Nigeria Energy Transition & Investment Plan

Update (2024)

November 2024

Nigeria Energy Transition & Investment Plan Update

Executive Summary

Access to energy remains a critical challenge in Nigeria, with 86 million people lacking access to electricity and 161 million without access to clean cooking solutions. Despite significant progress and strong institutional commitments toward achieving universal energy access, these figures highlight the urgency of addressing energy poverty as Nigeria charts its path to net-zero emissions by 2060.

The updated Energy Transition Plan (ETP 2.0) outlines the need for a **total installed power capacity of 277 GW by 2060,** similar to the 274 GW projected in the initial ETP 1.0. However, **the updated plan emphasizes greater reliance on renewable energy and energy efficiency** to drive the net-zero future. Significant investments are required in energy storage and emerging technologies, **with battery energy storage systems (BESS) needing 137 GW of capacity and hydrogen infrastructure requiring 36 GW.**

72% of diesel decentralized generators are expected to be phased out by 2030, as diesel is not a policy priority, and many existing units could be retired. In the industrial sector, **gas captive and embedded capacity is projected to reach 4.3 GW in 2030, and there is potential for exporting electricity in a net-zero power sector.**

Overall, the **cost of achieving a net-zero transition in the power sector has slightly decreased due to declining costs, particularly utility-scale solar PV.** However, **costs may rise in the transport sector if reliance on imported used electric vehicles (EVs) continues**. Imported EVs often have lower battery performance, creating inefficiencies in achieving net-zero targets.

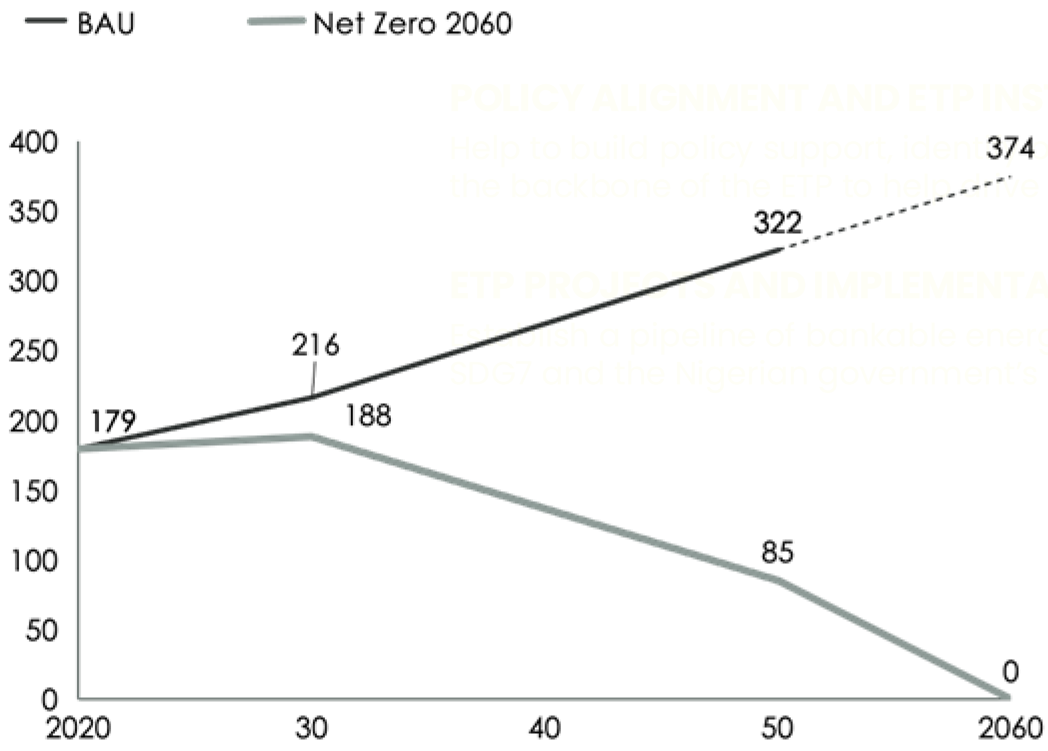
Nigeria's industrial growth highlights the need to utilize leapfrogging opportunities for clean energy. Failing to transition to clean energy could hinder industrial competitiveness in a global market increasingly driven by sustainability.

The updated ETP estimates that achieving net-zero by 2060 would require a **capital investment of approximately $500 billion USD above business-as-usual (BAU) levels.** However, this investment would result in **fuel savings of $686 billion USD, demonstrating significant economic and environmental benefits.**

Nigeria Energy Transition & Investment Plan Update

In 2022, the ETP was developed as a strategy for significant low-carbon development of energy systems across 5 key sectors

Energy-related GHG emissions trajectory, $MtCO_2e$



Key features of Nigeria's Net Zero pathway

Cooking

- emissions decrease by ~98% based on shift away from traditional fuels like firewood, charcoal and kerosene to **LPG (in the short term), bio-gas based and electric cooking**

Transport

- emissions decrease by ~97% due to **uptake of Electric Vehicles in passenger car and public transport segment**

