Nigeria Energy Transition Plan

Original context

While African countries account for ~10% of global emissions, stabilizing the climate and avoiding the worst physical risks is impossible without African countries also transitioning to net-zero emissions

However, Nigeria, like other African countries, faces a range of other imperatives, including:

- Lifting 100 million people out of poverty and driving economic growth
- Bringing modern energy services to the full population
- Managing the long term job loss in the oil sector that will result from reduced global demand as the global economy transitions to net-zero

We went through a process to identify the potential pathways for Nigeria to achieve Net Zero within the energy sector, and identify the appropriate time frame for delivering this goal

Objectives

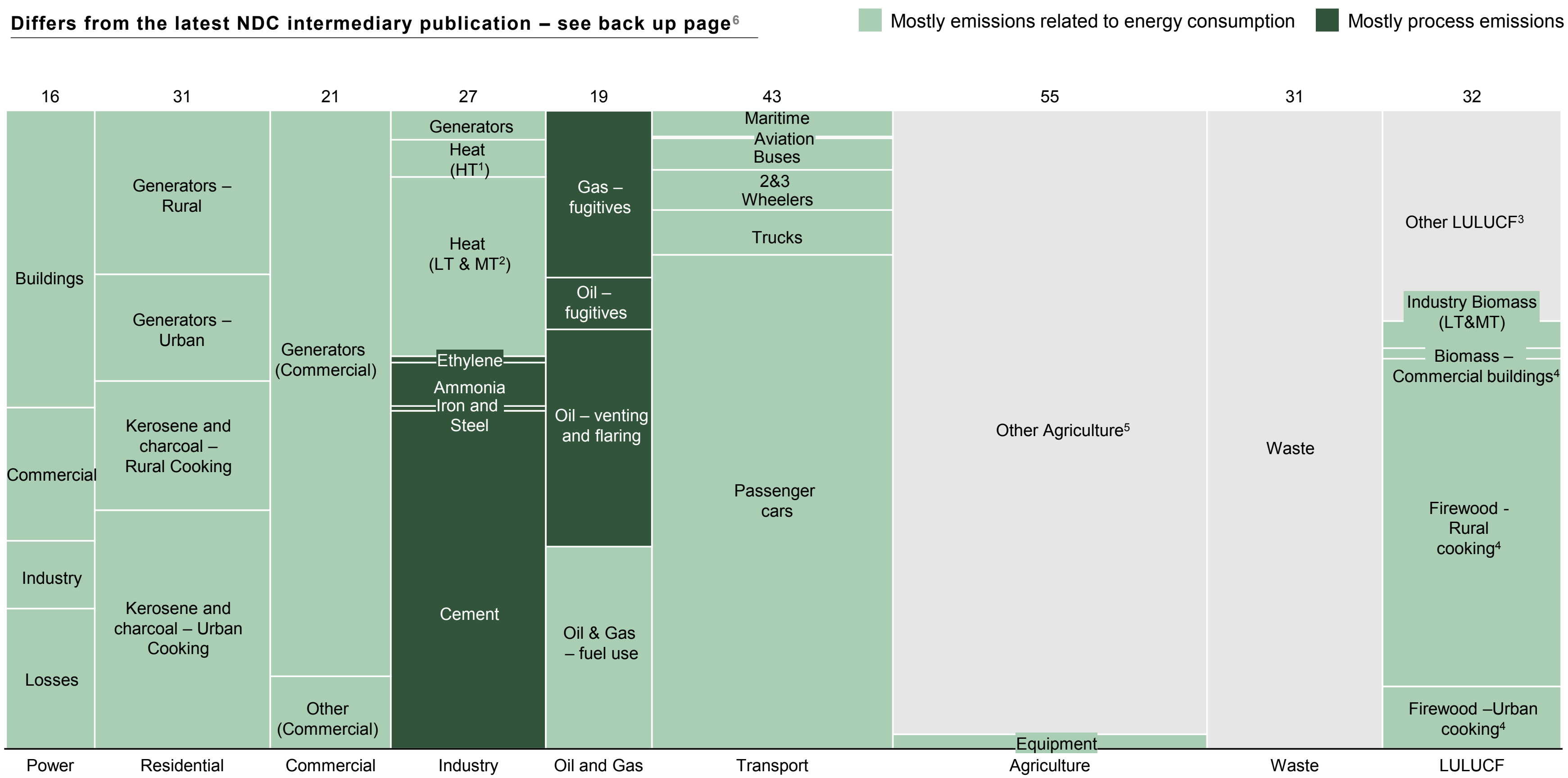
Develop a fact base on Nigeria's energy transition pathway and enable a decision on way forward:

- What is required for Nigeria to achieve Net Zero (by 2050)?
- What would be a realistic timeline that balances emission reductions with economic development imperatives?

Total GHG emissions of Nigeria in 2020 are estimated at ~275 Mt CO_2e, with 65% related to energy consumption and industrial processes

GHG emissions in Nigeria (2020), MtCO_2e

Differs from the latest NDC intermediary publication – see back up page[6]



275 Mt CO_2e

Total GHG emissions

179 Mt CO_2e

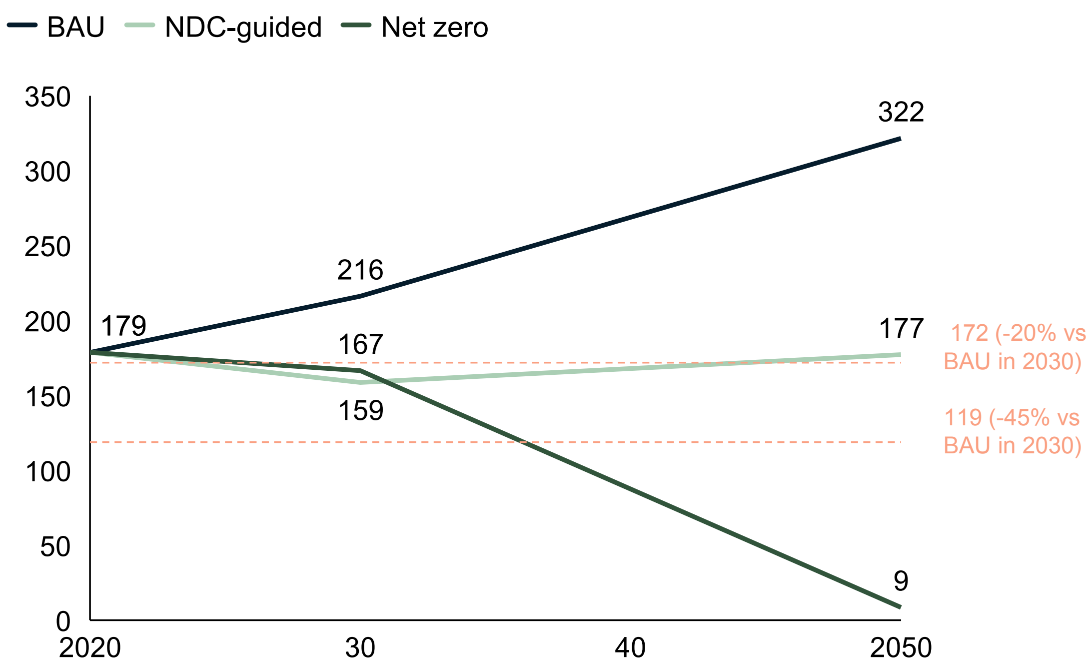
Total GHG emissions related to energy consumptions and selected industrial processes (O&G, cement – scope of this work)

1. High Temperature Heat; 2. Low-Medium Temperature Heat; 3. Land use, land use change and forestry; 4. Will be modelled as part of their end-use sector; 5. Emissions from livestock and soils 6. Slight discrepancy with NDC Intermediary 2020 due to lower emissions considered for O&G

Nigeria recently announced the NDC guided plan which represents a good start for the medium term to 2030, but it will not result in a net zero pathway by 2050

ONLY ENERGY AND INDUSTRIAL PROCESSES INCLUDED

GHG emissions trajectory, $MtCO_2e$



1. Out-of-scope emissions reduction have not been modelled (e.g., agriculture, waste and other LULUCF) and account for 137Mt CO_2e of residual in 2050, based on a standard GDP growth applied to the 2020 amounts
2. Nationally Determined Contribution

BAU (Business As Usual)
Projects emissions based on current pathway for macroeconomic development and without decarbonisation effort

Energy transition scenarios

NDC[2]-guided
Incorporates current national programs with decarbonisation effects:

