalable solutions, grow with household **needs** and **ability** to pay

Not all solutions are created equal when it comes to **climate impact**

Source: Authors' analysis

More recent efforts have advocated for a more ambitious level of service, known as the “Modern Energy Minimum”

- **No high-income country** is low energy. Data shows a correlation between income and energy consumption at country level
- High-income countries have annual electricity consumption above **3,000 kWh** per capita
- One common threshold for “**energy access”** is modest, roughly equivalent to 50 kWh per capita in rural areas, and correlated with incomes of $0.27 per day

The **Modern Energy Minimum (MEM)** sets a target of **1,000 kWh** per capita per year

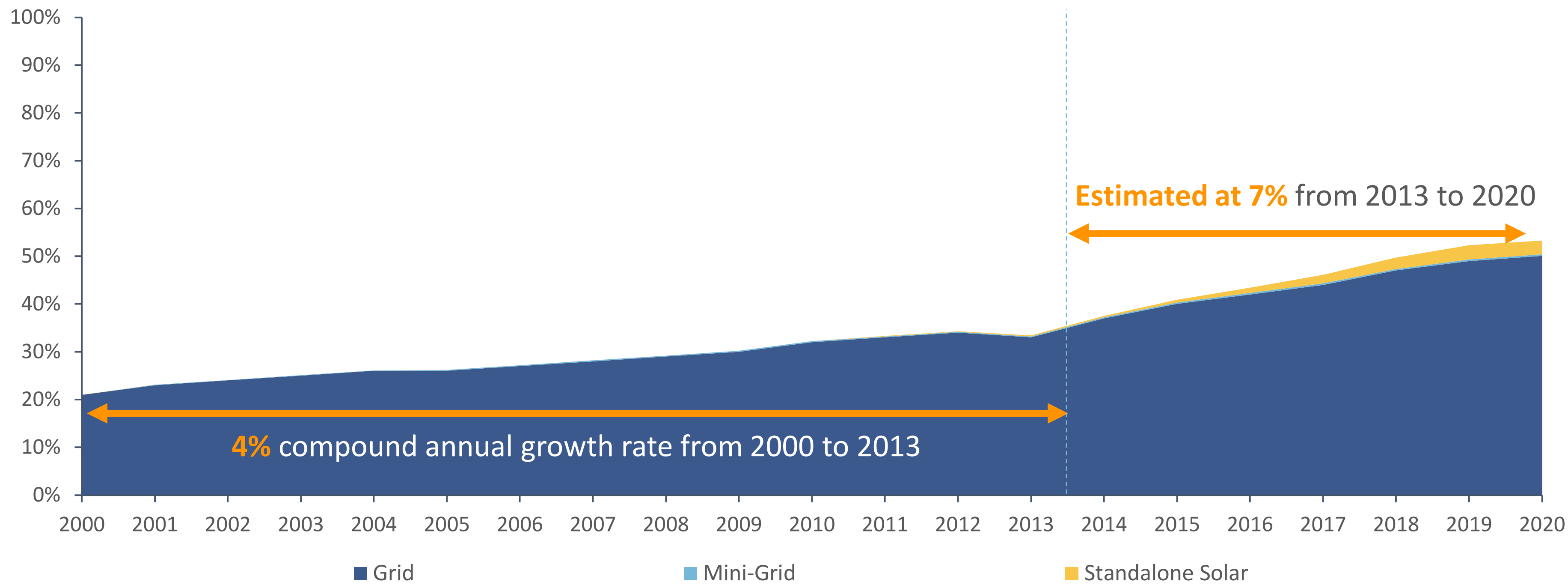
- Divided between 300kWh of household + 700kWh of non-HH electricity consumption
- Correlates with an income of $6.85 per day

Source : Energy for Growth Hub: The Modern Energy Minimum

Meanwhile, Africa's electrification trends show some promising progress toward SDG 7

- Recent grid connection improvements tied to **grid densification**
- Significant contribution from standalone solar, particularly in East Africa
- Despite these trends, business-as-usual yields a significant SDG 7 shortfall

African Household Electricity Access by Type



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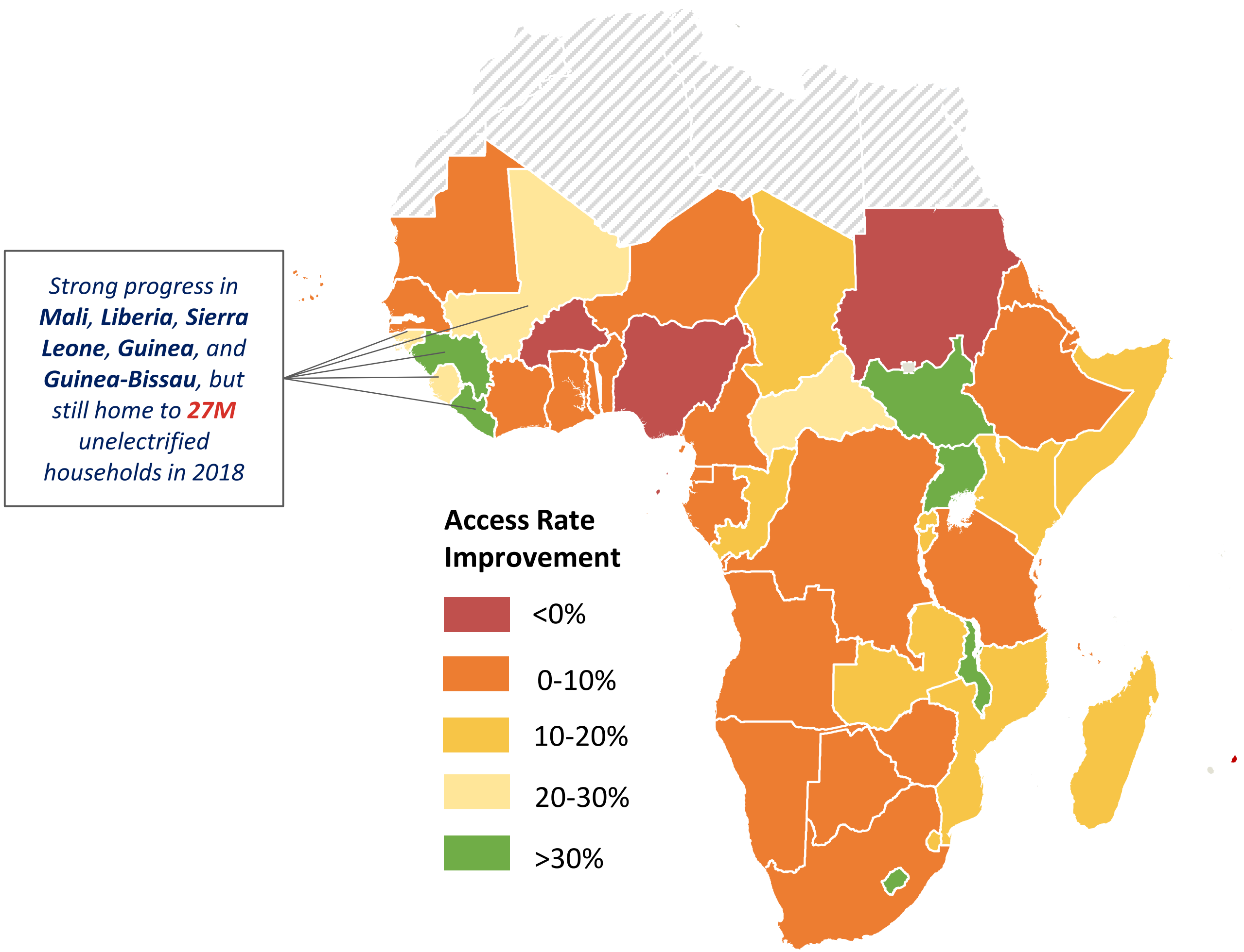
Source: Authors' estimations based on various sources including: 2020 Tracking SDG 7 Report; IEA Africa Energy Outlook 2019; GOGLA Off-Grid Solar Market Reports; ESMAP Mini-Grid Database

Though this progress is very uneven across countries

Sub-Saharan Africa Household Electricity Access (2018 vs. 2016)



46 percent

median access rate for Sub-Saharan African countries in 2016

8 countries

have population growth that is outpacing the rate of new connections

8 countries

have access in excess of **75%,** of which only 4 are not **small, island nations**

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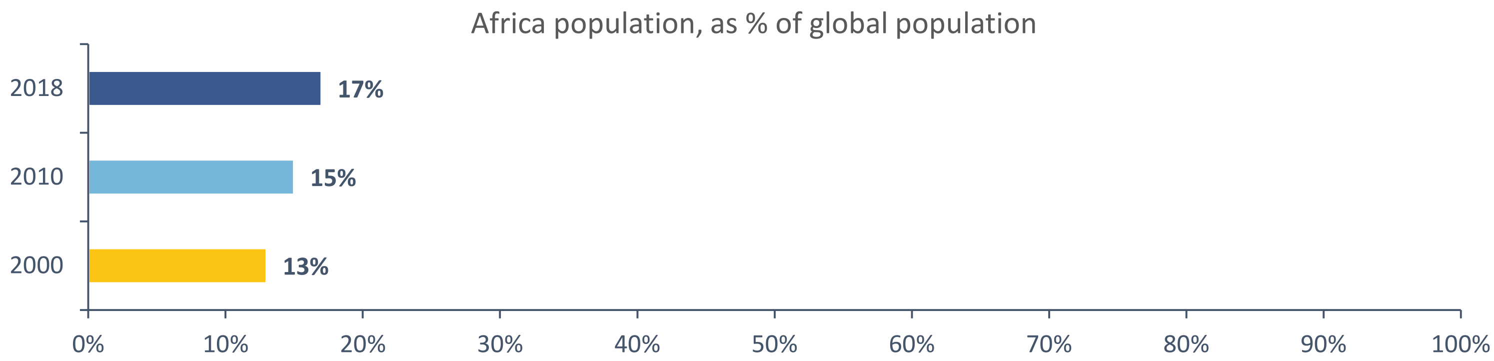
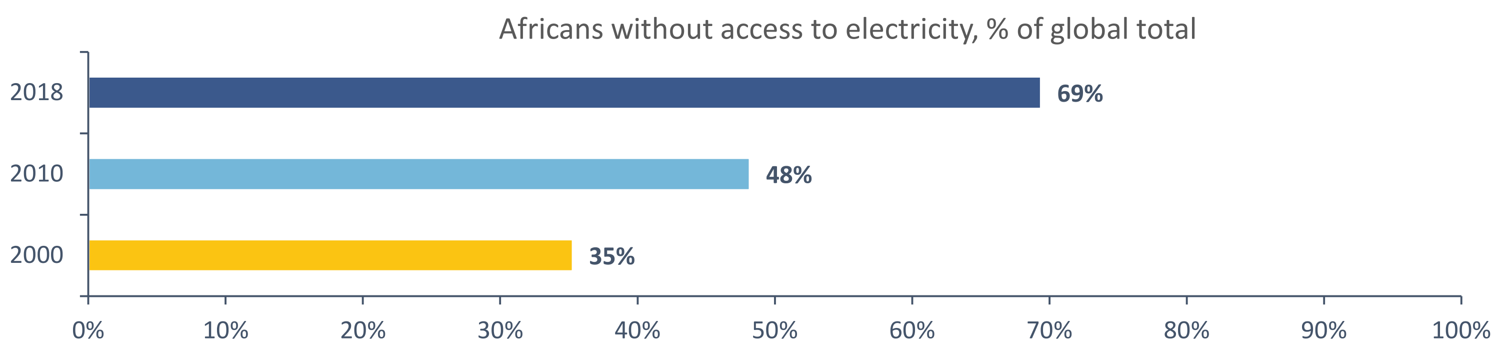
Source: Authors' estimations based on 2020 Tracking SDG 7 – The Energy Progress Report

And Africa is falling behind rest of world on electricity access

Africa’s share of the global population has seen modest growth since 2000



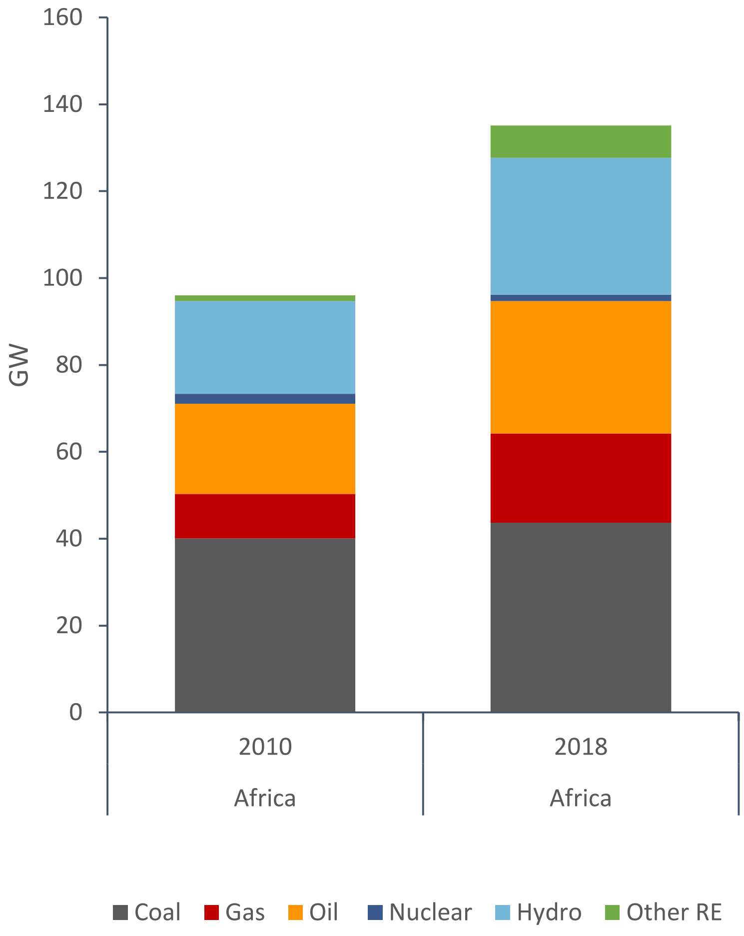
Yet it now hosts 69% of the world’s unelectrified households



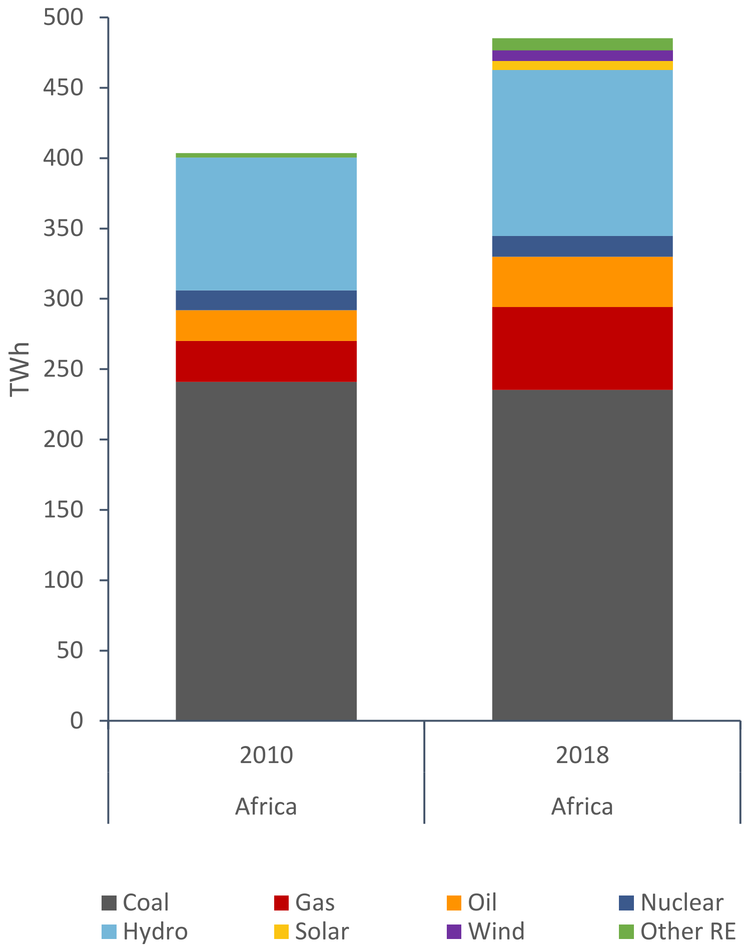
Source: Authors’ estimations based on ESMAP’s July 2020 Tracking SDG 7 Progress Report