Industry

- emissions decrease by ~97% despite industrial growth due to **decarbonization efforts in cement/ammonia production** and **100% shift to zero emission fuels for heating**

Oil and Gas

- emissions decrease by ~87% primarily driven by **fallen global demand** as well as **reduced flaring and improved electrification and energy efficiency** in upstream activities

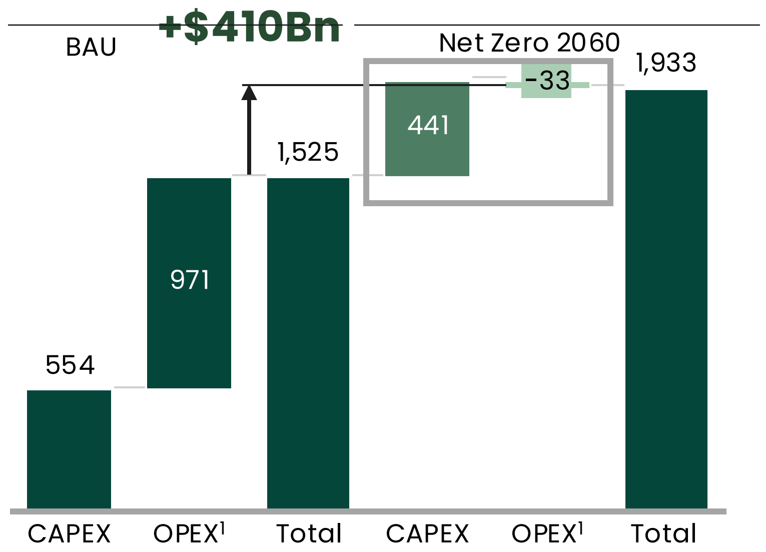
Power

- emissions decrease by ~100% as **solar increases and starts to replace gas** in its role as transition fuel and due to shift away from diesel/petrol generators

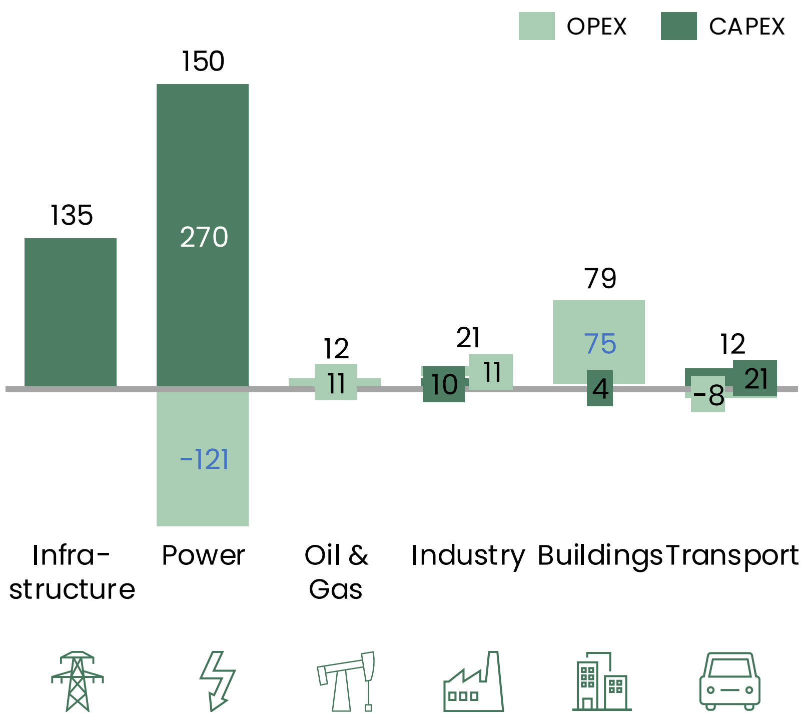
Initial estimates for Nigeria's Net-Zero pathway required $410 billion above BAU by 2060

The initial costing of the ETP indicated that enabling Nigeria's Net Zero pathway would require ~$1.9 trillion spending up to 2060, including ~$410 billion above business-as-usual spending which translates to about $10 billion per annum.

Incremental cost from BAU to Net Zero 2060, Bn USD



Incremental investments from 2021-60 to reach Net Zero 2060, Bn USD



Key insights

To get to Net Zero by 2060, **~$410Bn** is required **on top of BAU** spending **over 40 years**

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

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

Catalysing Commitments for Nigeria's Energy Transition through the Energy Transition Plan

Framework for Investment

The Energy Transition Plan (ETP) established a robust framework that acts as a catalyst for attracting funding and investment into Nigeria's energy transition sector. Since its launch, the ETP has facilitated the tracking of investments and commitments, providing a clear view of its tangible impact.

Diverse Stakeholder Contributions

These investments come from a diverse range of stakeholders, including local and international Development Finance Institutions (DFIs), donors, private equity firms, energy companies, grant-giving foundations, and joint ventures. Notable commitments include the NSIA-Vitol Carbon Vista Fund, Chapel Hill Denham & GEAPP Energy Transition Access Facility for Africa (ETAFA), and the Distributed Access for Renewable Energy Scale Up (DARES) programme.