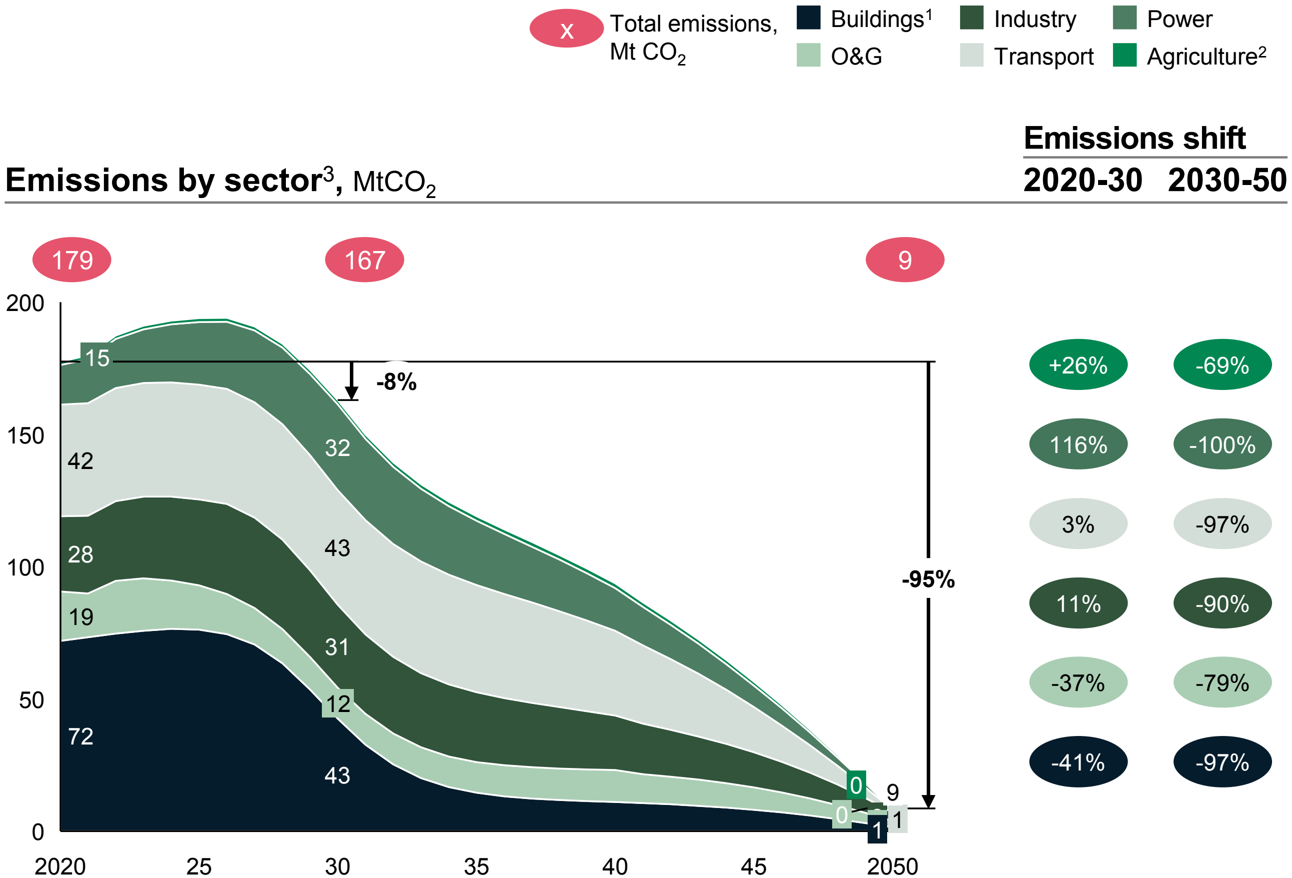
- Strong gas up take – 80% of vehicles to be CNG by 2050
- >50% of population using LPG for cooking

Net Zero 2050
Explores what it would take to get to Net Zero by 2050 to be aligned on 1.5°C pathway; main focus is a transition to full electrification of economy by 2050:

- ~250 GW of installed capacity; >90% renewable
- Electric vehicles making up 80% of fleet
- Clean cooking for >80% of the population

We developed a Net Zero pathway aligned with the rest of the world (i.e. Net Zero 2050)

Emissions by sector[3], $MtCO_2$



Emissions shift

2020-30	2030-50
+26%	-69%
116%	-100%
3%	-97%
11%	-90%
-37%	-79%
-41%	-97%

Key drivers of emissions

For each sector, Net Zero focuses on the technology that will maximise emission reduction

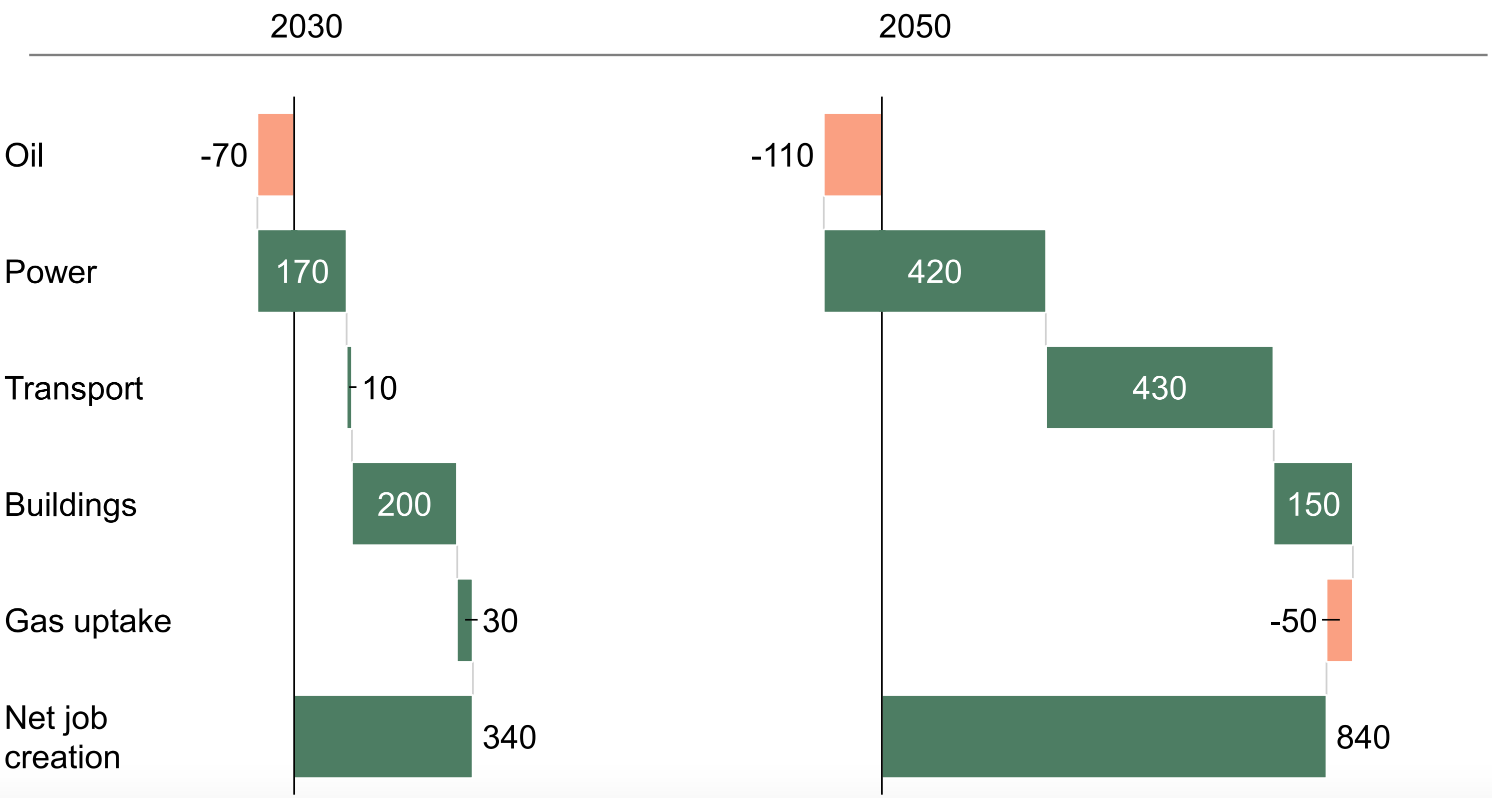
- **Buildings: emissions decrease by ~98%** by 2050, is primarily driven by shift to bio-gas based and electric cooking
- **Oil & Gas: emissions decrease by ~87%** by 2050 primarily driven by global response to climate change[4]
- **Industry**: **emissions decrease by ~97%** despite **~100% growth in industrial sector** due to decarbonisation efforts in cement and ammonia production and 100% shift to zero emission fuels for heating
- **Transport: emissions decrease by ~97%** due to uptake of EVs in passenger car segment
- **Power: emissions increase of ~116% by 2030** as gas use increases due to higher electricity demand. Post-2030 solar increases and starts to replace gas leading to 100% emission reduction by 2050

1. Includes LULUCF emissions from firewood removal
2. Energy emissions only
3. Non-energy agriculture, waste and other LULUCF emissions are outside scope and not shown here
4. Model for Net Zero scenario uses Nigerian oil production trajectory under a global 1.5ºC scenario

Source: McKinsey Decarbonisation Scenario Explorer

Job creation in the Net Zero scenario is higher than job losses both in the 2030 and 2050 time frames

Net job creation per sector, incremental thousand FTE jobs compared to 2020



Key messages

Job creation mainly driven by power and buildings sectors due to deployment of decentralized solar and clean cook stove distribution