Africa's power grids remain heavily dependent on fossil fuel-based power

Installed capacity by fuel in Africa, 2010 and 2018



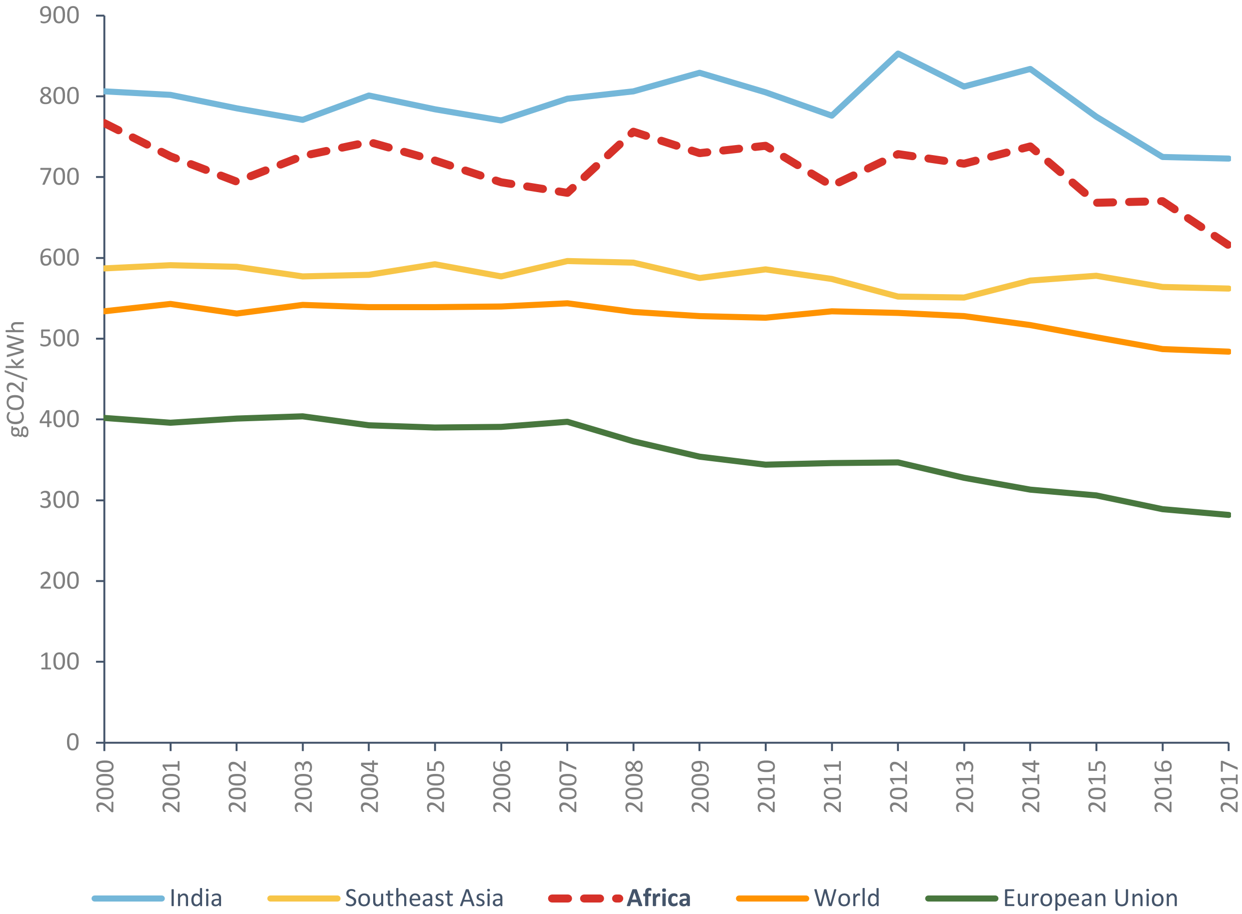
Electricity generation by fuel in Africa, 2010 and 2018



Source: Authors' estimations based on the IEA's 2019 World Energy Outlook and Africa Energy Outlook

And Africa's historical grid GHG emission trends have mirrored other parts of the world

GHG Intensity of Power Generation in Selected Regions



- Progress has been **inconsistent** in Africa, as seen by lumpy lines
- **Africa emissions** intensity remains relatively high compared to the **rest of world**
- Future trajectory depends heavily on Africa's **generation mix** and the extent to which it draws upon indigenous renewable resources (e.g. hydro, solar, wind)

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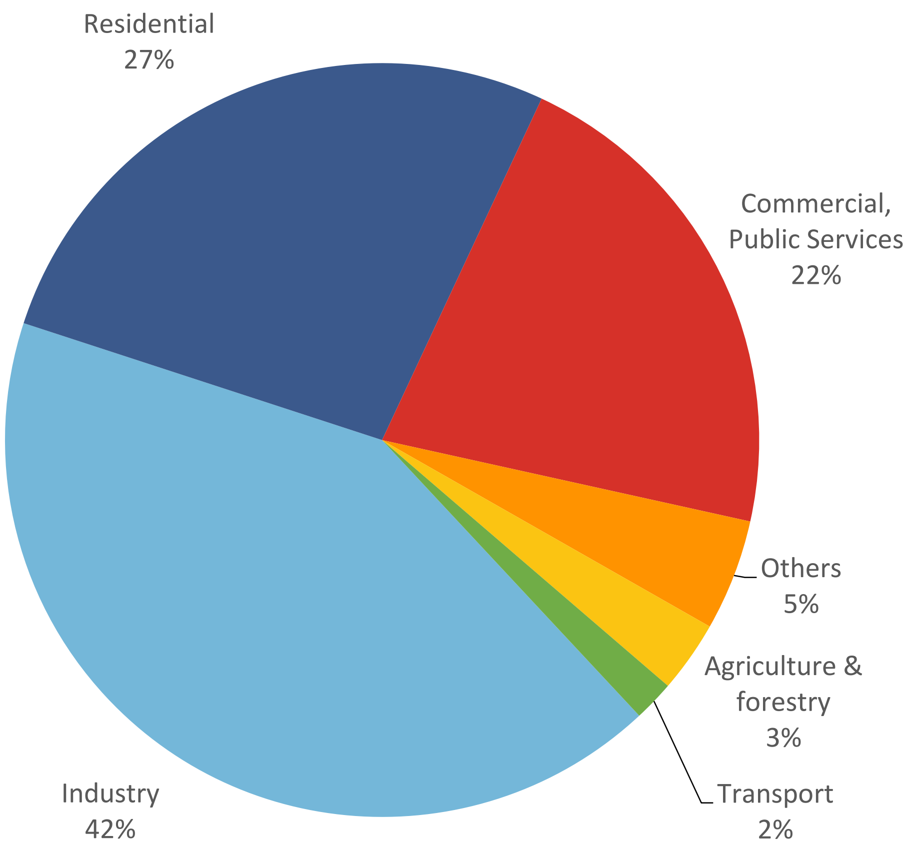
Source: Authors' estimations for Africa based on the IEA's 2019 World Energy Outlook and Africa Energy Outlook; IEA's Tracking Clean Energy Progress: Power; figures do not include impact of T&D losses

Africa’s backup genset epidemic: high-cost power with a big climate impact

More so than households, enterprises are the major driver of electricity demand globally and in Africa

Global electricity consumption by sector, 2017



69 percent

of global **electricity demand** driven by **industrial and commercial** off-takers

While still nascent, **Africa**'s commercial and industrial sectors similarly account for over **70% of total electricity demand**

27 percent

of global **electricity demand** originates from **households**

Despite lower access levels, households in Africa still account for **over 29% of the continent's electricity consumption**

Source: International Energy Agency – Electricity Statistics - Electricity Information 2019 Overview (publicly available)

Unreliable grid connections lead to massive use of fossil fuel-powered gensets, particularly by enterprises

As utilities struggle to keep up with growing electricity demand, grid reliability will likely worsen, exacerbating dependency on expensive, polluting backup generators

Unreliable grid connections

- In **developing countries**, unreliable grids are the primary driver for genset use:
  - ~**75 percent** of sites using fossil-fuel powered gensets are "**grid connected**"
- In **Africa** alone:
  - **36 countries** are considered to have unreliable grids[1]
  - Enterprises experience an average of **9 outages per month**, lasting a total of 81 hours (e.g.,> 10% downtime)
  - Unreliable grid connections result in an average **8 percent loss** in **business revenues**

=

Use of backup generators

- **Backup fossil-fueled generators** are used by households and enterprises
- **Powered** with **fossil fuels**, typically diesel or gasoline
  - Significant source of air pollutants
- Off-grid enterprises often resort to using gensets for power, particularly for **productive use applications**
- Some off-grid households use them as well, though fuel costs make them unaffordable for most

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[1] *An unreliable grid is defined as one in which local enterprises, on average, report 12 or more hours of electrical outages in a typical month; Source: World Bank Enterprise Surveys; photo credit: IFC.*

These gensets deliver power, but at a huge economic and climate cost

~ 7 million

estimated number of backup genset sites in Sub-Saharan Africa today, equivalent to **120 coal-fired power stations**

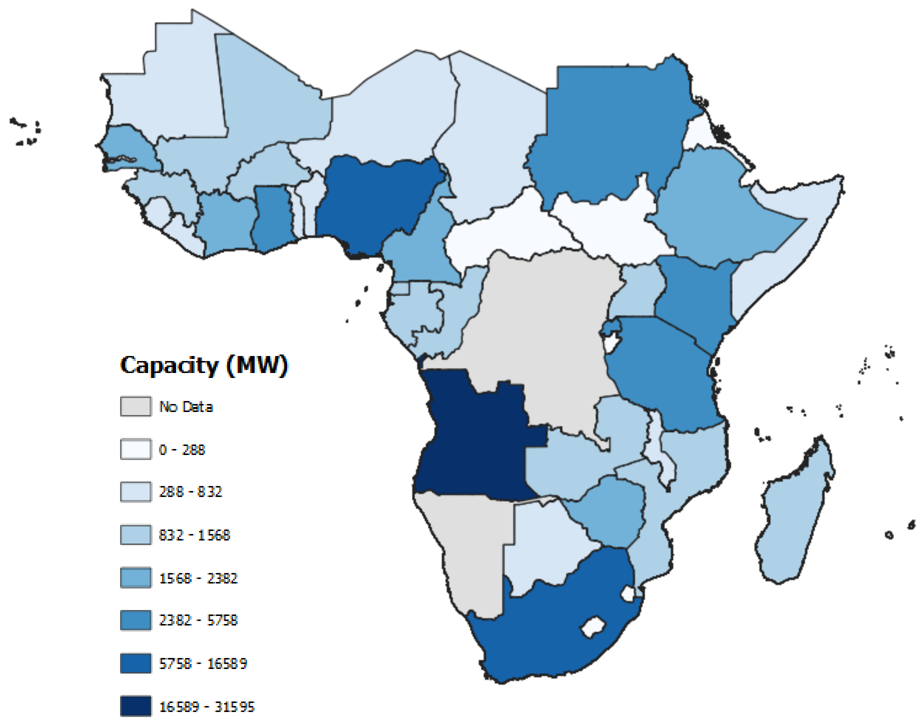
~US$13 billion

spent in Sub-Saharan Africa by backup genset users each year on **fuel**

20 percent

of gasoline & diesel consumed in **Africa** is a result of backup genset use, equivalent to 15-20 percent of spending on education & healthcare

Installed capacity of back-up generators in Africa, 2016



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Source: The Dirty Footprint of the Broken Grid, IFC and Schatz Energy Research Center at Humboldt State University, 2019

Clean cooking: what it is and why it matters for climate change and energy access

Why clean cooking solutions matter

Four billion people - half of the world's population - depend on polluting solid fuels, open fires or inefficient stoves to cook their food[1]

The annual costs are striking:

>4 million
premature deaths

1.4 billion
tons of **wood fuel** consumed, much of it **unsustainably**

US$38 – US$40 billion
spent on **solid fuels** for cooking

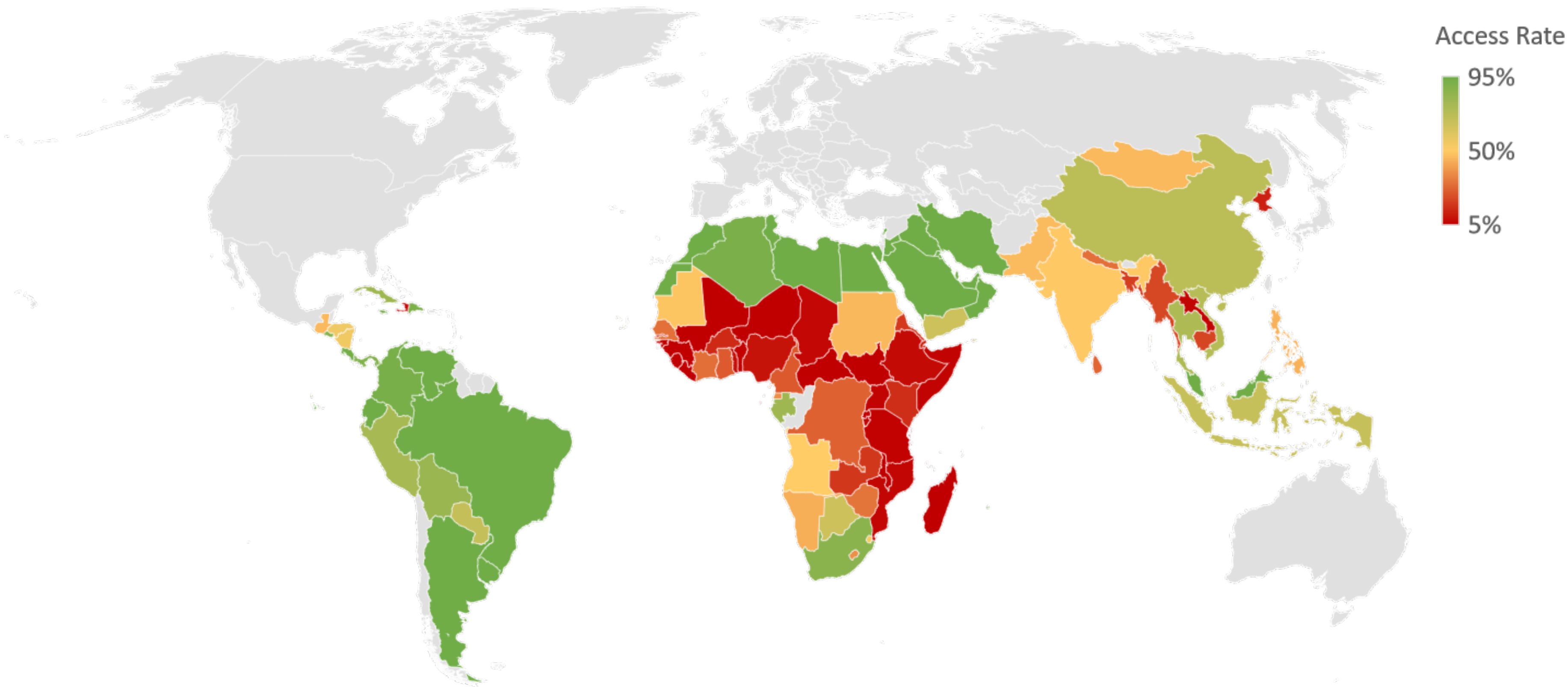
140 million
productive person-years **wasted on biomass collection**

Source: The State Of The Global Clean And Improved Cooking Sector 2015, ESMAP; The State Of Access to Modern Energy Cooking Services 2020, ESMAP; Photo: Arne Hoel/World Bank

Africa is the epicenter of the cooking crisis

Population growth in Africa is **outpacing** annual growth in **clean cooking access** across the continent; between 2010-2018, the number of people without access rose from 750 million to 890 million

Percentage of population with access to clean cooking by country, 2018



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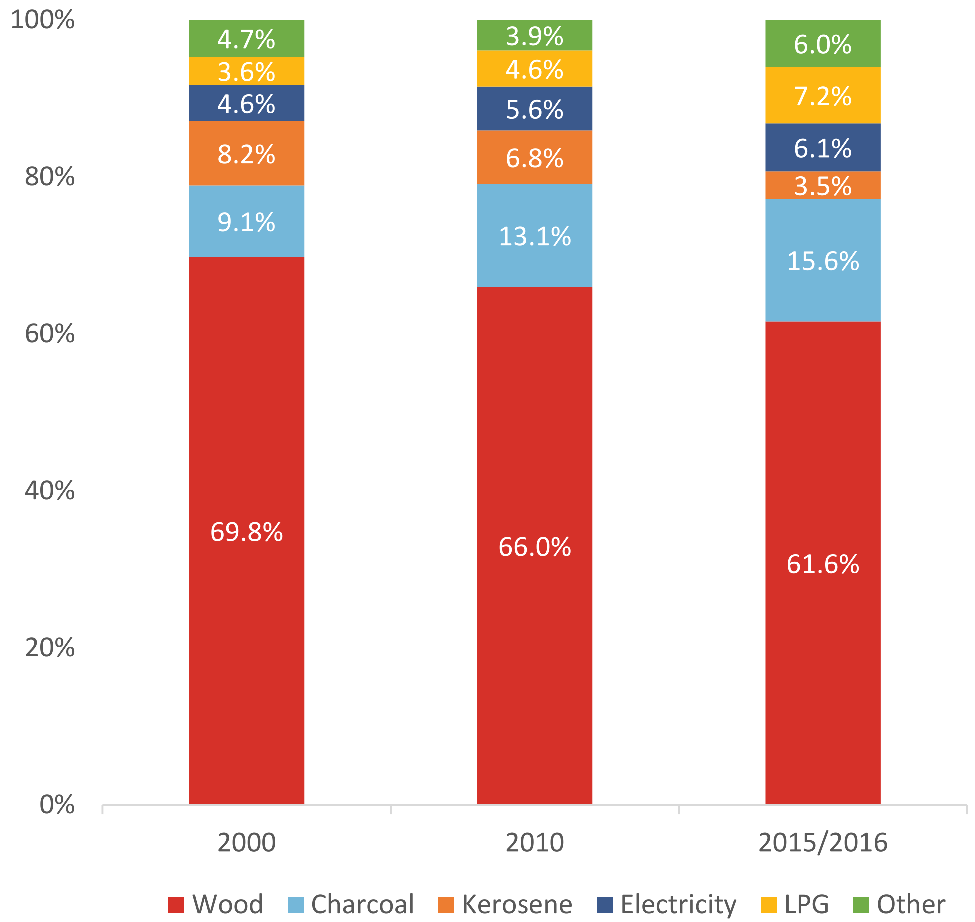
Source: ESMAP: The State Of Access to Modern Energy Cooking Services 2020

Africa's high solid fuel use costs lives and the climate

Africa primary household cooking fuel use by type, 2000, 2010, and 2015/16[1]



850 million+

Africans, or 80% of the continent's population, use **solid fuels** for primary cooking needs

600 thousand

Africans killed annually from household air **pollution**, making it the 2nd largest health risk in the region

600 Mt CO_2

of **global GHG emissions** comes from **solid fuel cooking** in Africa alone

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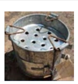
Sources: Clean and Improved Cooking in Sub-Saharan Africa 2014, ACCES; The State of Access to Modern Energy Cooking Services, ESMAP 2020; Authors' estimates

[1] Other includes a mix of both modern and traditional fuels, including natural gas, biogas, mined coal, dung, crop waste, etc.