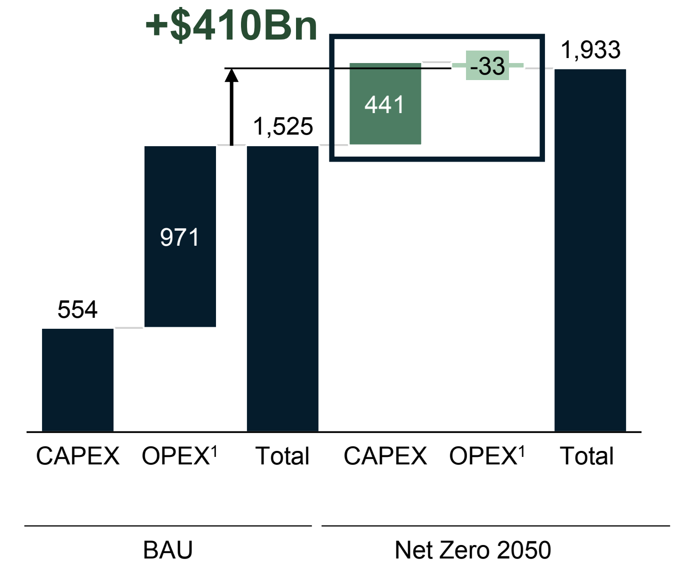
Transport creating significant amount of jobs only after 2030, due to late uptake of EVs and low infrastructure needs for CNG/LPG fueling stations

Clean cooking stoves distribution having higher short-term than long-term impact due to early transition from traditional to clean cooking stoves

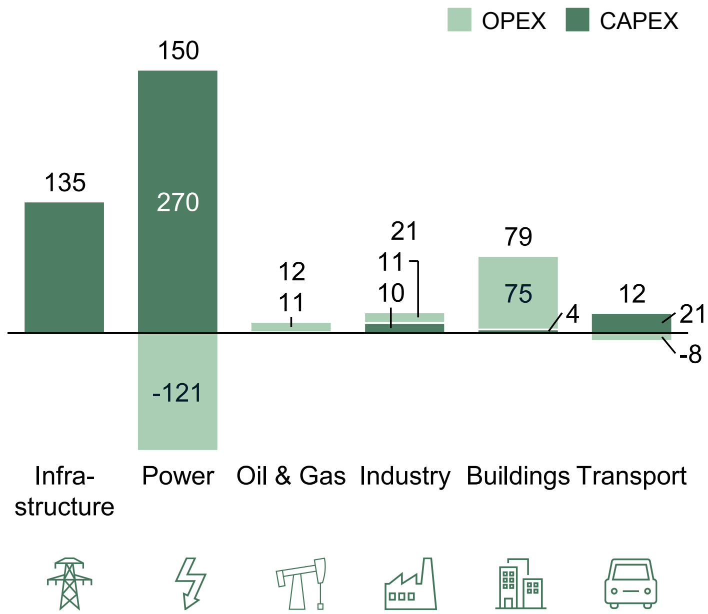
Gas uptake with significant employment potential for oil workers in the 2030 time frame

Financing: Enabling a Net Zero 2050 pathway requires ~$410 billion across the Nigerian economy in excess of BAU spending

Incremental cost from BAU to Net Zero 2050, Bn USD



Incremental investments from 2021-50 to reach Net Zero 2050, Bn USD



1. OPEX includes all fuel and other operational costs
2. Including Power and Gas transmission and distribution as well as refueling infrastructure

Key insights

To get to Net Zero by 2050, **~$410Bn** is required **on top of BAU** spending **over 30 years (~14Bn/yr)**

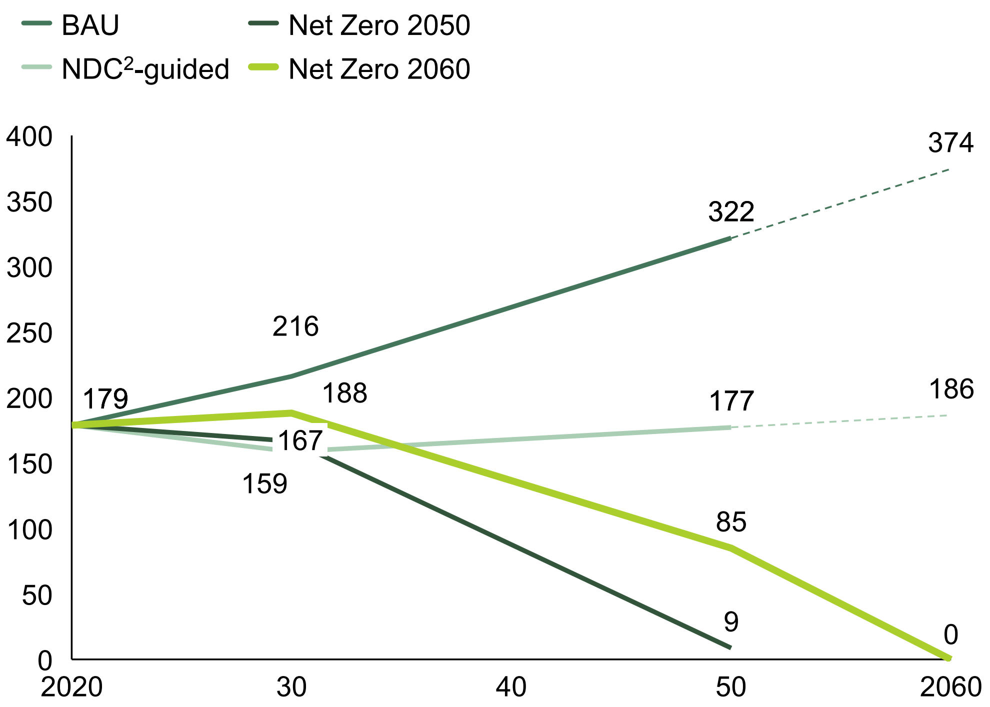
It is estimated that **~$5 – 6Bn p.a. of public funding would be required** to achieve Net Zero targets, in comparison to Nigeria's 2020 federal budget of ~$35Bn

This figure covers counter acting dynamics :

- **Most of the effort will be needed in the power sector**: extra CAPEX is needed to finance the power sector **generation capacity ($270Bn), and the T&D infrastructure ($135Bn)**
- **Significant savings in terms of fuel costs for power** considering the switch to 90% renewables **(-$121 Bn)** compensating for some of the CAPEX increases

A more realistic pathway for Nigeria to deep decarbonization could land on Net Zero by 2060

Energy-related GHG emissions trajectory, $MtCO_2e$



Main changes in alternative Net Zero scenario

Buildings

- Slower replacement of firewood stoves by less emitting technologies[3]
- Delayed take-off of electric and biogas stoves (+10 years)

Transport

- Lower penetration rate of EV passenger cars in 2050 (60% vs 80% in Net Zero scenario)

Industry

- Delayed installation of H2 furnaces (+10 years) and of zero-emissions low/mid temp heat (+5 years)

1. Out-of-scope emissions reduction have not been modelled (e.g., agriculture, waste and other LULUCF) and account for 278 Mt CO_2e of residual in 2070
2. Nationally Determined Contribution
3. Incl. LPG, efficient firewood, electric and biogas cook stoves

There are a number of important implications of Nigeria's Net Zero 2060 pathway

	Key implications
Costs	• **~$410bn** in incremental funding required to fund the transition between 2021 – 2060, translating to an average of **$10bn p.a.** over the time period • Public sector funding requirement estimated to be **$5 – 6bn p.a.**
Gas	• Gas commercialization by 2030 to expand by **+30%** vs. 2019, driven by LPG penetration for clean cooking and gas to power • By 2060, gas commercialization to fall by **~50%,** driven largely by decreasing global fossil fuel demand, increasing contribution of renewable power, and shift to carbon neutral cooking
Jobs	• Net Zero 2060 expected to create **840K** net jobs by 2060 • Job creation mainly driven by **power and buildings sectors** due to deployment of decentralized solar and clean cook stove distribution • **Transport creating significant amount of jobs only after 2030** due to late uptake of EVs and low infrastructure needs for CNG/LPG fueling stations

Several workstreams will be required to take near term actions in order to make Net Zero 2060 a reality (1/3)

	Workstream Overview	Workstream Actions
Power	Build out the more than **40GW of on-grid centralized power** (40% renewable) and associated infrastructure and the more than **6GW of decentralized renewable energy** that will be needed by **2030**	• **Accelerate de-bottlenecking of existing grid.** Determine how to fast track unlocking the full 13.5GW of existing generation capacity through existing initiatives (e.g. Presidential Power Initiative, World Bank Distribution Sector Recovery Plan, etc.) as well as new initiatives • **Scale-up new centralized generation and T&D.** Determine what new capacity will be required and develop roadmap for buildout. Package projects so that they can be developed into large scale auctions or be presented to potential investors • **Drive expansion of decentralized generation.** Determine levers to scale-up of mini-grids and solar home systems across the country, in coordination with existing initiatives (e.g. World Bank NEP, REA Solar Naija, etc.)
Buildings	Accelerate **Nigeria Gas Expansion Program Track 2** (LPG penetration), to allow gas utilization through medium term; prior to transitioning to carbon neutral cooking	• **Map distribution of LPG demand** using recently developed geospatial analyses (Nigerian Integrated Energy Plan) and determine the required new infrastructure to fulfil the demand (micro-distribution centres, retail skids, bottling plants) • **Support private sector investment in development of LPG infrastructure.** Engage with private sector investors to understand unlocks to investment • **Drive awareness of benefits of clean cooking**. Organize campaigns to drive adoption of clean cooking through targeted outreach and educational efforts. • **Improve affordability of LPG cookstoves.** While the benefits of LPG cooking are significant, there is still an affordability gap. Effort will need to be made to address the fuel cost, or offset cost of new cook stove apparatus