Solving the cooking challenge requires a shift to modern fuels

Making the shift must overcome significant barriers, including willingness and ability to pay, building fuel supply chains, and behavior change relative to traditional cooking approaches

	Traditional fuels				Modern fuels			
	Stopgap cooking		Improved Cooking		Modern Fuel		Renewable Fuel	
Stove Type	"3-stone"		Improved artisanal		“Standalone" stove		“Standalone" stove	
	Unimproved artisanal		Industrial		“Grid-tied"		“Grid-tied"	
Fuels	Wood		Wood	Coal	LPG		Electric*	Pellets
	Charcoal		Charcoal	Kerosene	Natural gas		Biogas	Ethanol
	Coal						Solar	
Example	Traditional Metal Stove	Chitetezo Mbaula	Burn jikokoa	Envirofit G-3300	LPG Stove Télia n°2	LPG/NG 2B SS gas stove	Mimi moto	SAFI Cooker
Image								
Fuel Type	Charcoal	Wood	Charcoal	Wood	LPG	Natural gas/LPG	Pellets	Ethanol
Efficiency	23%	20%	44%	34%	49%	N/A	47%	64%
GHG Emissions	Very high	High	Medium	Medium	Low	Low	Very low	Very low

Source: Clean Cooking Alliance’s ‘Clean Cooking Catalog’; authors’ analysis.
**Renewability of electricity depends on country generation mix.*

Africa's choice of modern cooking transition depends on the emissions intensity of fuel sources

- In **Africa**, electric stoves have higher emissions than other fuel/stove combinations due to the **fossil fuel-heavy grid** generation mix
- The most GHG emissions-friendly solutions involve **lower-carbon fuels paired with highly-efficient stoves**

Fuel Type	Fuel Type	Fuel emissions intensity *kgCO2e/GJ*	Stove Efficiency *%*	Stove and fuel emissions intensity *kgCO2e/GJ*
Traditional stove	Charcoal	100	23%	434
Traditional stove	Wood	67	20%	337
Basic ICS	Charcoal	103	30%	343
Basic ICS	Wood	61	25%	249
Industrial ICS	Charcoal	103	41%	253
Industrial ICS	Wood	61	34%	181
Std. Kerosene	Kerosene	89	45%	198
Std. LPG	LPG	75	49%	153
Industrial Ethanol	Ethanol	24	64%	38
Industrial Pellet	Pellets	19	47%	41
Std. Electric	Electric	169	75%	226
Induction Electric	Electric	169	85%	199

**Each fuel has a GHG emissions intensity factor (kgCO_2e per gigajoule of fuel burned) which illustrates the carbon-intensity of the fuel when burned. When used in a particular stove, only a percentage of the burned fuel is converted into useful energy, resulting in a higher GHG emissions intensity in practice.*

Source: Authors' analysis based on multiple sources including Penisse et al, Bailis et al, Clean Cooking Alliance's Clean Cooking Catalog, inter alia.

Africa's energy access pillars and climate finance opportunities

Previewing the thematic pillars and climate scenarios

Our analysis is based on separate pillars, focused on:

Electricity Access

1 — Tier 1 Universal **Access**

1.5 — Modern Energy Min. Universal **Access**

2 — **Back-up Genset** Eradication

3 — Improved **Cooking**

Within each of these **pillars,** we generate the following **scenarios**:

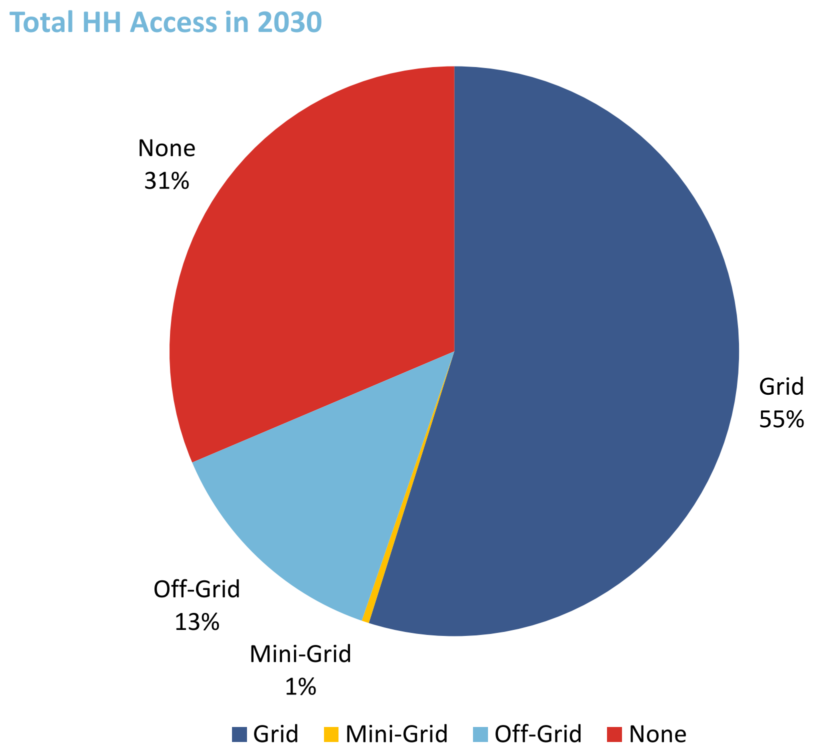
- **BAU** (Business-as-usual) — **Business-as-usual**: future trajectory based on historical trends
- **HC** (High-carbon) — **High-carbon**: technology deployed to achieve universal access are relatively emissions intensive
- **LC** (Low-carbon) — **Low-carbon**: technology deployed to achieve universal access heavily leverage low-carbon technologies

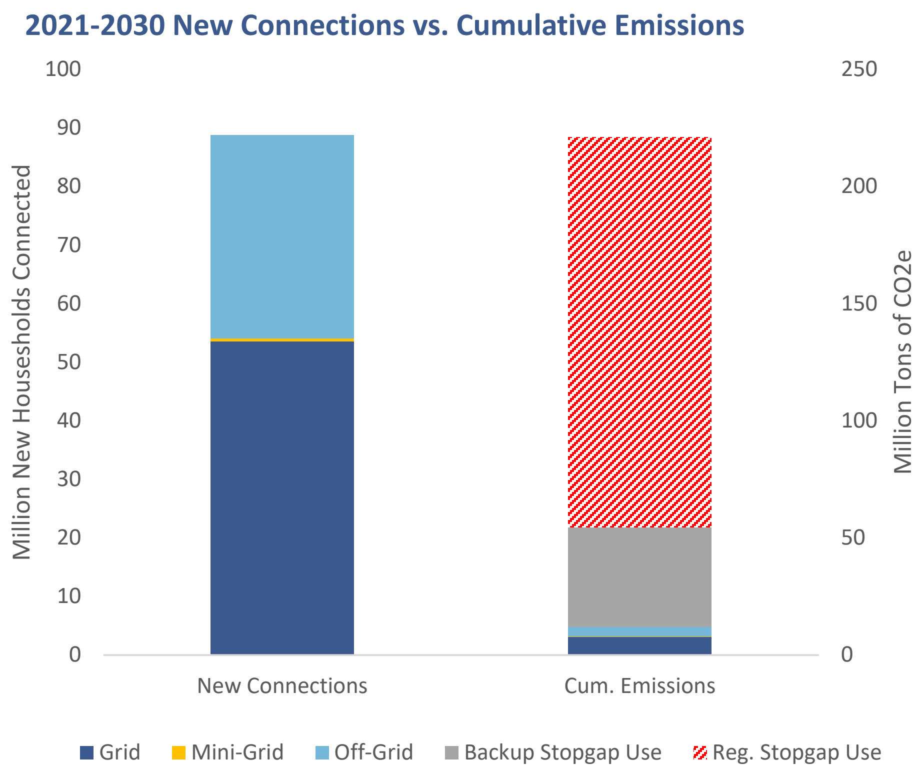
Each model allows benchmarking of scenarios to estimate avoided CO_2 emissions

Pillar 1: universal household electricity access by 2030

Pillar 1– Tier 1 Threshold

Business-As-Usual (BAU): model shows only 69% of HHs would have access in 2030[1]; significant stopgap emissions footprint





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- **Reflects expected access situation through 2030 if current trends in grid, mini-grid, and standalone solar access continue**
- **About 89 million households will gain access; a somewhat larger number will remain unserved**
- **Cumulative emissions of 418 $MtCO_2e$, of which 50 percent from continued stopgap use**

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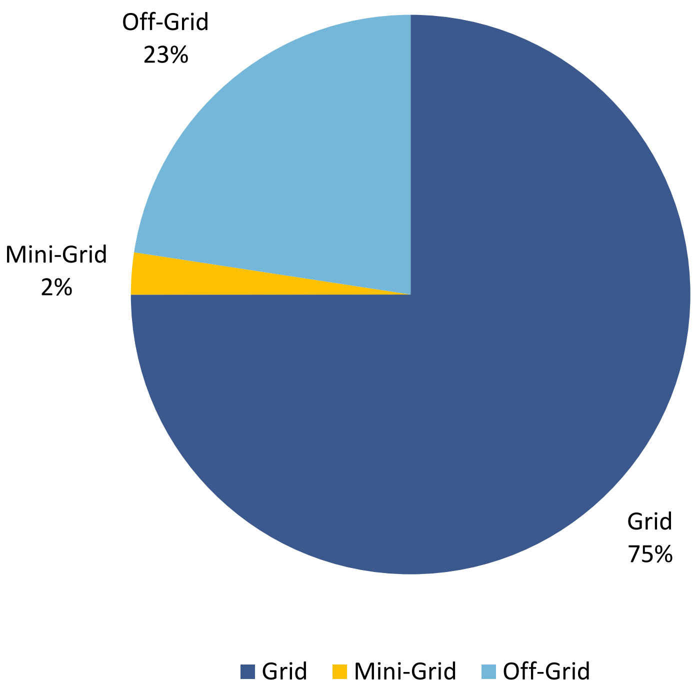
[1] Projections through 2030 based on recent historical trends in grid expansion, mini-grid construction, and OGS sales. All scenarios assume UN-DESA's medium population growth scenario and average household sizes shrinking in line with historical averages. Backup stopgap use refers to emissions from the ongoing use of stopgap solutions by HHs with electricity access; reg. stopgap use refers to stopgap emissions from unelectrified HHs

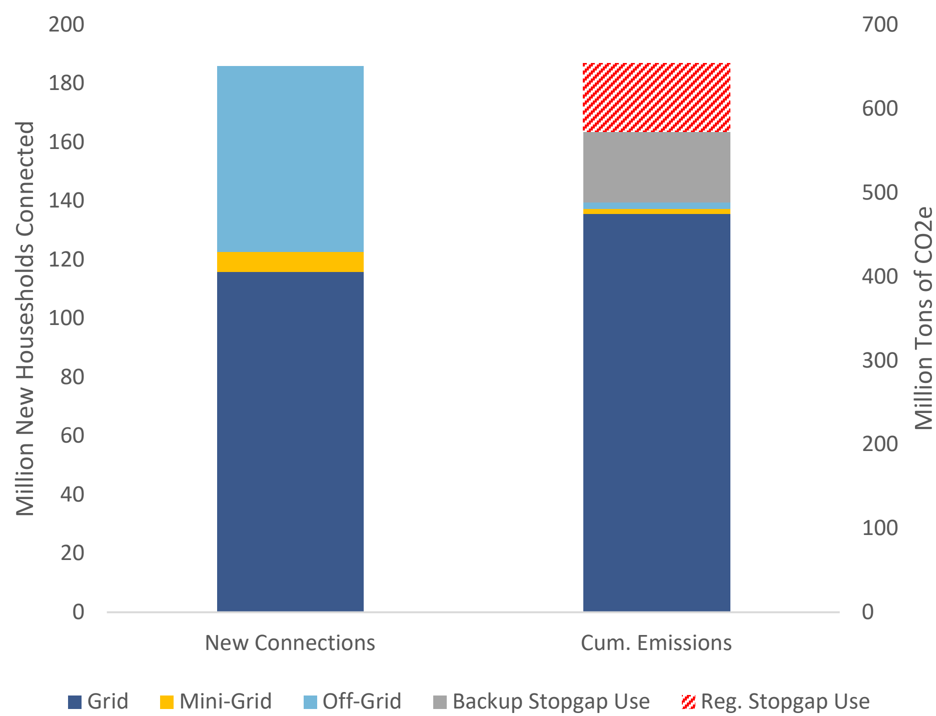
Pillar 1: HH access | Scenario: high-carbon

Tier 1 high-carbon scenario: universal access, with a 53% increase in CO_2e emissions compared to BAU

Total HH Access in 2030



2021-2030 New Connections vs. Cumulative Emissions



- **Universal access achieved** by 2030 through a **higher-carbon scenario** whereby the **grid** plays a large role, and associated emissions intensity rises to levels similar to **India today**
- Mini-grids and standalone solar also figure prominently, but the former continue to use fair amounts of **diesel**
- **Cumulative emissions of 654 MtCO_2e**, including an over 40 MtCO_2e reduction in stopgap emissions vs BAU

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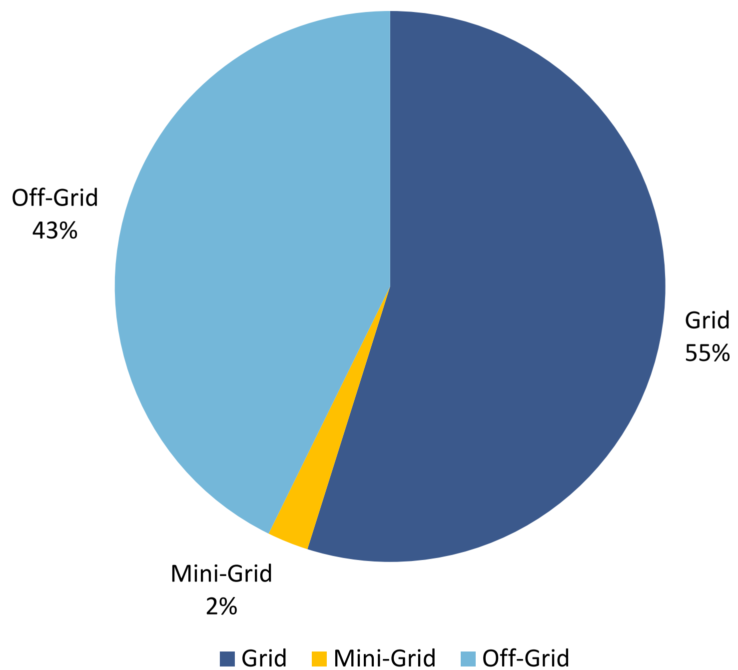
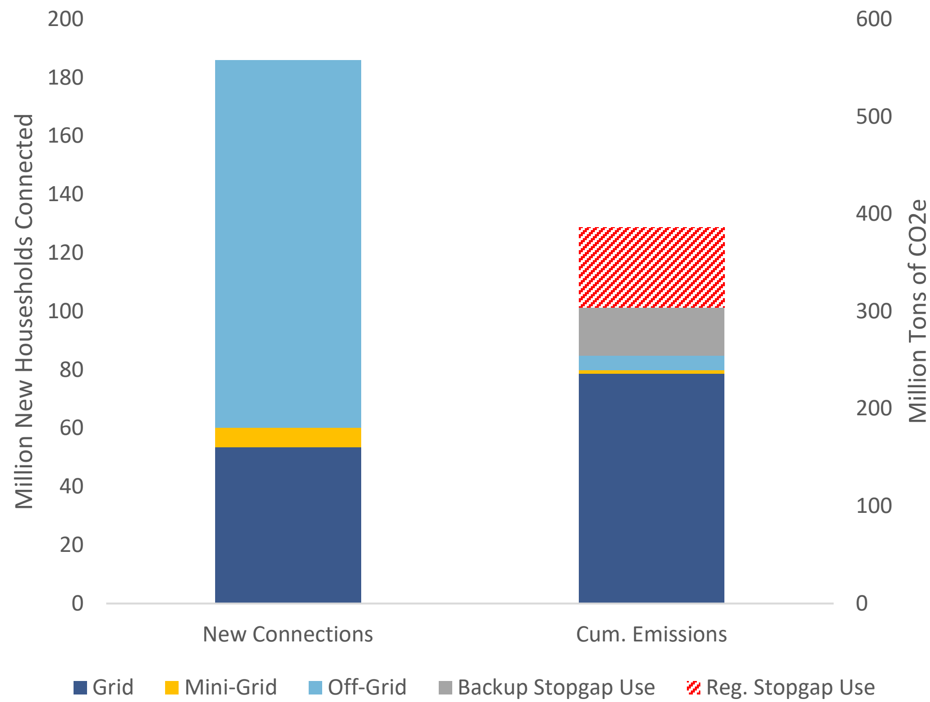
[1] Grid emissions intensity in the high-carbon scenario increases by 1.5% annually to nearly 800 kgCO_2e/MWh when factoring in T&D losses. New mini-grids maintain approximately the same generation breakdown as the existing stock in Africa (50% diesel; 20% diesel-RE; 30% RE). Reduction in stopgap emissions is limited given the large number of new grid users who will continue using stopgap solutions to deal with poor grid reliability.

Tier 1 low-carbon scenario: universal access, smaller carbon footprint than BAU

Total HH Access in 2030



2021-2030 New Connections vs. Cumulative Emissions

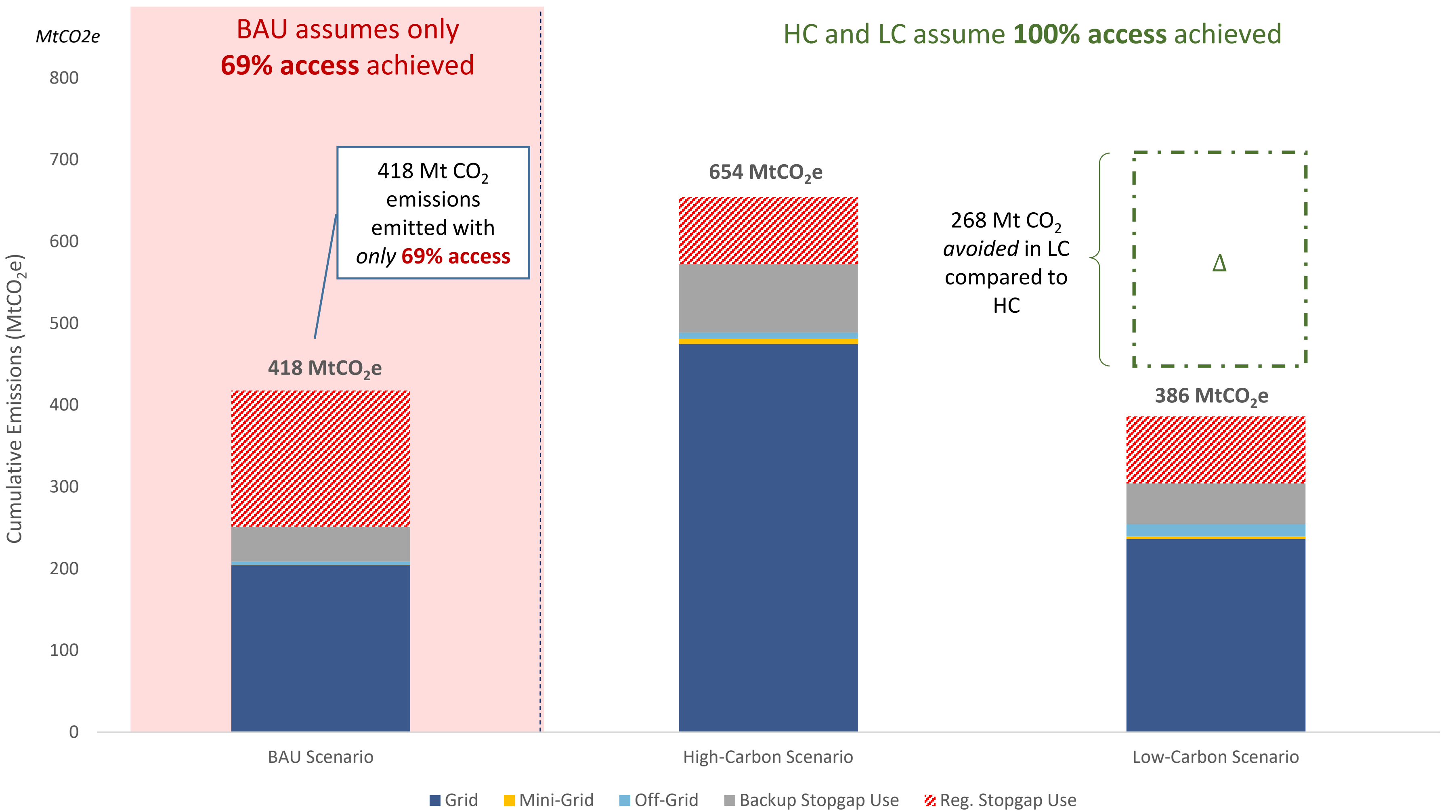


- **Standalone solar**, **green mini-grid solutions** account for **majority** of new **household connections** through 2030
- Lower dependency on grid generation; **emissions intensity decreases** in line with historical trends;
- **Limited GHG footprint** of **off-grid technologies** means that emissions impacts relative to BAU are rather **limited**
- **Cumulative emissions of 386 MtCO_2e**, including an estimated 77 MtCO_2e avoided stopgap emissions vs BAU

[1] Grid emissions intensity in the low-carbon scenario decreases slightly to just over 650 kgCO_2e/MWh when factoring in T&D losses. The share of RE-only mini-grids increases considerably to 80% by 2030. The reduction in stopgap emissions is more significant than the high-carbon scenario as fewer households gain access through an unreliable grid.

Emissions impact of universal access scenarios vary widely: low-carbon scenario has net avoided emissions of 268 Mt CO_2e

Comparison of 2021-2030 Cum. CO_2e Emissions

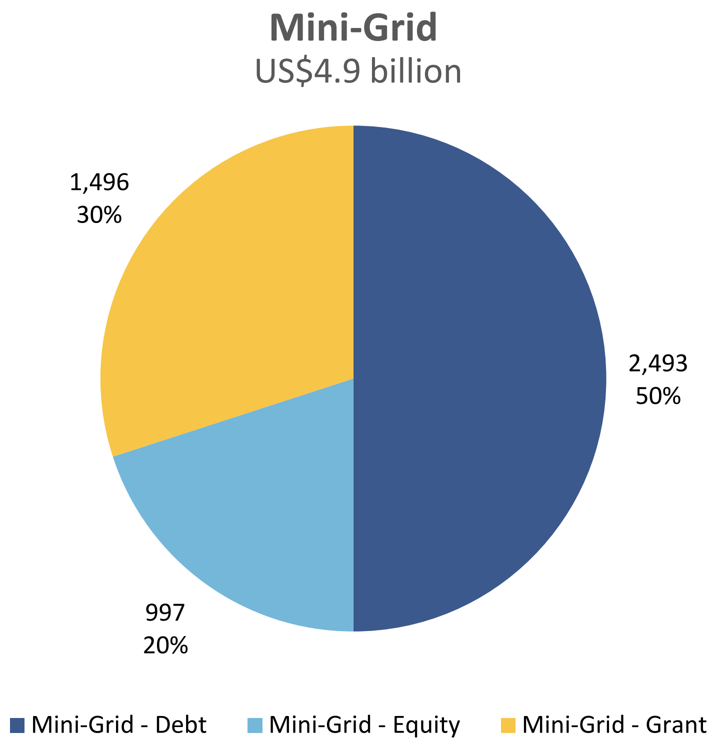


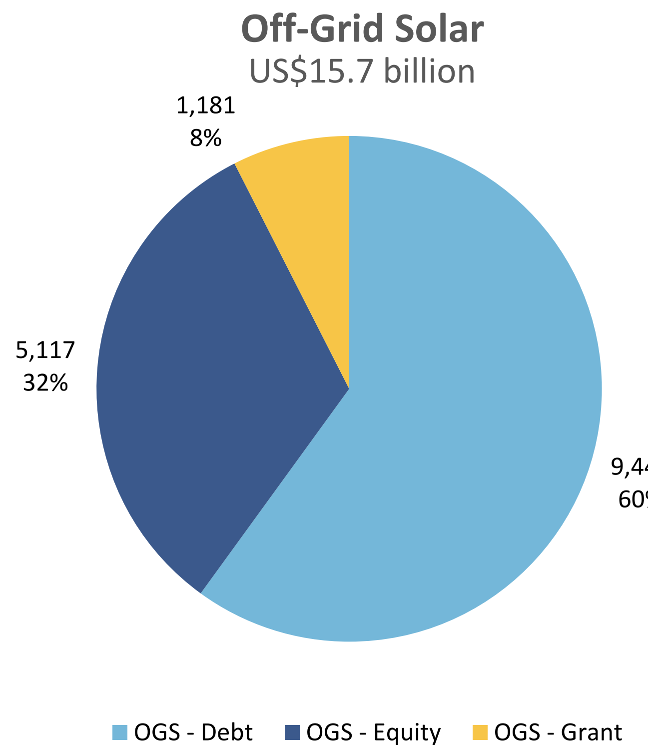
[1] The low-carbon scenario has lower estimated emissions than the BAU scenario since emissions from electrification activities are more than offset by reductions in stopgap emissions (particularly from kerosene and candles)

Tier 1 low-carbon electrification scenario yields a US$20.7 billion climate finance opportunity

- **Off-grid solar** financing need of **US$15.7 billion**, yielding **first time access** for **125.7 million** households
- **Mini-grid** financing of **US$4.9 billion** required, delivering access to **6.8 million** households

Base Demand: Off-Grid Solar & Mini-Grid Capital Needs, 2021-2030





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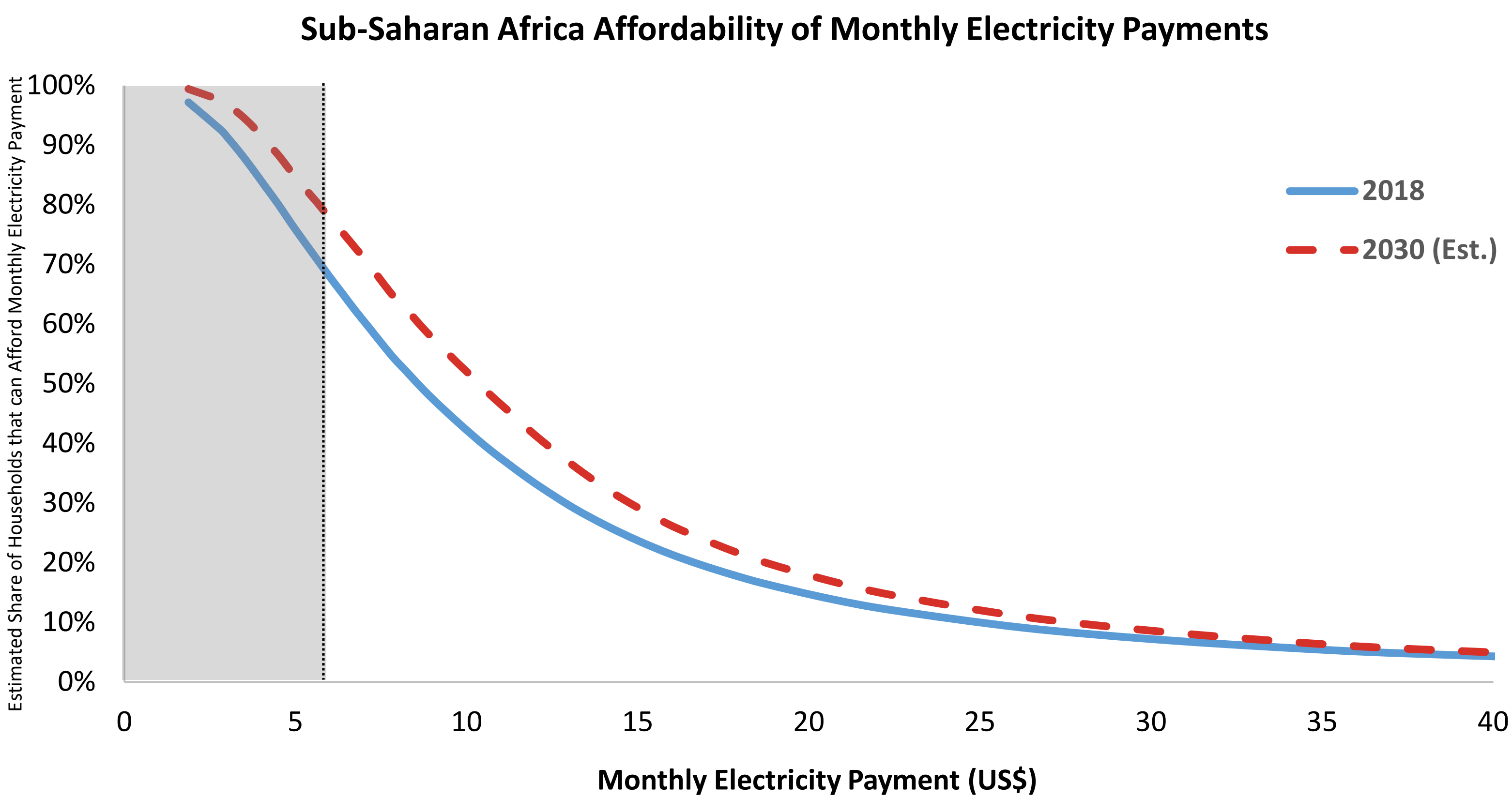
[1] Quantum and blend of financing needs are based on the historical needs of mini-grid developers and OGS distributors as well as the authors' expectations about the evolution of system costs through 2030. Financing amounts do not include additional end-user subsidies that would be required to ensure Tier 1 OGS systems or mini-grid electricity is affordable for all households by 2030.