Several workstreams will be required to take near term actions in order to make Net Zero 2060 a reality (2/3)

	Workstream Overview	Workstream Actions
Transport	Given that the timeline for EV adoption is expected to be longer in Nigeria (i.e. EV passenger vehicles still 10 – 20 years away) **focus should be on laying the groundwork for the initial phases of the transition from ICE to EV,** specifically two-wheeled electric vehicles (E2W), three-wheeled electric vehicles (E3W) and public buses	• **Develop roadmap for electrification** of 2-wheeled vehicles (E2W), 3-wheeled vehicles (E3W) and public buses • **Map required charging infrastructure for E2W, E3W and Buses**. Define at a regional level where charging infrastructure would be needed • **Enhance policy.** Develop required policies to enable the scale-up of E2W, E3W
Oil and Gas	**There is a clear role for natural gas in Nigeria's Energy Transition Plan** to support the electrification of the economy (e.g. to provide required gas power generation required for flexible capacity) and the transition to lower carbon cooking (LPG)	• **Increase gas commercialization to support existing and new gas power projects.** The Ministry of Petroleum's Decade of Gas Committee has put in place a roadmap and governance structure to realize Nigeria's Decade of Gas • **Drive sector decarbonization.** Shape oil and gas sector decarbonization initiatives to address the carbon emissions coming from oil and gas. Map the carbon emission reduction levers and their applicability to the Nigerian context • **Enhance policy and market structures.** A number of policies may be necessary to support sector decarbonization (e.g. gas flare reduction requirements, carbon market development to support capture projects and offset projects, etc.) • **Ensure just transition.** Identify portions of the workforce that would be adversely affected by the transition and develop roadmap of initiatives to minimize the impact • **Develop new low-carbon businesses.** Evaluate feasibility to scale-up new green businesses, e.g. green and blue hydrogen, and identify potential pilot projects

Several workstreams will be required to take near term actions in order to make Net Zero 2060 a reality (3/3)

Workstream Overview | **Workstream Actions**

Industry

Focus on the most carbon intensive sectors of industry in Nigeria, prioritizing **cement and ammonia production** for decarbonization

- **Set out roadmap to decarbonize existing production methods.** Work with the largest cement manufacturers in Nigeria to implement key levers (e.g. substitute clinker with calcinated clay)
- **Enhance policies and build market structures**. Change existing policies or introduce new ones to incentivize industry decarbonization (e.g. carbon pricing). Evaluate and address trade-offs of policy changes, and pathway to implementation
- **Hydrogen.** Shape roadmap to scale-up market for both blue and green hydrogen production. For blue hydrogen, this will require the development of a set of market incentives to make carbon capture economically viable in Nigeria.
- **Bioenergy Carbon Capture and Storage (BECCS).** Define pathway to scale-up biomass collection and processing and build out the required infrastructure

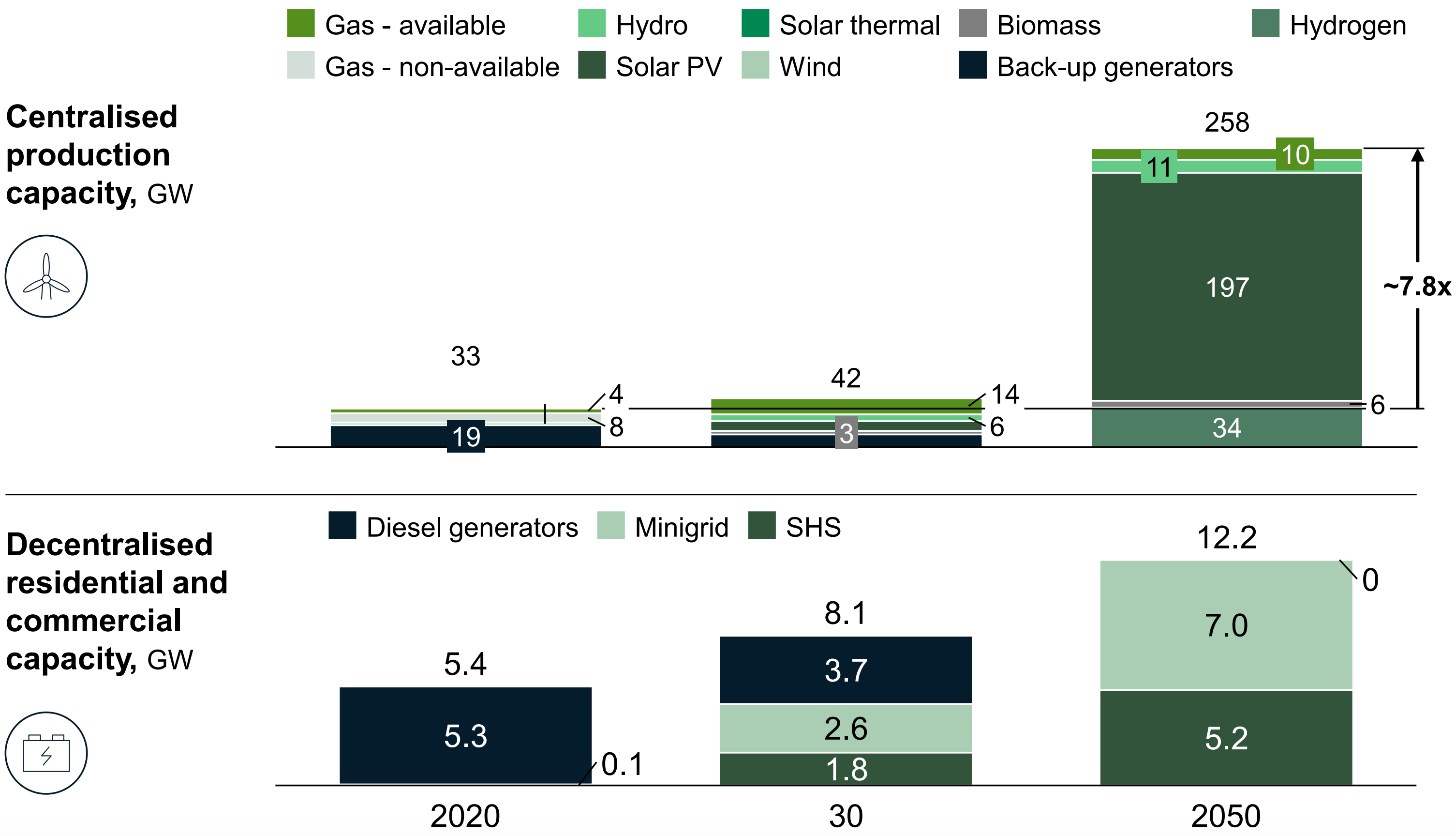
Financing

FGN will need to **finance a portion of the transition,** but will need the **support of key funding partners to fund the balance**

- **Validate full cost requirement.** Refine cost estimates and identify what could be funded by FGN, what could be funded by domestic private sector actors, and what development partner financial assistance would be required
- **Engage with development partners and climate financiers.** Consolidate support required from development partners and present an integrated perspective
- **Investor attraction and marketing.** Work with financial advisors to develop marketing materials, organize investor summits and package infrastructure projects into investable opportunities
- **Determine of sources of public funding.** Interface with the Ministry of Finance to ensure adequate budget provision across years

BACKUP – Sector Deep Dives

Power: Nigeria's energy transition requires a solar-driven generation capacity increase at an unprecedented scale



Key messages

Large increase of **centralised** generation **capacity** in **Net Zero:**
7.8x in 2020-50

Implied buildout of utility-scale solar of ~7GW/year (compared to ~3GW/yr in California 2019, and 0.4GW/yr in South Africa (2016 – 2020)

- **Significant uptake** of **solar PV** (197 GW installed in 2050 vs 8 GW in 2030)
- **Existing gas capacity prioritized** and **stranded** capacity not used in 2050 in **Net Zero** scenario
- Complete **elimination of diesel generators**

Probable need to prioritize sector electrification based on:

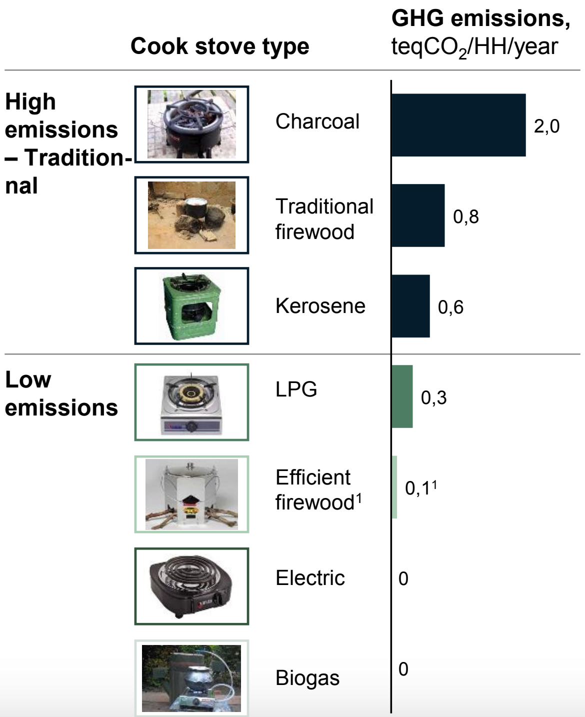
- Universal access to electricity
- Operational feasibility (e.g. difficulties of transport vs cooking electrification)

1. Electrolyzers producing hydrogen - used as a storage option

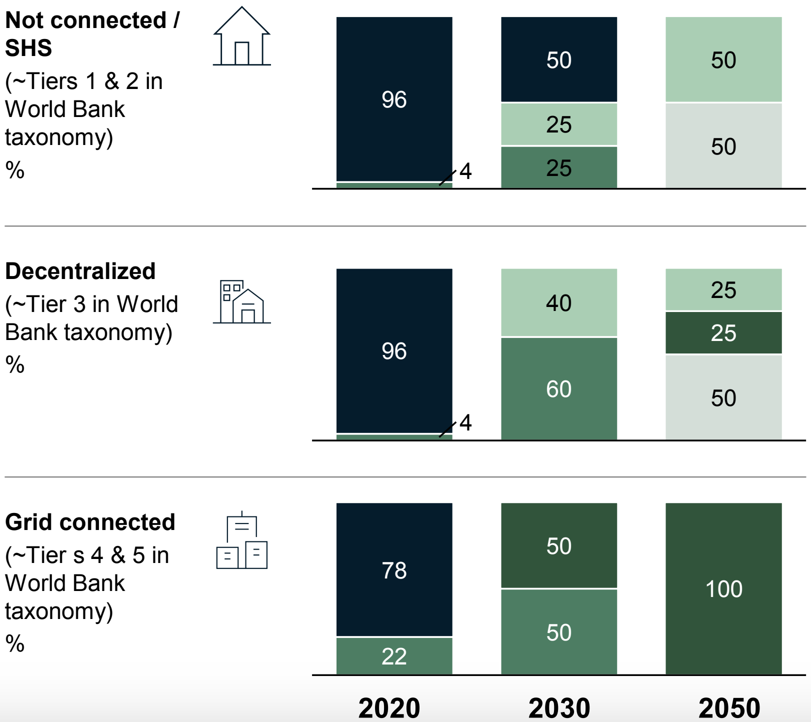
Buildings: Traditional cooking is the biggest source of building emissions: Net Zero will require a differentiated cooking technology mix evolution depending on the type of household

(X%) Share of households · LPG · Biogas/other clean biomass[2] · Electric stove · Efficient firewood · Traditional[2]

Cook stove types and emissivity



Assumption on cooking technology mix evolution per type of household to reach Net Zero by 2050



Nigeria Example

Assumptions

Strong uptake of **LPG stoves** considering its relevance across household categories and Nigeria's natural gas endowment used as **stepping stone in Net Zero scenario by 2050**

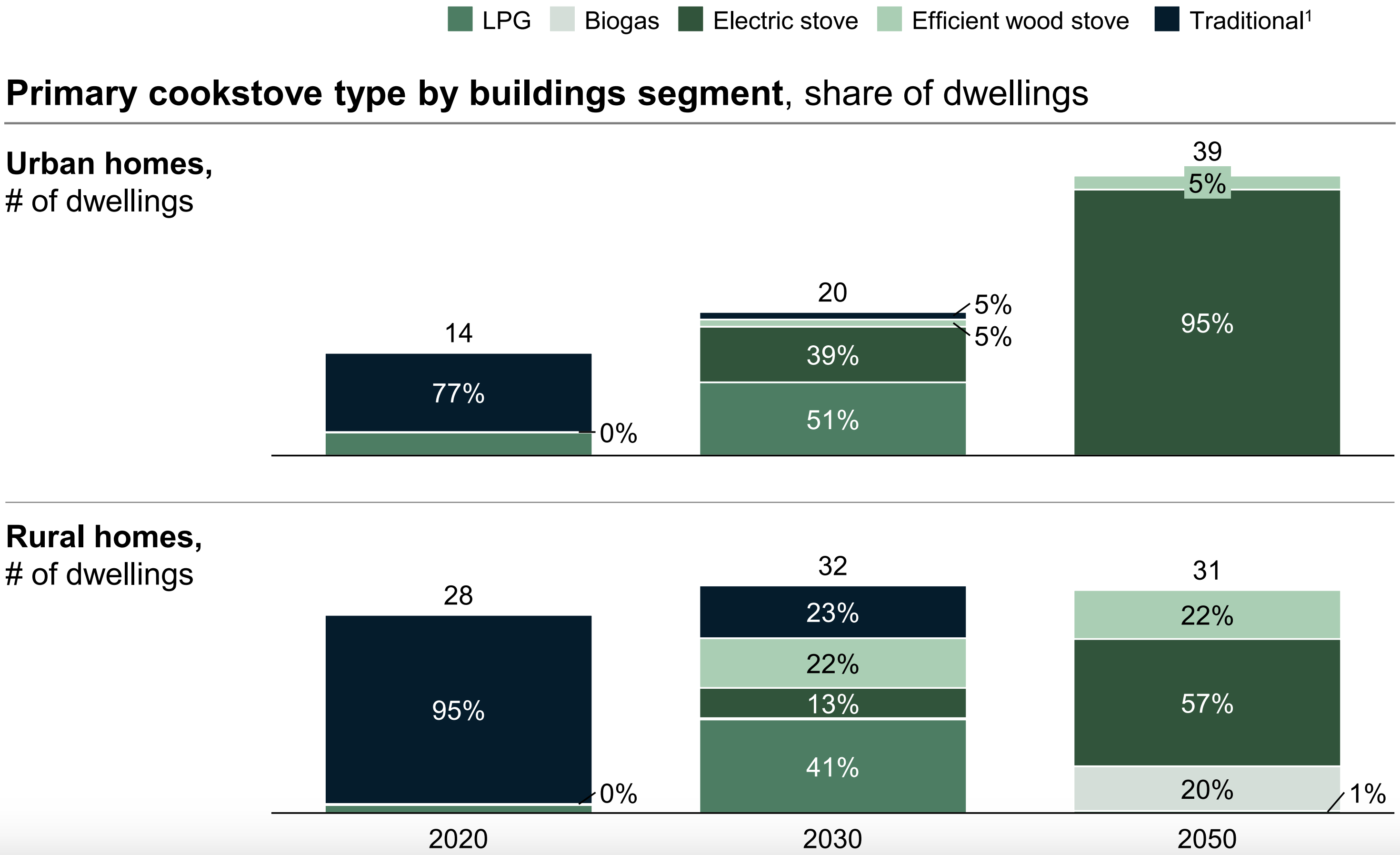
Biogas and **electric** cookstoves prioritized for deployment by 2050 since carbon neutral:

- **Electric** cookstoves used in **grid-connected** households
- **Biogas** available in **rural areas** (mainly **off-grid** as **primary electricity source), in replacement of LPG (LPG cookstoves** easily **converted** to **biogas)**

Efficient firewood stoves to replace **traditional firewood** and **charcoal,** and **LPG** to replace **kerosene**, where electricity and biogas can not reach 100% penetration

1. Considered as low emissions in comparison with traditional firewood stove
2. Includes traditional firewood, charcoal and kerosene

Buildings: 95% of urban and 60% of rural homes using electricity to cook by 2050 in the Net Zero scenario



Key messages

2020 – 2030:

- GHG emissions reduction from **replacement of traditional firewood with LPG and efficient wood stoves**
- Further reduction in **Net Zero** scenario due to **partial electrification,** esp. in **urban areas**

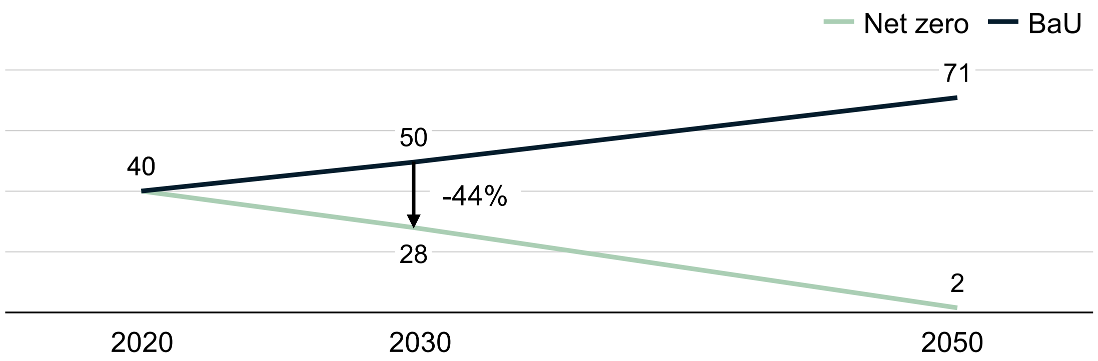
2030 - 2050:

- **Higher** uptake of **electric cookstoves** (95% in urban homes, 57% in rural) and **replacement of LPG by biogas** and **traditional wood stoves by efficient wood stoves**

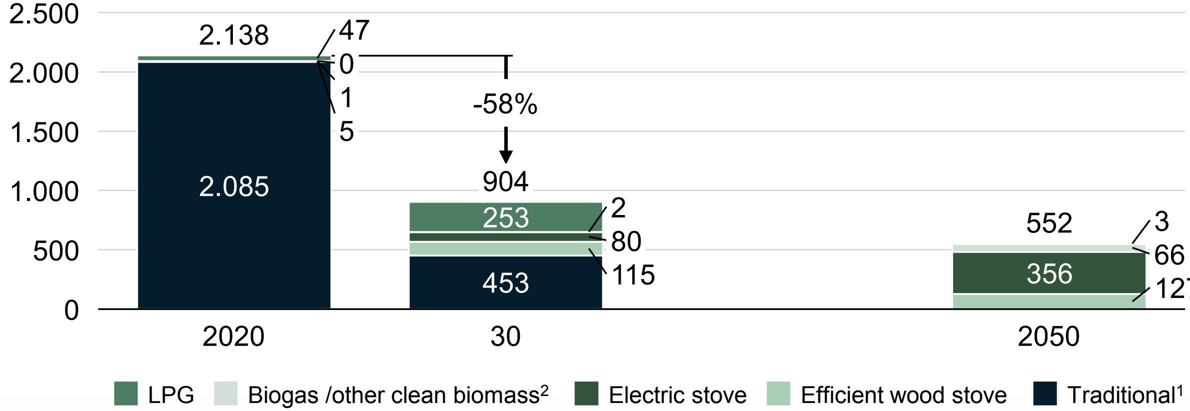
1. Includes traditional firewood, charcoal and kerosene

Buildings: Replacement of traditional firewood results in a reduction of both GHG emissions and cooking energy requirements

GHG emissions for cooking, $MtCO_2e$



Energy consumption for cooking, PJ



Key messages

Strong reduction of GHG emissions in **2030** compared to business-as-usual: **- 44% emissions**

In **Net Zero** reduction is due to **replacement of 100%** of the **traditional firewood stoves by electric cook stoves, biogas** and **more efficient firewood stoves**

Significant **reduction of energy needs despite population increase** as inefficient firewood stoves replaced by more efficient technologies (incl. LPG, electric, biogas, efficient firewood)

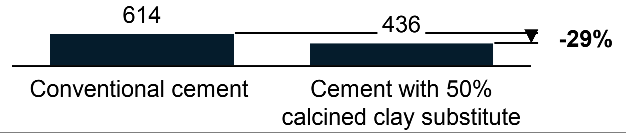
1. Includes traditional firewood, charcoal and kerosene
2. Includes bioethanol

Industry: A switch to low-emissions technology for Industry is essential but some solutions are only viable post-2030

Description | **Emissions (t CO_2e/t)**

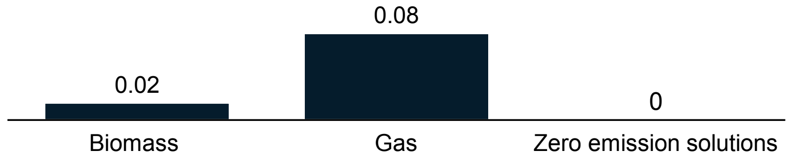
Feedstock substitute in cement

- Substitution of 50% clinker with calcined clay can reduce cement emissions by 30%



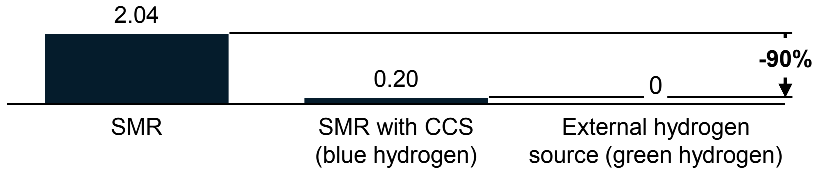
Low-carbon heating alternatives in industry

- Emissions from heating today are driven by high biomass and gas dependency
- Zero emissions solutions include solar boilers, heat pumps, electric boilers for low-/mid- temperature heating and hydrogen furnaces for high-temperature heating



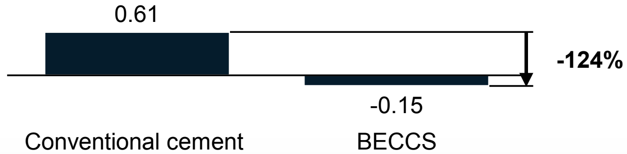
Utilise green/ blue hydrogen in ammonia production

- Existing and new facilities built pre-2030 to use SMR[2] to produce hydrogen with CCS to capture carbon from SMR process (blue hydrogen)
- Facilities constructed post-2030 to use green (or blue) hydrogen as hydrogen market develops



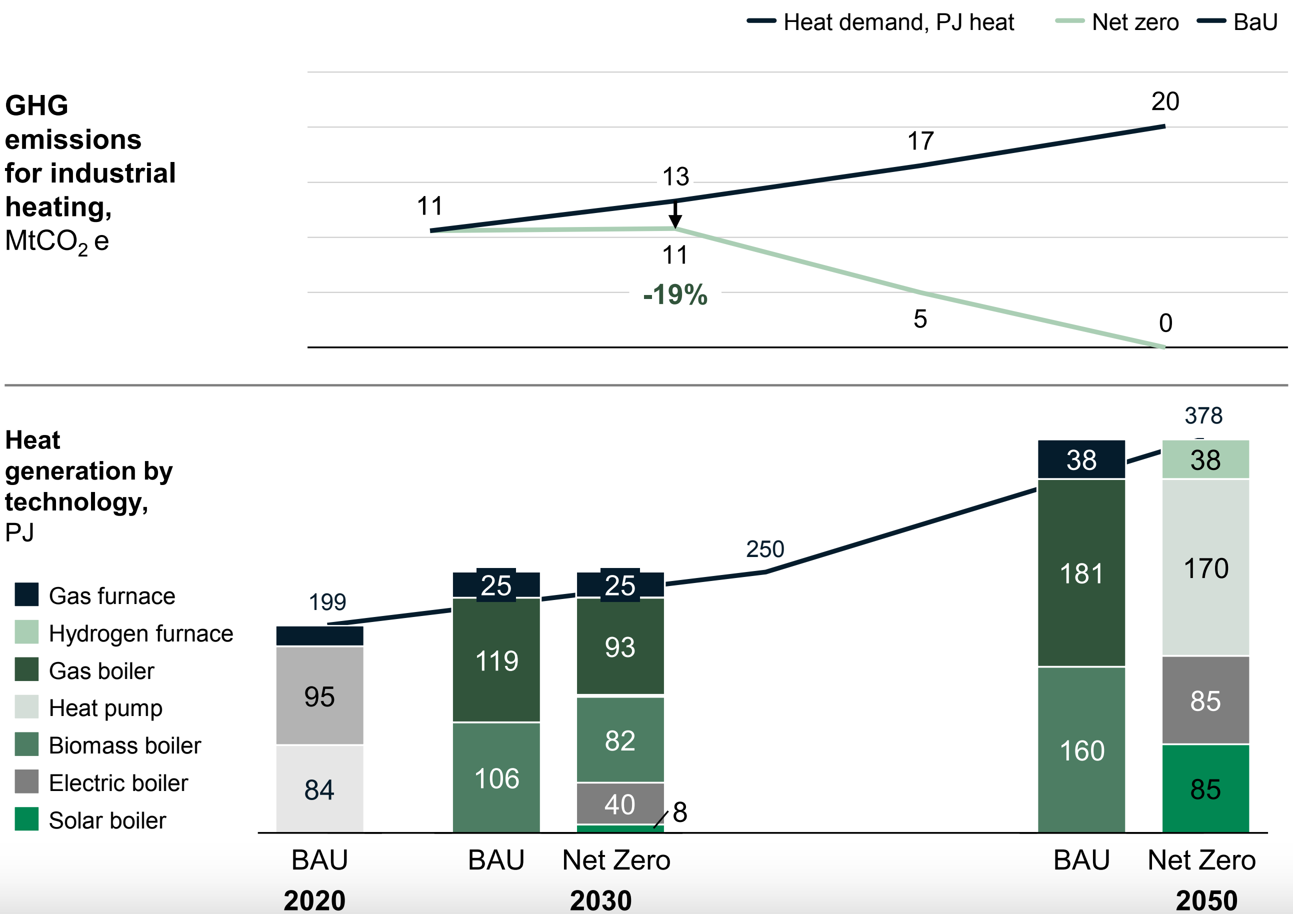
Deploy BECCS[1] in cement production

- BECCS incorporates producing energy from biomass and capturing and storing the carbon from this process to produce negative carbon emissions. Can be used in cement production to achieve net negative emissions



1. BECCS = Bio Energy and Carbon Capture and Storage
2. Steam methane reform – method of producing hydrogen and carbon monoxide by reaction of hydrocarbons with water.