US$2.5 billion required in consumer subsidies to achieve universal access under low-carbon scenario

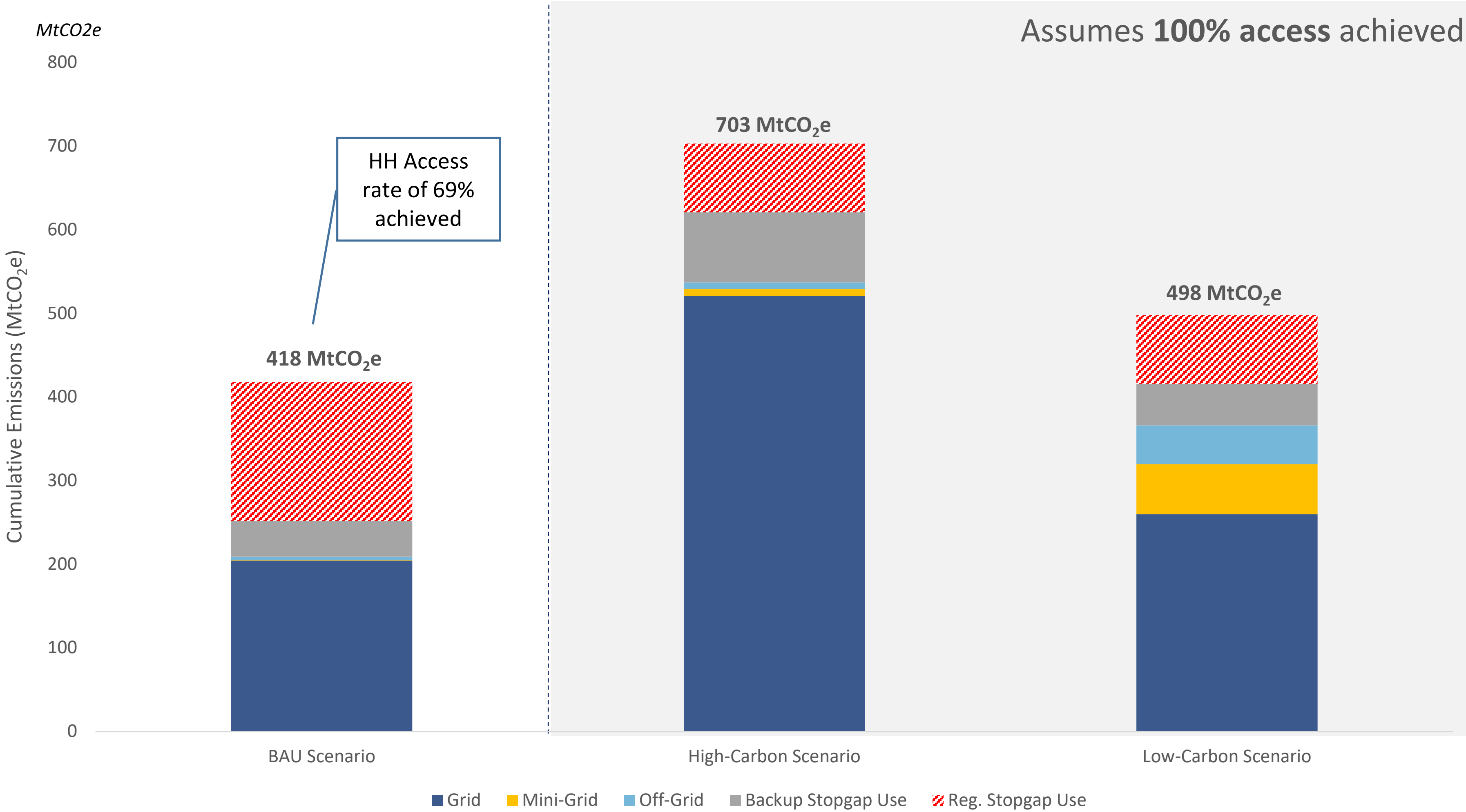
- **42 million households** that need but cannot afford T1 OGS by 2030
- **31% of households** without grid or micro-grid connections that require subsidy for T1
- **$2.5 billion** total financing required if 50% demand-side subsidy is provided



Pillar 1.5– Modern Energy Minimum Threshold

MEM yields additional 112 Mt CO_2e (compared to Tier 1), though per capita consumption increases to 130 kWh/year

High Demand: Comparison of 2021-2030 Cum. CO_2 Emissions

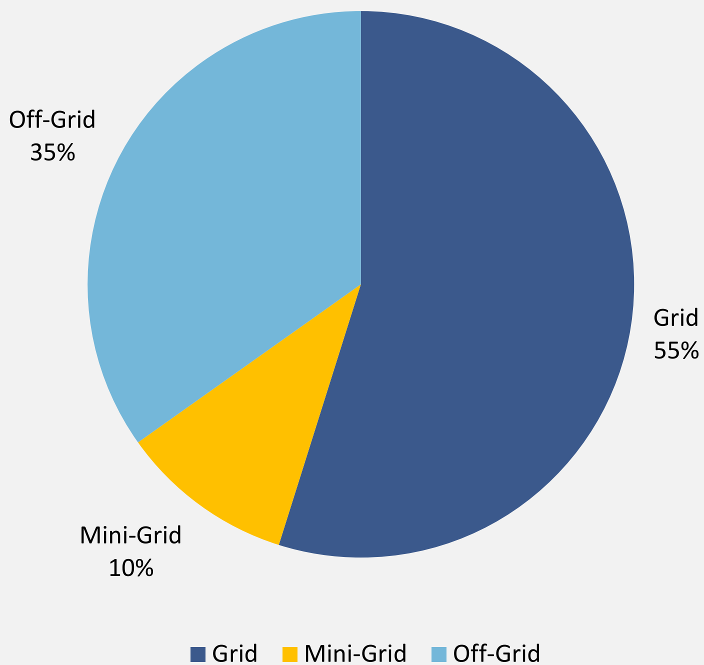


Source: *Catalyst predictive model outputs*

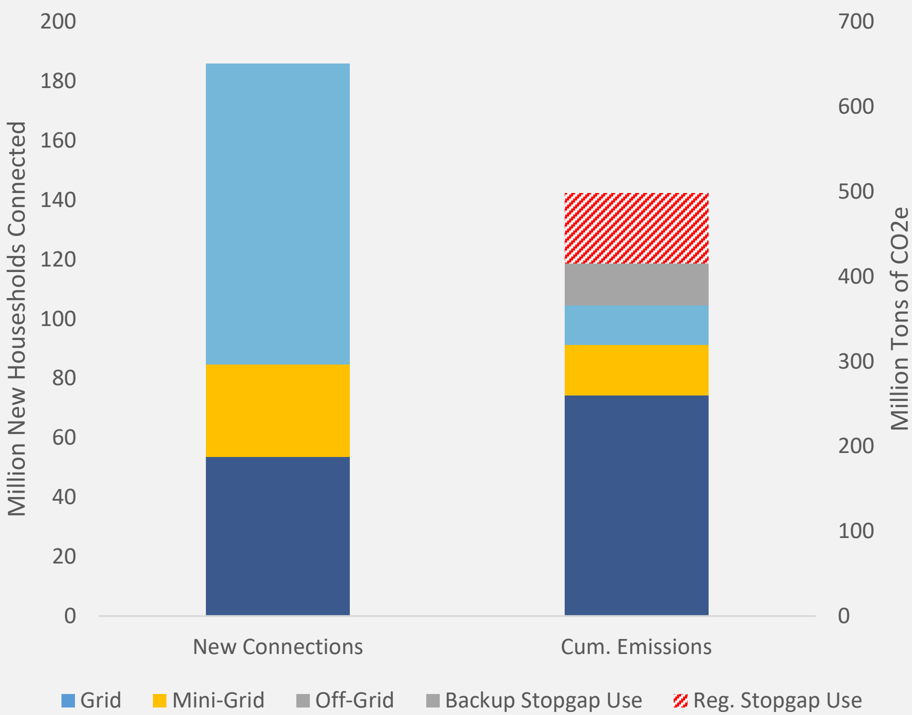
[1] MEM scenario results in increased CO_2e emissions due to higher overall electricity consumption per capita as well as the need for larger mini-grids and off-grid solar systems (Tier 2 and 3), which have higher emissions associated with their manufacture and distribution

MEM requires 25M more mini-grid and 37M more Tier 3 OGS connections relative to Tier 1

Total HH Access in 2030



2021-2030 New Connections vs. Cumulative Emissions



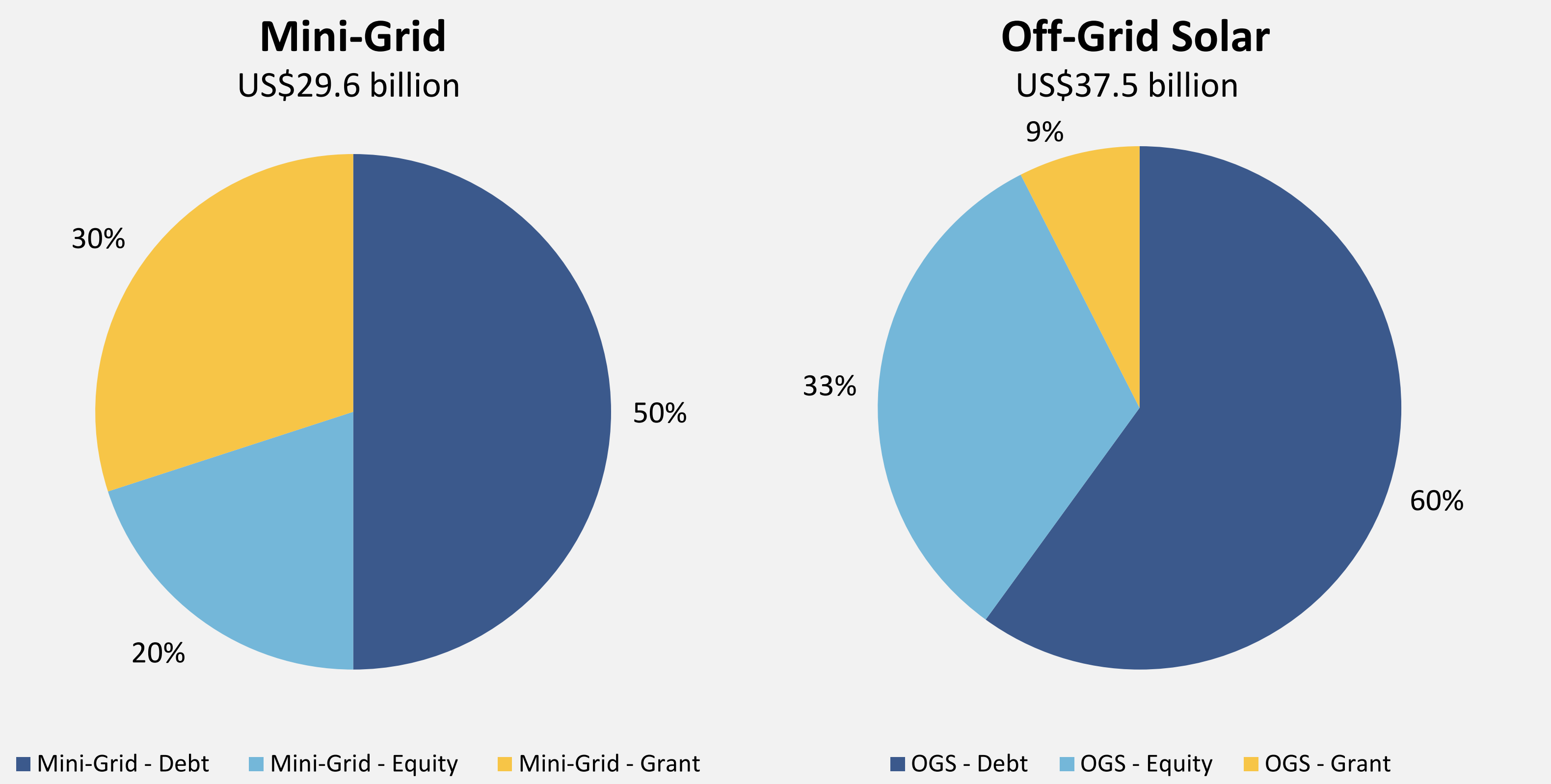
- MG and Tier 3 systems required to deliver on scenario's assumed per capita consumption of 130 kWh p/a by 2030
- Over the period, mini-grids account for 16 percent of new connections and Tier 3 OGS nearly 20 percent
- In the MEM scenario, average per capita electricity consumption increases by 57 percent, and emissions 27 percent, relative to the base case

[1] *The 130 kWh/capita MEM annual target for 2030 is an average, with some grid HHs overshooting (i.e., getting grid, mini-grid, and Tier 3 off-grid solar access) while others have Tier 1 or 2 access.*

MEM's low-carbon electrification scenario yields a US$67.1 billion climate finance opportunity

- Larger systems required to deliver **higher per capita demand of 130 kWh** per year by 2030
- **Off-grid solar** connects **101 million** households at a cost of **US$37.5 billion**, while mini-grids require **US$29.6 billion** to electrify **31.3 million households**

High Demand: Off-Grid Solar & Mini-Grid Capital Needs, 2021-2030



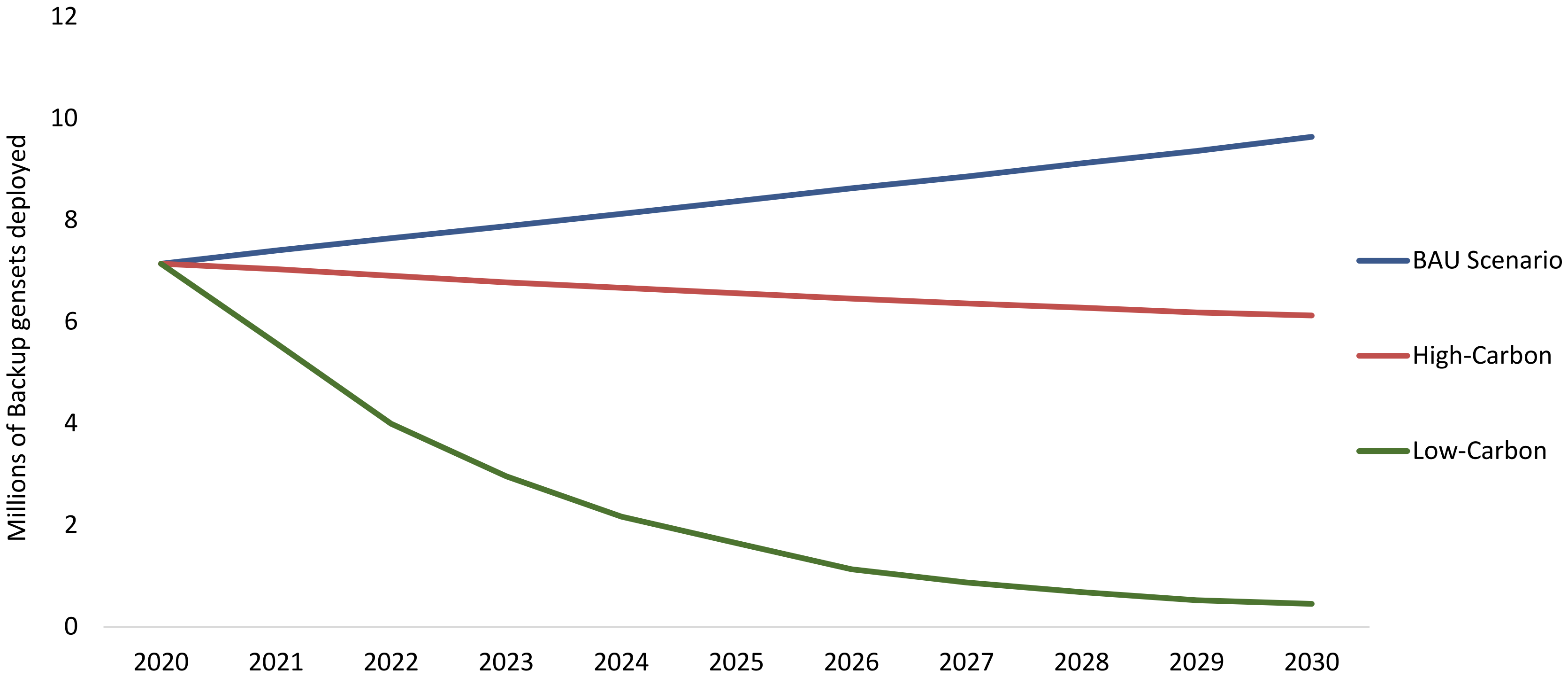
[1] *The quantum and blend of financing needs are calculated as in the Tier 1 scenario, but to meet the MEM target, larger mini-grids and a higher share of Tier 2 and 3 SHS are required. Financing amounts do not include additional end-user subsidies that would be required to meet targets for all technology types.*

Pillar 2: eliminating backup genset use by African enterprises and households by 2030

The pace of phasing out fossil-fuel burning gensets with renewable solutions impacts scenario emission profiles

- **High-carbon scenario** assumes that, when gensets reach end of life, 10 percent are replaced with renewables
- In **low-carbon scenario**, at end of life, 50 percent of gensets are **replaced** with renewables; by 2030 nearly all gensets are retired

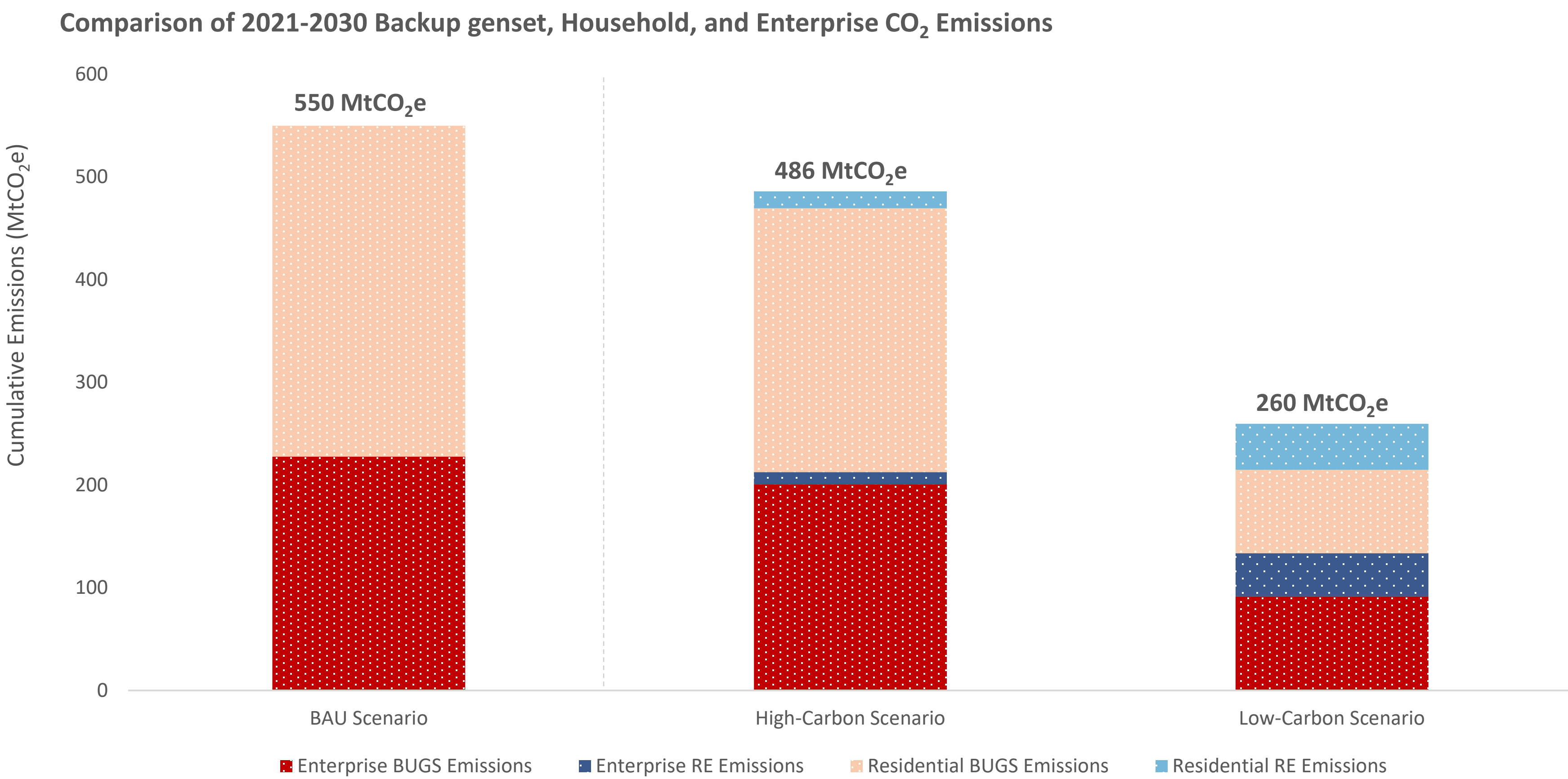
Evolution of Backup Genset Fleet for Households and Enterprises by Scenario, 2021-30



[1] The 10% and 50% replacement rates specifically occur when gensets reach their rated lifetime. As such, the total percentage of gensets replaced over the 10-year period exceed the replacement rates.

Displacing 9.2 million backup gensets with decentralized renewables reduces African emissions by 226M tons of CO_2e

- Emissions reductions are driven by the growth rate in backup genset fleets and the rate at which **backup gensets are replaced by** renewables; replacement rates are varied across scenarios
- **BAU** has highest carbon footprint because renewables do not become part of the fleet mix



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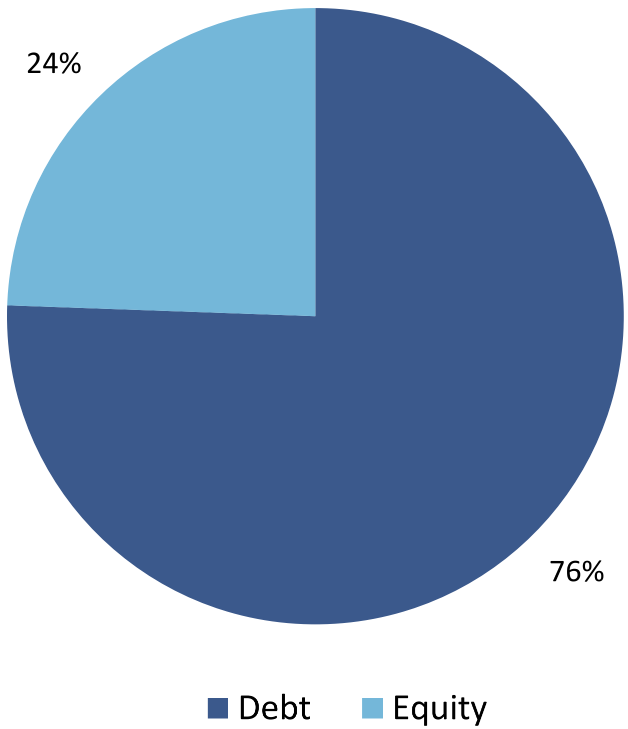
1. The modeling assumes that average capacity factors of back-up generators remain fixed over time, in line with historical averages (i.e., assumes no improvement or deterioration in grid reliability).

Low-carbon scenario yields a US$134.4 billion climate finance opportunity

- Displacing **9.2** million backup generators with a total generation capacity of **163 gigawatts** comes at a significant cost
- Generator displacement in later years is forecasted to be considerably cheaper thanks to **sharp reductions in RE technology costs**, particularly lithium-ion batteries

Back-up: Renewable Energy Capital Needs, 2021-2030



[1] *Quantum and blend of financing needs are based on the authors' estimates and expectations about the evolution of solar+battery system costs through 2030. Grant needs for purveyors of genset replacement technology are expected to be very limited given the strong financial case for making these investments, with debt financing playing an even more significant role due to C&I enterprises' proportionally larger working capital needs.*

Pillar 3: moving African households that cook with charcoal onto clean cooking solutions

Clean Cooking: establishing a plausible 2030 scenario for Africa

What

- Achieving universal clean cooking in Africa by 2030 **not feasible**
- This research posits a plausible low-carbon cooking scenario whereby African **charcoal users transition to modern fuels**

Why

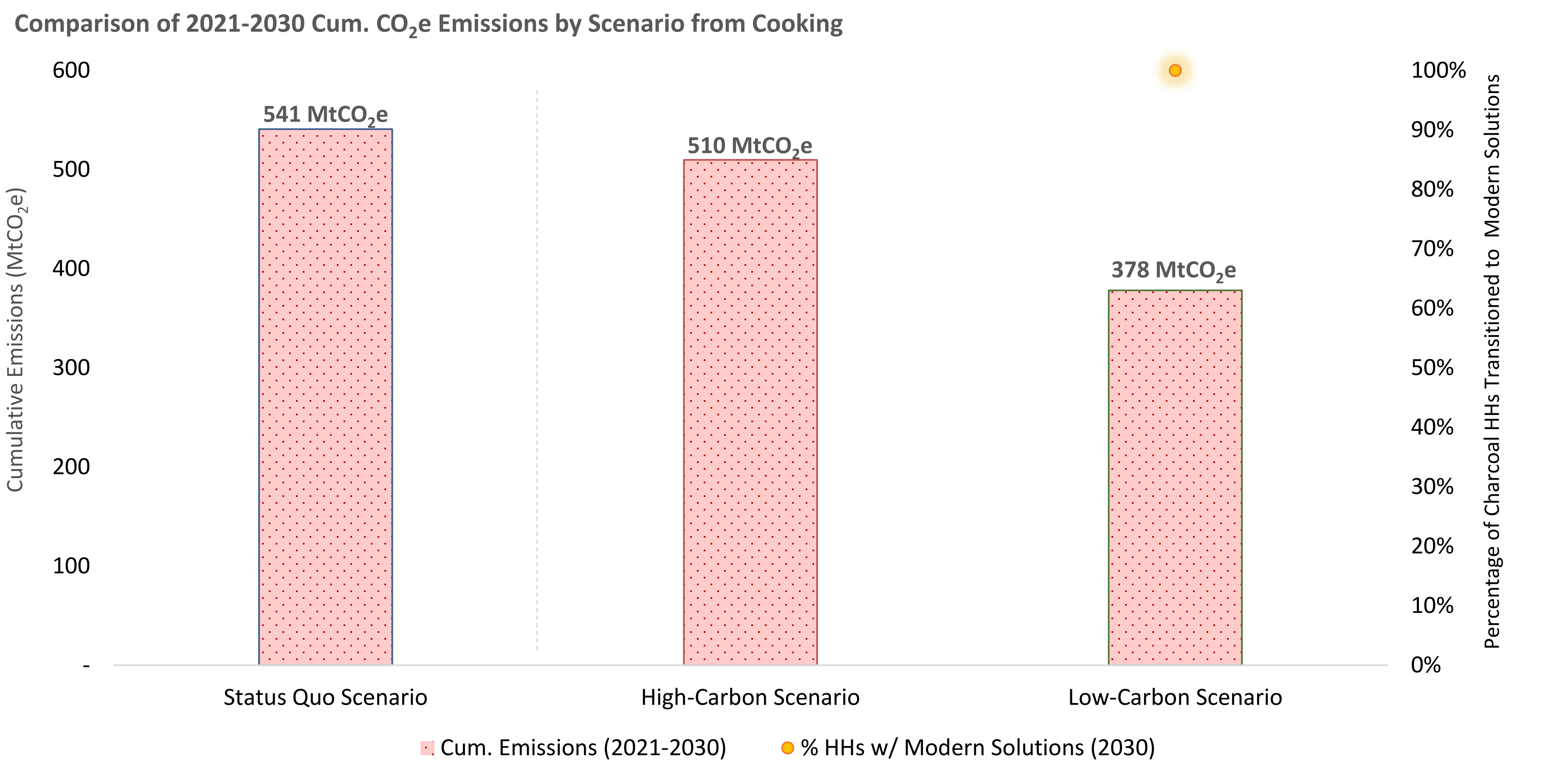
- Household's using **charcoal** are most likely to switch to **modern fuels** because:
  - Charcoal users have an **existing willingness and ability to pay** for fuel
  - Charcoal **has established distribution channels** that could be used for modern fuels
  - Charcoal users are typically in urban or peri-urban areas, thus **easier to access** and in greater density

How

- Our cooking model estimates the impact of **moving charcoal users onto modern fuels**, including LPG, electricity, ethanol, and wood pellets
  - Scenarios vary by the percentage of charcoal-using HH that shift to modern fuels by 2030
  - High-carbon assumes 25%; low carbon assumes 100%; black carbon emissions are not included

Displacing charcoal with modern fuels in Africa yields 132 million tons of avoided CO_2e emissions

39 million new households would cook with **modern fuels**, representing an 83 percent increase in primary[1] modern fuel users in Africa



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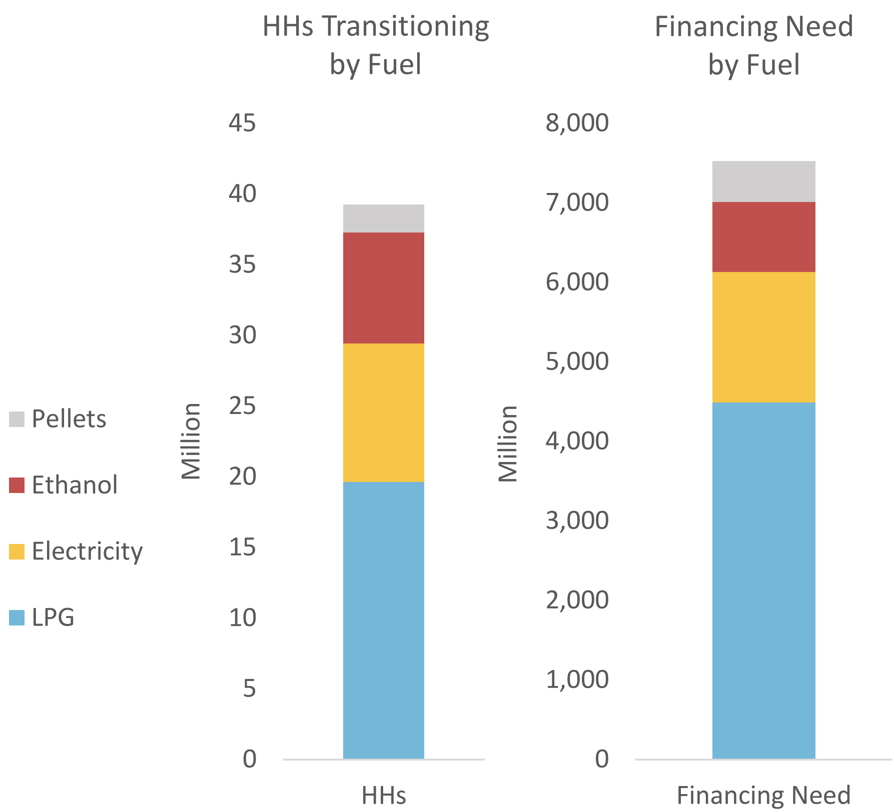
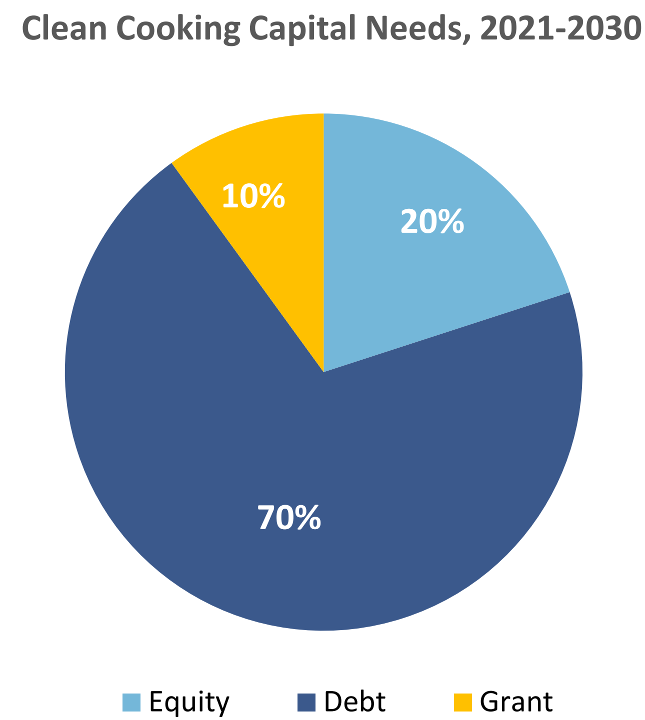
[1] *In a household, the primary fuel is the one which accounts for the majority of cooking needs.*

Displacing majority of charcoal with modern fuels in Africa would cost US$7.5 billion

The majority of charcoal households transition to LPG and electricity (*though stacking continues*)

$7.5 billion investment required to produce and distribute stoves and build downstream infrastructure



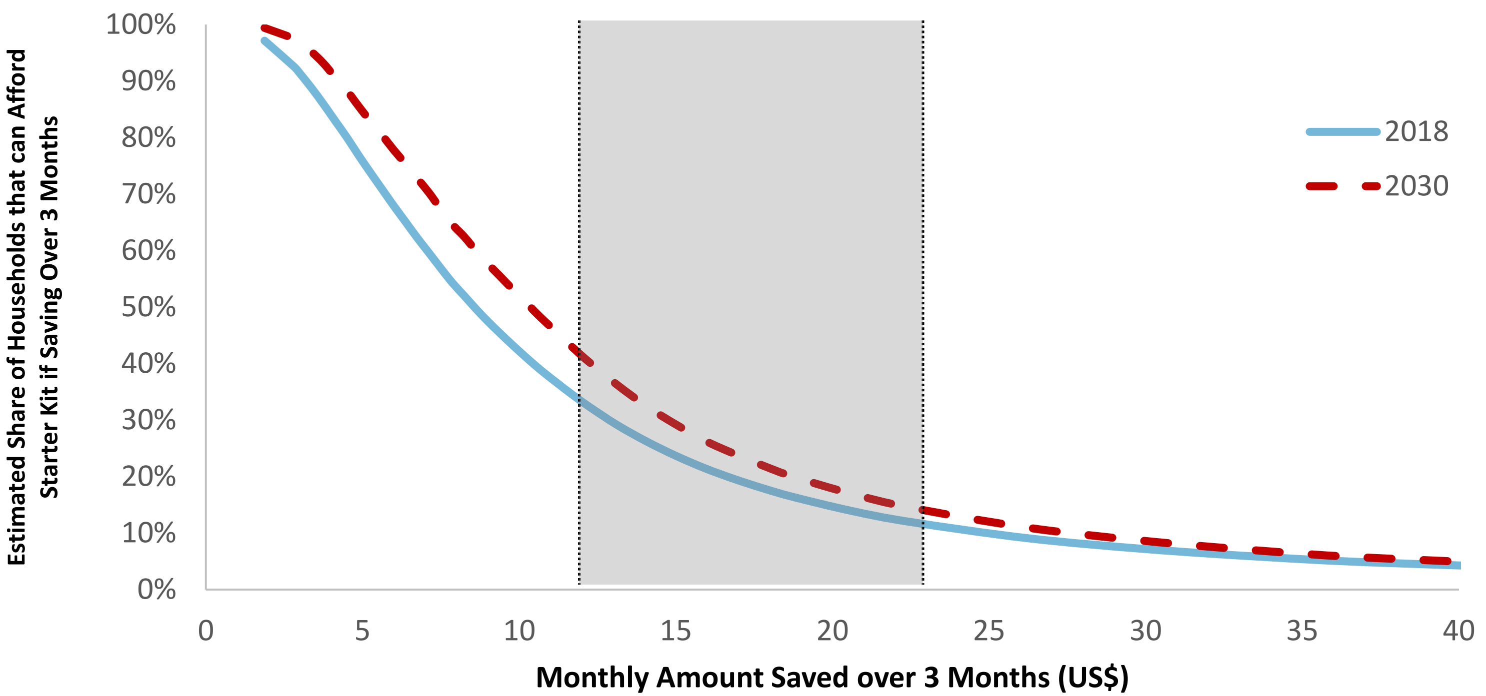


[1] *The model assumes that charcoal households that transition to modern fuels continue to meet 30% of their cooking energy needs with charcoal*
[2] *Investment requirements for modern fuel transitions are based on estimates from the Modern Energy Cooking Services (MECS) programme and include stove and downstream infrastructure investment needs*

The upfront cost of converting to modern fuels is high, ~$70 for typical 'starter kits' (e.g., stove, cylinder, etc.)