Industry: A complete shift of current heating technology is required to achieve Net Zero by 2050



Key messages

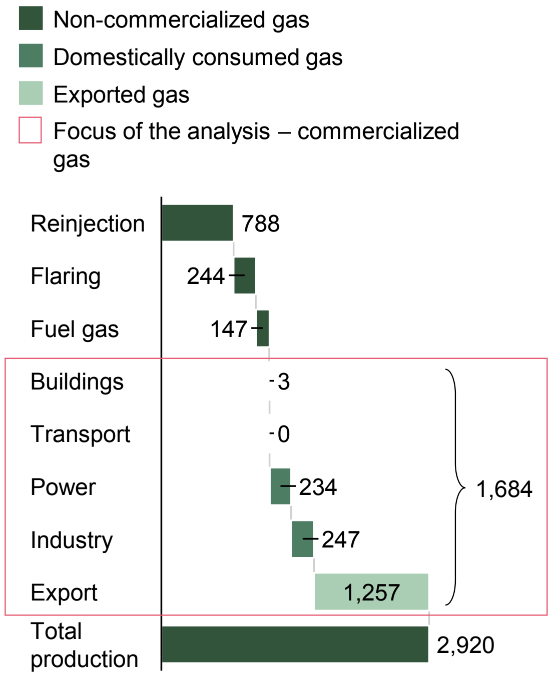
A **complete shift to zero emissions technologies is required to decarbonise heating** whereas **gas-based industrial heat processes increase emissions beyond 2020 levels** as growing heating demand outpaces decarbonization impact of gas

- **BAU: ~90% increase in emissions during 2020-50,** with continued reliance on gas and biomass boilers
- **Net Zero: 100% decrease in emissions during 2020-50,** zero emission fuels for all applications:
  - Heat pumps used by large industrial players in 2050, high CAPEX but more efficient than electric boilers
  - Combination of electric and solar used for remainder of low-/mid-temperature heat. Hydrogen used for all high-temperature heat by 2050

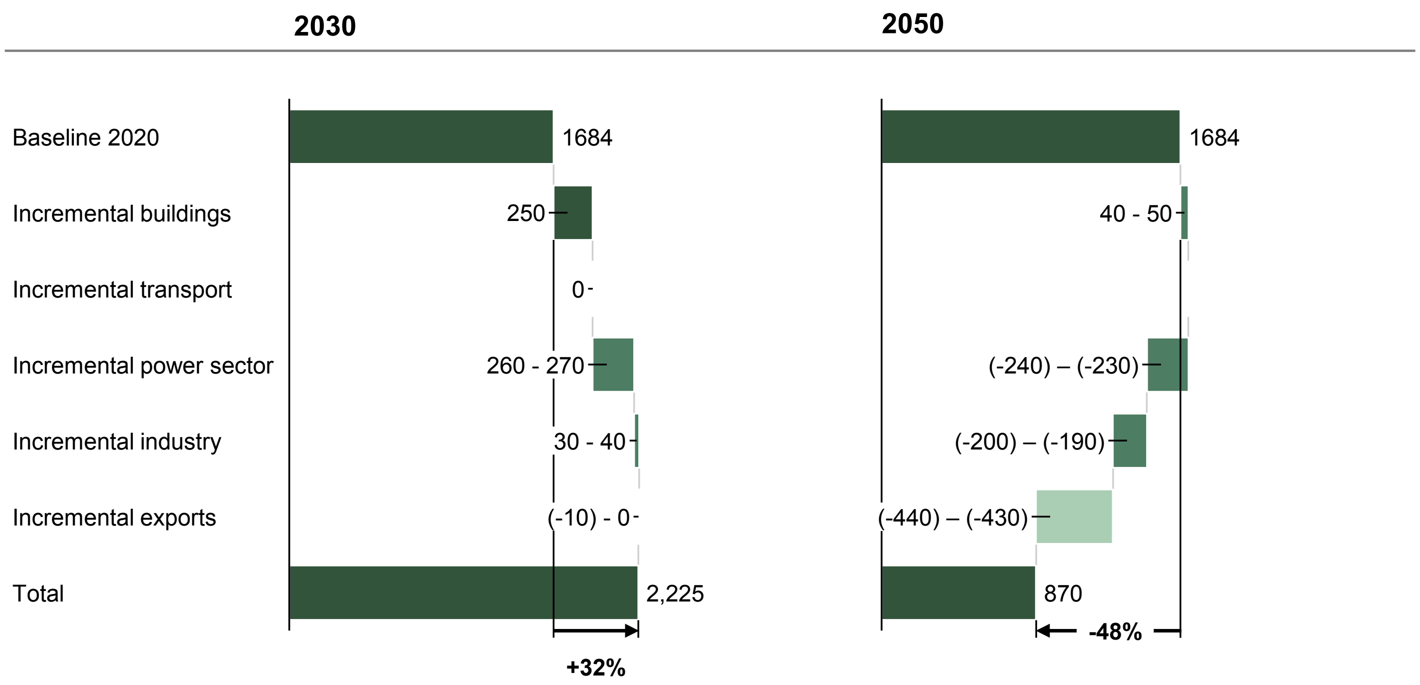
Net Zero focuses on **stopping the growth of biomass boilers through introduction of electric boilers by 2020-30**. Post-2030, a concerted effort is made to shift all heating to zero emissions alternatives

Oil and Gas: The energy transition presents the opportunity to commercialize more domestic gas in the short term but will result in a long long term decrease beyond 2050

Nigeria gas consumption in 2019, bcf



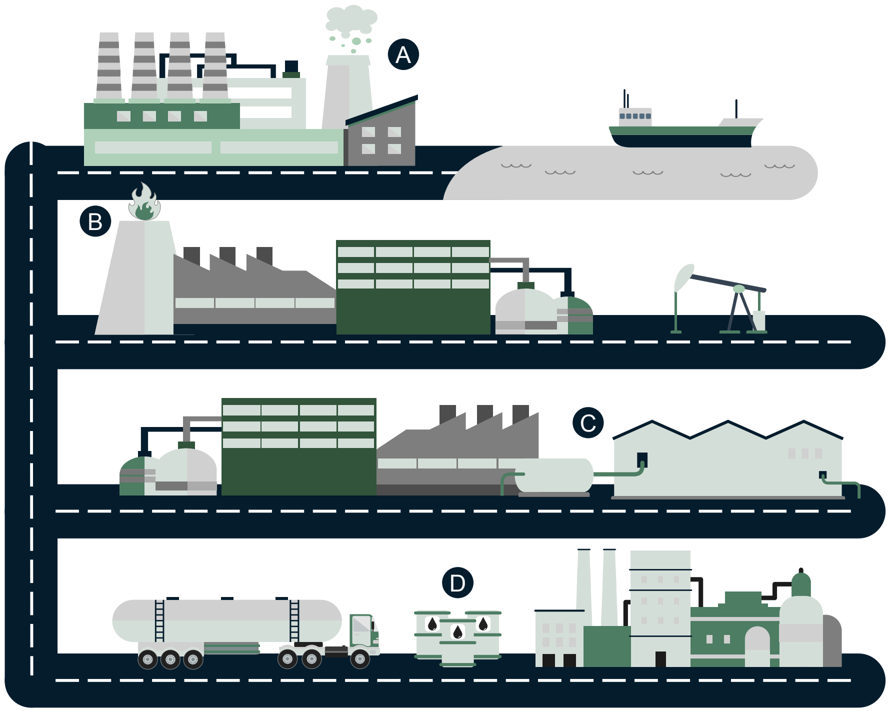
Incremental[1] commercialized gas under Net Zero scenario, bcf



1. Assumption: all incremental demand added to gas production, i.e. no cannibalization of gas exports
2. Driven by global demand

Source: NNPC annual statistical bulletin 2019, team analysis, McKinsey Energy Insights, EIA

Oil and Gas: Emissions from the sector come mainly from flaring and fuel use during production