- Moving the **39 million** households cooking primarily with charcoal today onto modern fuels will require a **subsidized starter** kit or **PAYGO modalities**.
- We estimate that without widespread PAYGO modalities for the various modern fuels, an upfront subsidy of 50% of the equipment cost, totaling $2 billion over 10 years will be required to move charcoal users onto modern fuels.

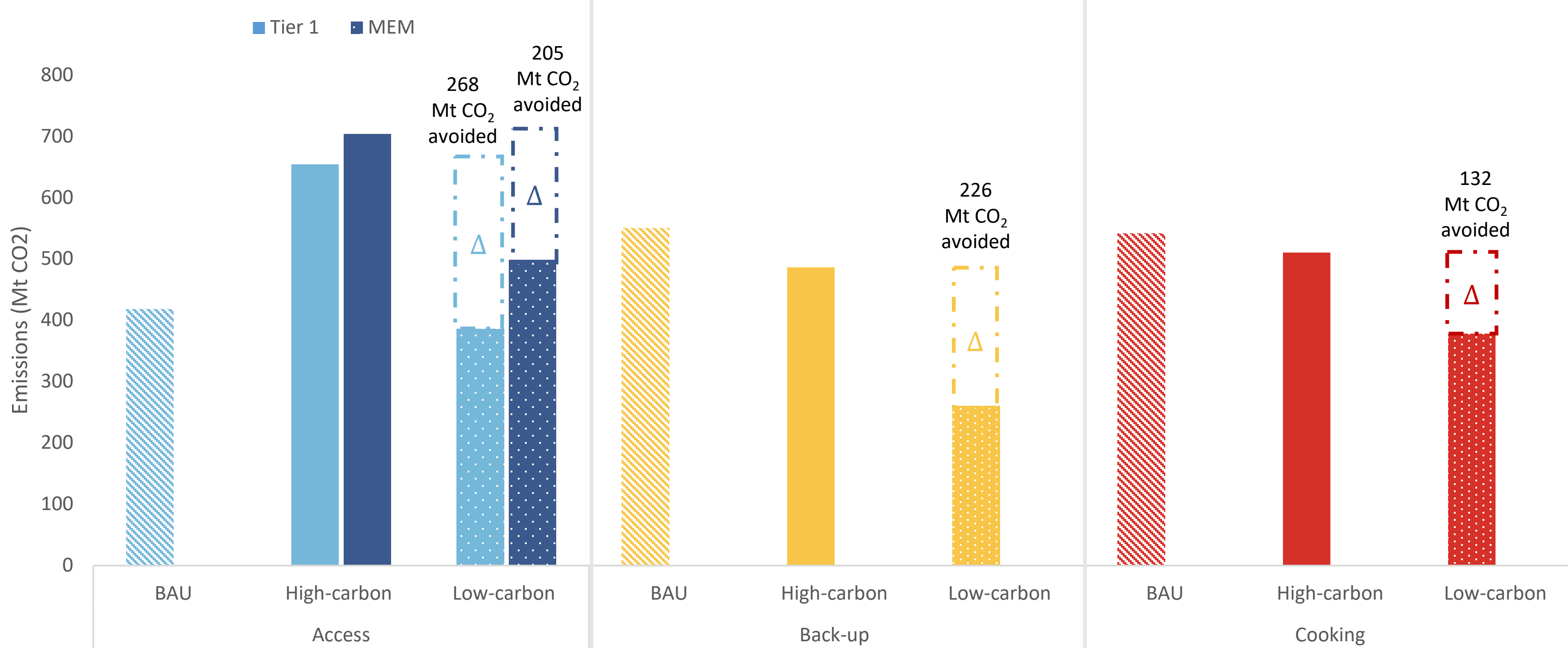
Share of households that can afford starter kit based on monthly savings over 3 months



Africa’s SDG 7 and SDG 13 call to action

These scenarios avoid 563-626 million tons of CO_2, deliver significant SDG 7 impacts, and unlock a substantial climate finance opportunity

Emissions from plausible low-carbon scenarios are benchmarked against equally plausible high-carbon counterfactuals; the difference between the two constitutes the avoided emissions



	Access		Back-up	Cooking
Impact	130 million households get first time access		9.2 million gensets retired	37 million households using clean fuels
Financing opportunity	$20.7B (Tier 1)	$67.1B (MEM)	$134.4B	$7.5B

TOTAL: **$162.6B (Tier 1), $209B (MEM)**

Source: *Catalyst predictive model outputs*

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[1] The Tier 1 scenario sees expansion of all access technologies (grid, mini-grid, and OGS of various sizes) but the majority of low- and lower-middle income households get access via Tier 1 OGS technologies. The Modern Energy Minimum (MEM) scenario targets per capita consumption levels of 130 kW by 2030 and thus more households need mini-grid connections and Tier 2 and 3 OGS systems as a result.

Summing up Africa's low-carbon access scenarios: huge impact, significant avoided CO_2 emissions, large climate opportunity

7 AFFORDABLE AND CLEAN ENERGY

A **low-carbon scenario** contributes massively toward **universal access and improved cooking**

132 million
new connections from **off-grid** technologies delivered

9.2 million
gensets used by enterprises and households **displaced**

39 million
new households would **cook with modern fuels**

13 CLIMATE ACTION

A **low-carbon scenario** benchmarked against a high-carbon scenario **yields**

Up to 626 million
tons of **avoided CO_2e emissions** over the next decade

A **low-carbon scenario** requires substantial volumes of **new capital**

US$162-209 billion
climate finance opportunity

Three calls to action to climate-first investors to help catalyze the SDG7- climate finance nexus

1 Finance existing energy access enterprises

via existing vehicles **(e.g. CrossBoundary Energy Access Facility, Energy Access Ventures, Facility for Energy Inclusion)** to quickly scale impact and get Africa on the low-carbon SDG7 trajectory.

2 Support new, innovative mechanisms

to monetize social & environmental impact of DRE enterprises, such as **Universal Electricity Facility, Decentralized Renewable Energy Credits,** and **Digital Carbon Credits.**

3 Help define the next wave of investment opportunities

that leverage the co-benefits of the SDG7-SDG13 nexus & **roll out new solutions to unlock climate funding for the DRE sector.**

$200+ Billion

Climate Finance Catalysed

Commissioned by

Shell Foundation | The Rockefeller Foundation

Produced by

CATALYST
OFF GRID ADVISORS

Backup genset research produced in association with

Schatz Energy Research Center

Inputs from a Technical Working Group, comprised of representatives from

IKEA Foundation

RMI
ENERGY. TRANSFORMED.

Sustainable Energy for All

Backup genset research was based on previous work commissioned by

IFC | International Finance Corporation
WORLD BANK GROUP

The Report is endorsed by key DRE industry associations

AMDA

Clean Cooking Alliance

GOGLA

Annex: research methodology & additional analysis

Key questions guide the research agenda

Electricity access: Providing first-time electricity access

+

Greening back-up generation: Solving the unreliable grid challenge

+

Modern cooking access: Moving HH to modern cooking solutions

=

SDG 7/13 Nexus: Improving access, reducing emissions

- How to transition households off stopgap solutions and onto modern, affordable, and reliable sources of electricity?
- What are the avoided emissions associated with a low-carbon universal electrification scenario (and in a high demand context)?
- What would it cost to make this a reality?

- How do we get enterprises and households off their dependency on backup fossil-fueled generators (backup genset)?
- What are the emissions from the use of backups, and what would the counterfactual look like?
- How much would it cost to replace backup generators with renewable backup technologies?

- What are the emissions associated with traditional cooking methods?
- What would it look like if a meaningful percentage of users were to graduate to modern cooking solutions?
- What would this cost and what are some of the other key considerations?

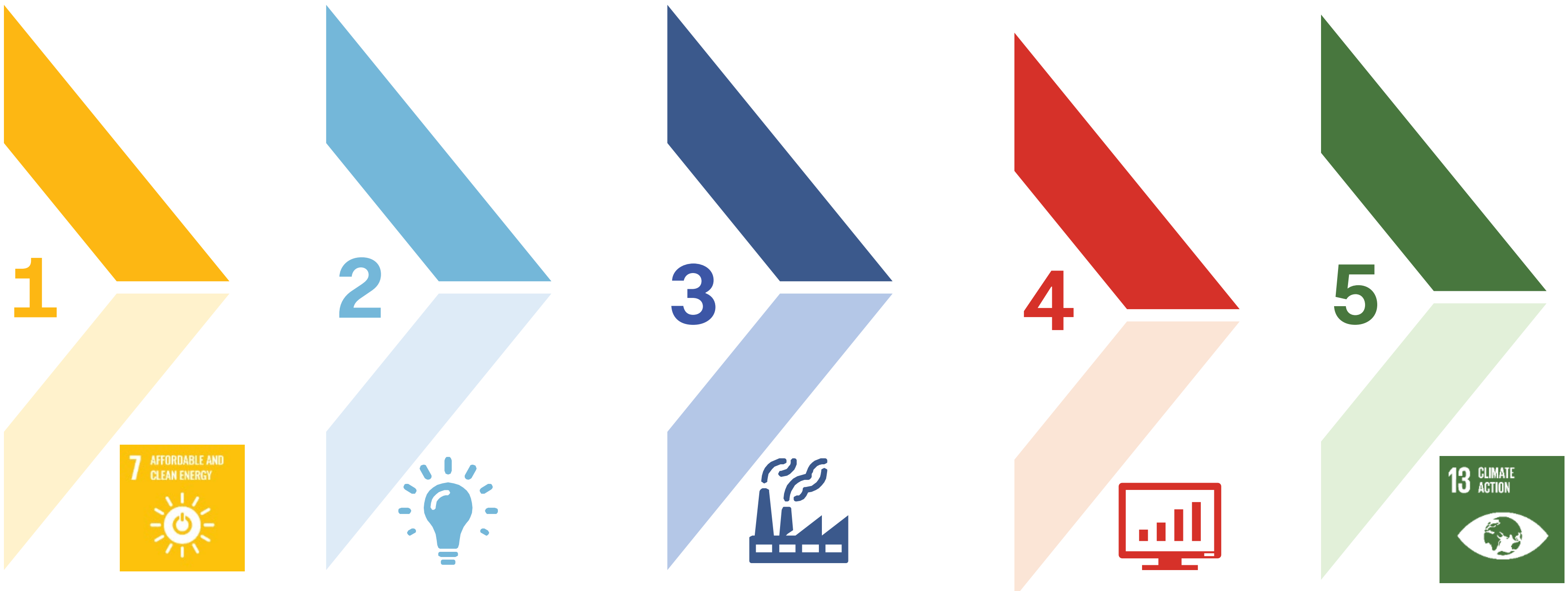
- What is the climate impact (measured in GHG emissions) of different universal electrification (and improved cooking) scenarios?
- What is the climate finance opportunity associated with a low-carbon universal electricity access scenario?

Research scope: focused on portions of SDG 7 and 13

Climate Finance Opportunity		Our Coverage
Global	🟡	Africa, India, Myanmar only
SDG 7: Access to affordable, reliable, sustainable, and modern energy for all	🟢	Off-Grid Solutions for Households
	🟢	Grid Extension for Households
	🟡	Cooking access for Households
	🟡	Electricity Access for Enterprises
SDG 13: Take urgent action to combat climate change and its impacts	🟢	Carbon Scenarios
	🟢	Avoided Emissions
Increase share of renewables	🟡	Households (Backup genset)
	🟡	Enterprises (Backup genset)
Leveraging climate finance for SDG 7/13 nexus	🟢	Universal electrification
	🟡	Improved electricity access
	🟡	Cooking access

🟢 Full alignment 🟡 Partial alignment

We built empirical models, with 5 main components



1. Modeling to derive each technology's **contribution towards achieving SDG 7**, via different scenarios, including 'high demand' universal access

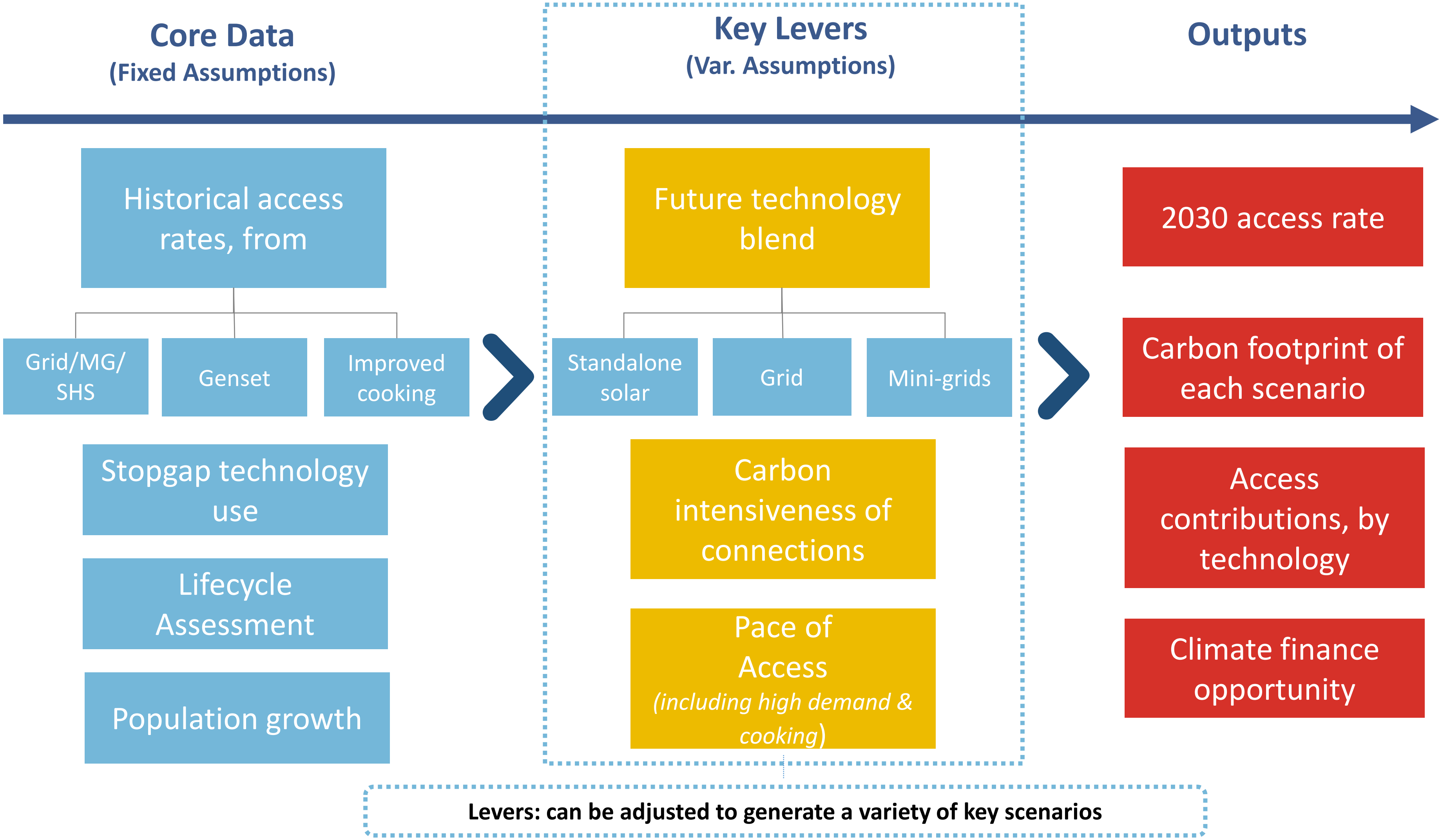
2. Modeling **indirect** GHG emissions of each electricity **generation** & **cooking technology, plus those from stopgap lighting**