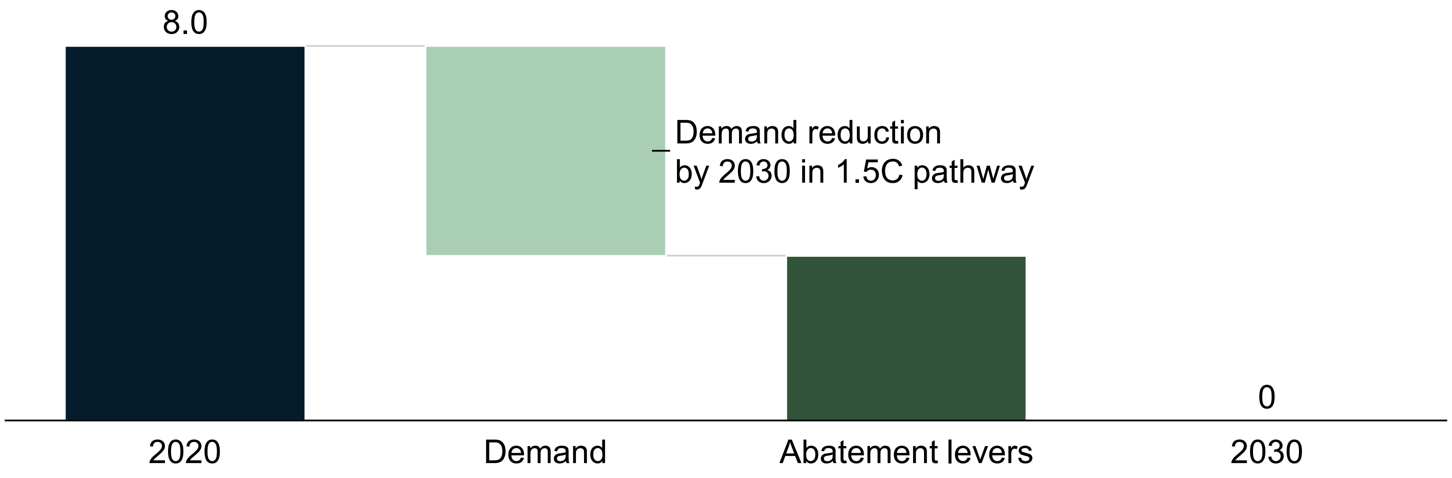


			2020 Emissions, Mt CO_2 e
A	**Fugitives** Unintended	Unintentional releases, e.g., leakages from faulty seal or leaking valve – essentially CH_4 (methane)	6
B	**Venting and Flaring** Intended	Oil & Gas that cannot be used or recovered economically or releases for safety reasons is burned instead of being sold or vented – essentially CO_2	8
C	**Refining** Unintended	Nonrecoverable losses during the refining process due to poor control over the process	0
D	**Fuel use during Oil & Gas production** Intended	Gas consumption during the extraction and refining processes	9

Source: Third National Communication (TNC) of the Federal Republic of Nigeria; Team analysis

Oil and Gas: Flaring has been targeted as the priority to tackled by 2030, with both cost positive and cost negative abatement options required

Oil flaring emissions decarbonization breakdown,
Mt CO2e



Cost positive abatement options:
- Improve flaring efficiency
- Export gas through pipeline

Cost negative abatement options:
- Repurpose gas

Key Messages

Exporting through gas pipeline is the most cost positive lever for emission reduction from flaring

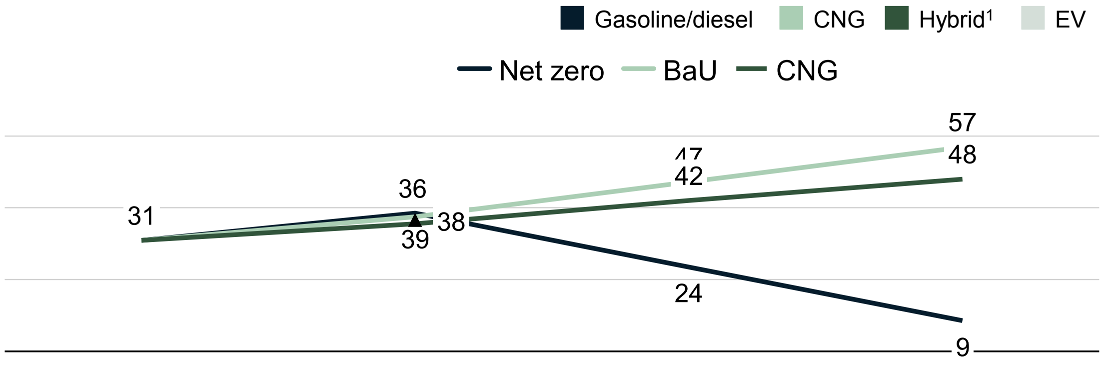
BAU: 2050 emissions would ~90% reduced from today due to demand reduction

NDC-guided and Net Zero 2050: both cost positive and cost negative abatement options are required to achieve complete flaring removal by 2030

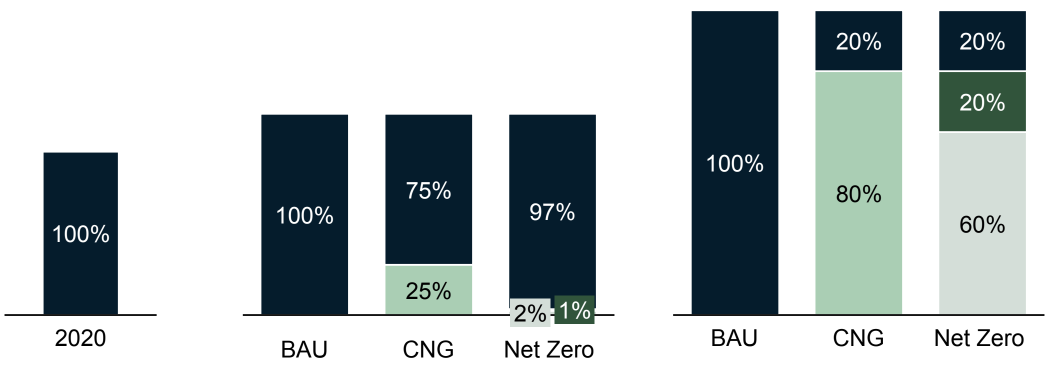
Source: IEA, TNC

Transport: Only an electric-based system can significantly reduce long-term carbon emissions in Transport, but setting up such a system requires immediate choices

GHG emissions transport, $MtCO_2$ e



Ramp-up of electric vehicles
% of cars transitioned to alternative fuel source



	2020	2030	2050
Total # of cars, Mn	**12.1**	**14.9**	**22.5[2]**

Key Messages

The decision to shift to **a natural gas vs. electric-based system needs to be taken now** to build out infrastructure and facilitate transition to achieve 2030 and 2050 targets

Changing from one system to another again (i.e., from gasoline/diesel to natural gas to electric) by 2050 would be expensive and result in stranded assets

While passenger cars grow 2x by 2050, potential exists for 3 contrasting systems by 2050:

- **BAU pathway:** maintains an **ICE fleet**
- **CNG pathway:** transitions to a **gas-based system** implying 55% carbon emissions growth by 2020-50
- **Net Zero:** transitions to an **electric-based system implying** 73% carbon decrease from 2020 baseline by 2050 and 85% from BAU 2050

Natural gas allows for a slightly faster emission reduction to 2030 compared to EV due to availability of technology

Natural gas reduces emissions ~20% compared to ICE whereas hybrids can reduce emissions ~50% and EVs 100%

Remaining emissions are to be expected by 2050 considering that cars will not be replaced at a sufficiently rapid pace

1. A hybrid is an ICE vehicle with an electric motor
2. Lever assessed independent of mode shift which is included in Net Zero

Transport: A switch to low-emissions transport technology is essential, but the technology choice depends on the electricity access

✓ Suitable   ✓ (dashed) Technically feasible but requires development to make financially viable

Technology	Description	GHG emissions, $kgCO_2$ e/km	Relevant if primary electricity source is … Not connected	Decentralised	Grid connection	Rationale
Natural gas vehicles	Natural gas vehicles use natural gas as a fuel source. Natural gas passenger cars emit ~20% less CO_2 e than the equivalent ICE vehicle	0.12	✓	✓		Not electricity-dependent, therefore suitable for both urban and rural settings under today's electricity access conditions
Electric Vehicles	EV vehicles use electricity as a fuel source. EVs contribute no emissions in the transport sector. If emissions are generated in the production of electricity, these are accounted for in the power sector	0		✓ (dashed)	✓	Considered a post-2030 option in Net Zero as grid access increases and decentralised solutions become financially viable
Hybrid Vehicles	Hybrid vehicles use both gasoline and electricity as a fuel source. Hybrid passenger cars can reduce emissions ~50% from the equivalent ICE vehicle	0.08	✓	✓ (dashed)	✓	Considered a post-2030 option in Net Zero as grid access increases and decentralised solutions become financially viable
Biofuel blends	Biofuel blends can be used in existing ICE vehicles to reduce emissions. Bioethanol blend of 10% and biodiesel blend of +20% is within the technical limit of gasoline and diesel engines respectively	0.10 0.03 0.13	✓	✓		Biofuels can be used with existing ICE vehicles to reduce emissions
Mode shift	Mode shifting from passenger cars to public transport or electric 2-3 wheelers can reduce emissions and congestions	0[1]		✓	✓	Grid connection required for buses, however 2-3 wheelers could use decentralised generation

1. Assumes shift to electric buses or electric 2-3 wheelers