3. Modeling **direct** GHG emissions from **household and enterprise electrification, household cooking**

4. Using emissions modeling results from **step 2+3** to derive **total emissions** from step 1 scenarios

5. Modeling the **Climate Finance Opportunity** in Africa, India, Myanmar

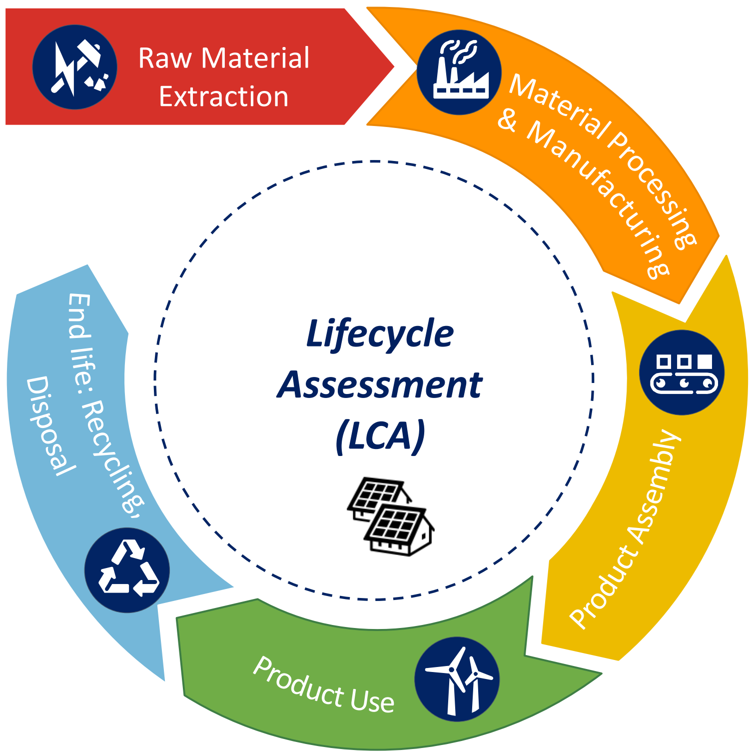
We modeled various SDG 7 scenarios and the associated carbon footprint



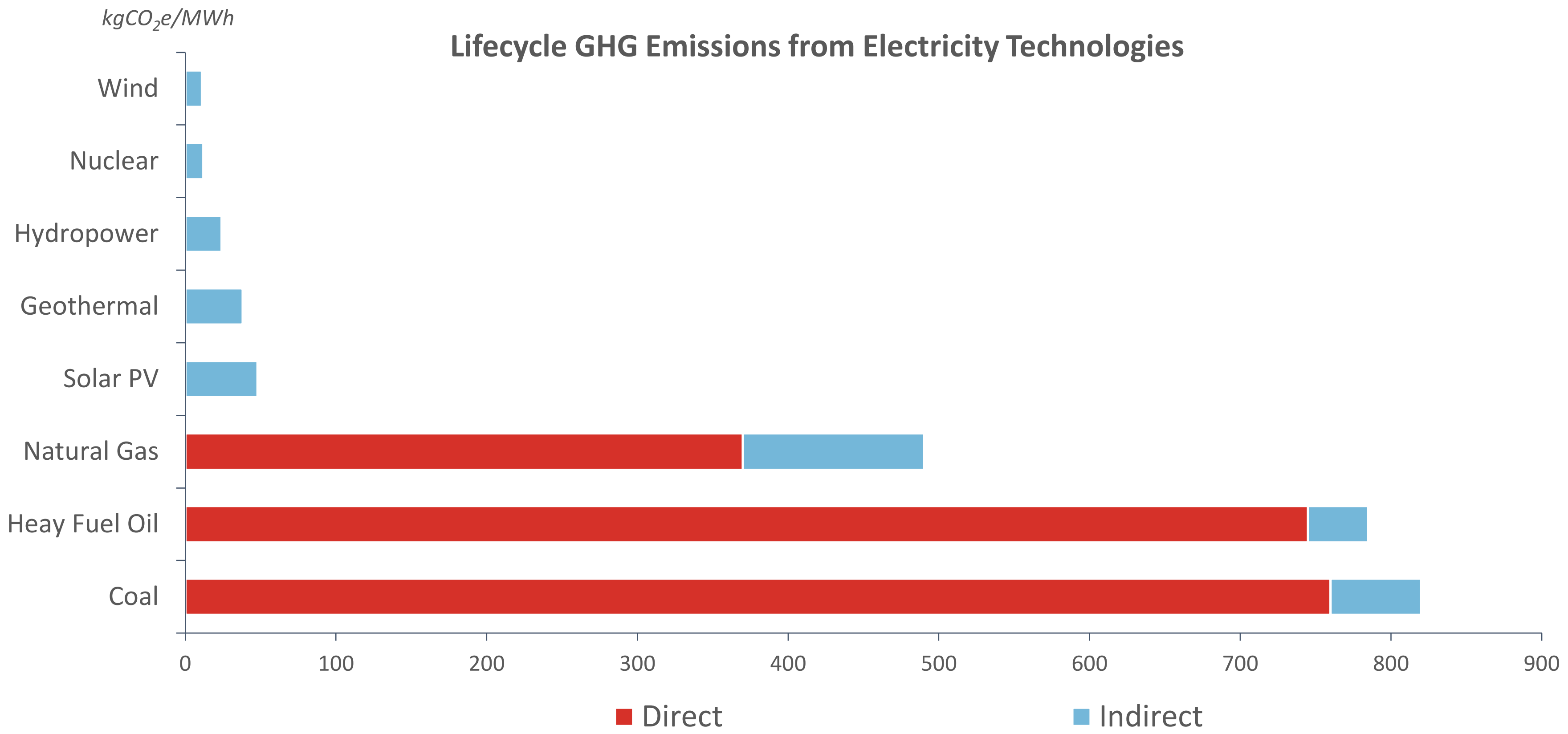
We undertook lifecycle assessment to understand the GHG footprint of each generation technology

Every energy technology has a carbon footprint, even low-carbon technologies

- 'Cradle to grave' approach in **lifecycle assessment (LCA)**
  - Assesses environmental impact from extraction (cradle) to end use (grave) of **energy technologies**:
    - Grid-tied generation (e.g., solar, gas)
    - Mini-grids
    - Standalone home systems
    - Stopgap solutions
    - Standalone genset
- LCA of energy technologies to capture **GHG emissions**
  - LCA captures CO_2 associated with the production of all energy technologies
  - No carbon footprint from operation of solar technologies (unlike fossil fuels)



Lifecycle GHG emissions of utility-scale power generation technologies

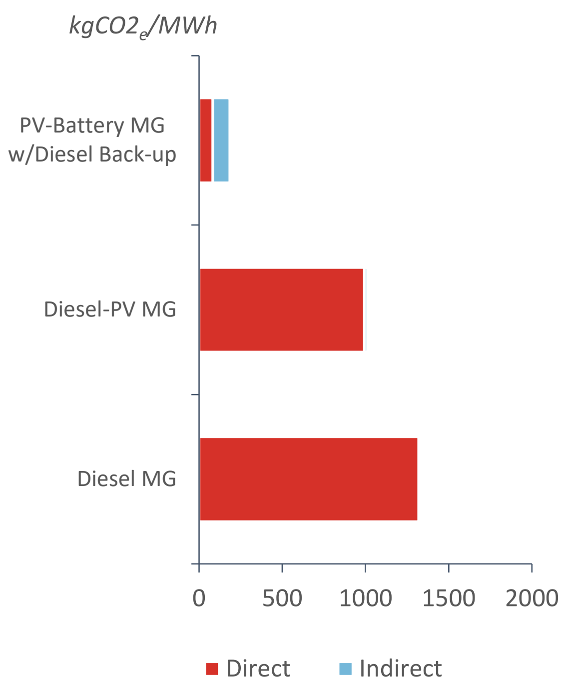


- **Indirect** GHG emissions: generated from extracting, processing and manufacturing activities associated with manufacturing, transporting, and assembling generation technologies
- **Direct** GHG emissions: generated from operation of generation technologies, post-installation

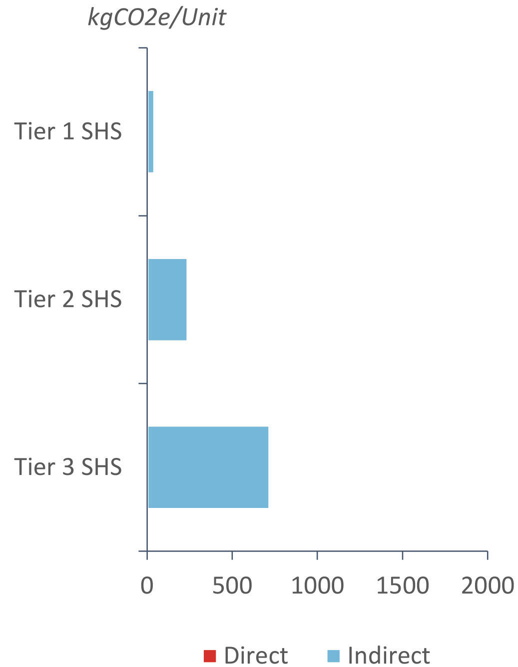
Source: Climate Change 2014: Mitigation of Climate Change - Fifth Assessment Report of the Intergovernmental Panel on Climate Change

Standalone, mini-grids, and genset: varied units of measure, and significantly different GHG footprints

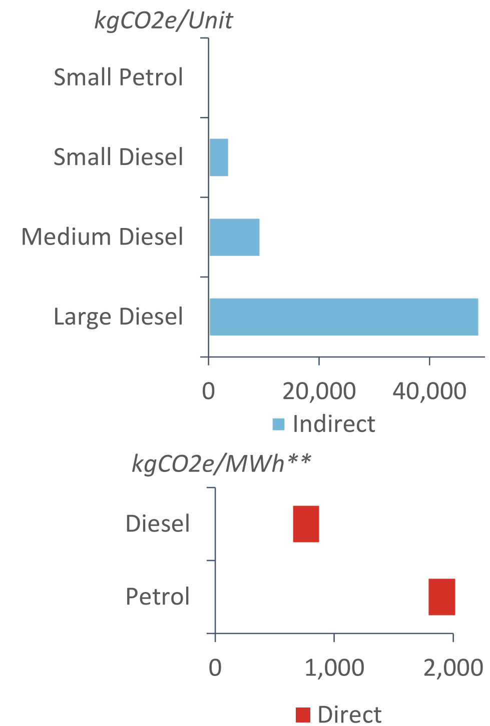
Mini-Grid Systems



Standalone Solar



Genset



- Off-grid and mini-grid technologies offer **lower-emissions access scenario**, but *only if* fossil fuel-based generation sources are minimized
- While the level of service provided by **Tier 1** standalone solar solutions is limited to lighting and basic charging, HH can graduate to larger **Tier 2**, **3** systems as needs and purchasing power increase

Shell Foundation | The ROCKEFELLER FOUNDATION | CATALYST OFF GRID ADVISORS

*Source: Authors' research based on existing LCA methodologies for various technologies. *Emissions assume 1,000 kWh of electricity generated. **Direct emissions ranges by generator fuel type.*

Emissions from stopgap lighting solutions vary drastically as well…

Modern, reliable electricity technologies often displace massive amounts of CO_2e emissions

1,000 kg CO_2e

emitted per year on kerosene lanterns, and particularly open wick models

15 kg CO_2e

emitted per year on battery-powered torches, mobile-phone torches, or small solar lanterns

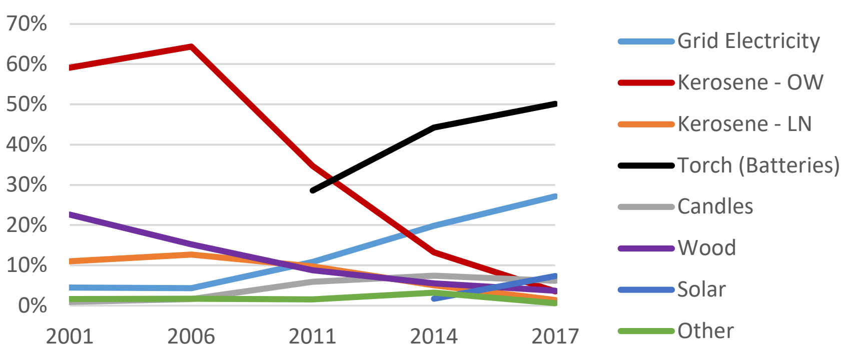
Kerosene (hurricane lantern)	**Kerosene** (open wick)	**Candles**
Mobile Phone Torch	**Flashlight** (dry cell-powered)	**Wood**

...though our research shows a promising shift away from high polluting stopgap technologies (1/2)

Rwanda

- HHs using kerosene as primary lighting source dropped from 70% to 5% between 2001 and 2017
  - In 2017, kerosene accounted for <10% of stopgap lighting used in the country
  - Torches powered by dry-cell batteries now primary lighting source for 70% of unelectrified HHs

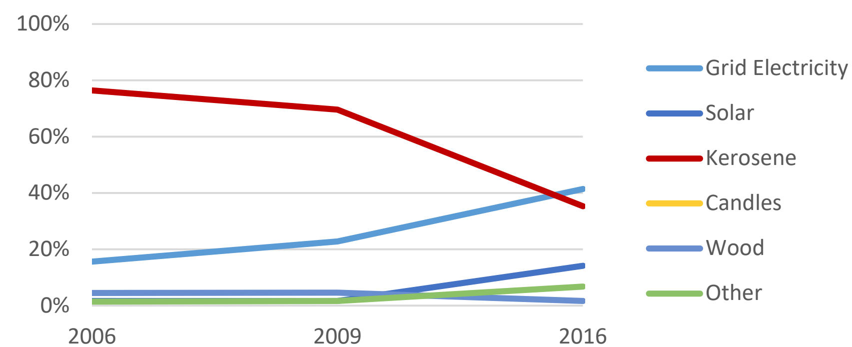
Rwanda - Primary HH Lighting Source



Kenya

- Kenya is a major outlier, with sticky kerosene users who switch mostly to the grid or solar
  - In 2017, kerosene still accounted for nearly half of stopgap lighting used in the country
  - Torches were the primary lighting source for just 5% of households in 2016

Kenya - Primary HH Lighting Source



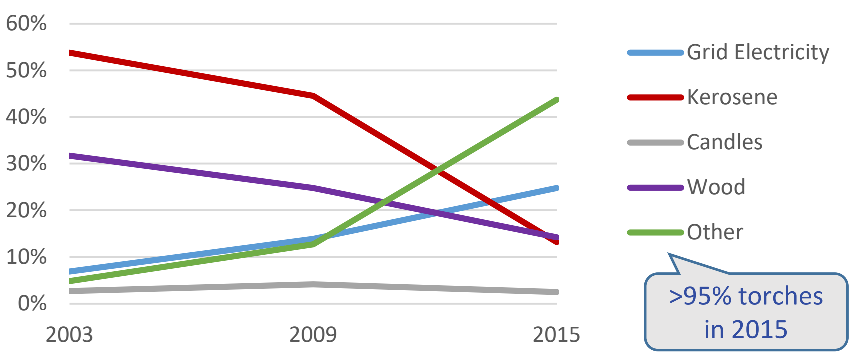
Source: Authors' analysis: multiple household survey data across a total of 11 African countries, India and Myanmar.

Country-level deep dives show a striking shift in kerosene usage (2/2)

Mozambique

- HHs using kerosene as primary lighting source dropped from 54% to 13% between 2003 and 2015
  - In 2015, kerosene accounted for <20% of stopgap lighting used in the country
  - Torches powered by dry-cell batteries are primary lighting source for >40% of unelectrified HHs

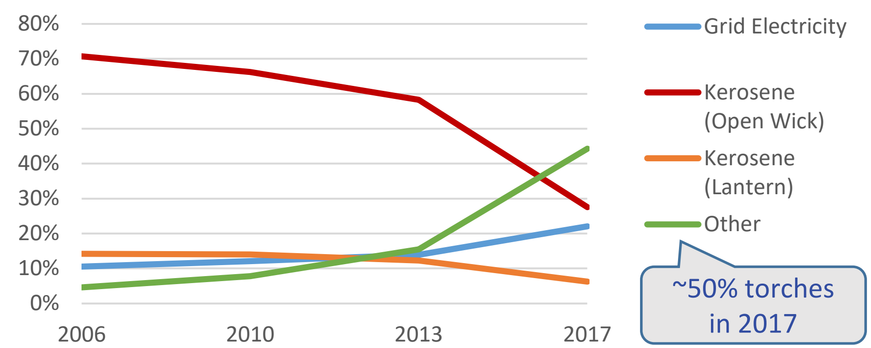
Mozambique - Primary HH Lighting Source



Uganda

- HHs using kerosene as primary lighting source dropped from 85% to 34% over the last decade
  - Torches powered by dry-cell batteries now primary lighting source for >21% of unelectrified HHs
  - In 2017, kerosene did still account for approx. half of stopgap lighting used in the country

Uganda - Primary HH Lighting Source



Source: Relatório Final Do Inquérito Ao Orçamento Familiar (2003-2015); Uganda National Households (2006-2017)