Significant Financial Commitments

To date, stakeholders have collectively committed **$16.1 billion** toward Nigeria's energy transition, offering financial support and forging strategic partnerships aligned with the country's objectives. Additionally, donor commitments before and after the ETP launch total **$3.6 billion**, reflecting growing confidence in Nigeria's energy transition roadmap.

The increased funding post-ETP launch underscores the plan's critical role in facilitating and guiding investments, propelling Nigeria closer to achieving its long-term energy transition goals.

Significant progress has been made toward achieving the initial objectives of the Energy Transition Plan

	Objective	Progress
1	**Secure at least $10 billion financing commitment by COP27** to kickstart the implementation of Nigeria's Energy Transition Plan. This target is based on the estimated cost of $10 billion per annum to implement the plan.	**To date, $16.1 billion in funding commitments has been made towards implementation of Nigeria's Energy Transition Plan**, from a diverse group of investors, including oil and gas companies, private equity firms, local and international development finance institutions (DFIs), energy companies, and grant-giving foundations
2	**Secure 3-5 agreements with Original Equipment Manufacturers (OEMs) to begin the local manufacturing/assembly of key technologies** such as electric vehicles, decentralized solar systems etc. in Nigeria by 2025.	**Significant progress has been made in advancing local manufacturing and assembly in Nigeria**, with **OEMs increasingly setting up assembly lines for critical net-zero technologies** such as **solar PV, electric mobility, and battery manufacturing**. This drive is bolstered by **Nigeria's lithium reserves**, which present opportunities for developing a **robust local supply chain for energy storage solutions**. These efforts align with the broader goals of fostering **innovation and building domestic capacity** to support the country's **energy transition**.
3	**Secure 1-2 agreements for skills and knowledge transfer** with private sector leaders, research institutions and other partners, with immediate focus on upskilling labor for the power and buildings sectors.	**NAPTIN**, in partnership with **GIZ**, has enhanced its curriculum and plans to train **over 2,000 technicians annually** to support the renewable energy sector. **SEforALL and InfraCredit** facilitated a session with **PenCom** to promote renewable energy financing, address regulatory challenges, and position it as a **viable asset class**, advancing skills and knowledge for the **energy transition.**
4	**Play a leadership role for Africa by promoting a fair, inclusive and equitable energy transition** in Africa that will include Gas as a "transitionary fuel" , ending energy poverty and industrialization.	**Nigeria has reinforced its leadership in Africa's energy transition through the implementation of the Nigeria Gas Flare Commercialisation Programme (NGFCP),** for the conversion and utilization of flared gas. Additionally, **regional collaboration and learning exchanges with Ghana and Kenya** have facilitated knowledge sharing and capacity building.
5	**Streamline existing and new government related energy transition initiatives** (e.g., Decade of Gas, Solar Naija programme) to align with energy transition plan and Net Zero by 2060 commitment.	**In 2023, the Electricity Act was enacted**, granting **Nigerian states the authority to independently govern and regulate their electricity sectors**, including grid-connected areas. **Lagos State received support in developing its subnational electricity regulator** in alignment with the **Lagos State Electricity Bill**, which has been passed by the **State House of Assembly**. **Preliminary engagements have also taken place with Enugu State**, following their expressed interest in establishing a **regulatory framework**.

Key sectoral developments have taken place since the launch of the ETP (2022–2024) (1/2)

Power

In 2023, the Electricity Act was passed, empowering Nigerian states to independently govern and regulate their electricity sectors, including grid-connected areas. This allows states to set local tariffs, shape their energy mix, reduce reliance on diesel generators, and address supply shortages. Additionally, multiple partners are working to reduce dependence on fossil-fuel generators by promoting solar PV solutions as a cleaner alternative. A Fossil Fuel Displacement Study was conducted in Lagos State to guide the design, development and delivery of a state-wide fossil fuel displacement programme to replace fossil fuel-based self-generation of power.

In December 2023, the World Bank approved the Nigeria Distributed Access through Renewable Energy Scale-Up (DARES) project, marking it as the largest single distributed energy initiative of the World Bank globally. The Nigeria Integrated Energy Planning tool played a critical role in the development of DARES, which builds on the successful implementation of the Nigerian Electrification Project (NEP). The project aims to scale proven initiatives and expand into new priorities, including Solar Hybrid Minigrids, Standalone Solar Systems, Productive Use, and Urban Access through Rooftop Solar. Designed to provide electricity to 17.5 million Nigerians by 2029, DARES will deploy a total of 465 megawatts (MW) of power, significantly bolstering Nigeria's energy infrastructure.

Industry

Government policies and public-private partnerships are supporting the decarbonization of Nigeria's cement industry, with companies such as Lafarge Africa Plc, Dangote Cement and BAU Cement leading efforts in using alternative fuels, launching low-carbon cement products, and improving energy efficiency.

In 2024, the UK FCDO's Manufacturing Africa programme undertook a comprehensive cement decarbonisation study to explore opportunities for reducing emissions in Nigeria's cement industry. As part of the study, a webinar was held in March 2024, in collaboration with Nigeria's Council on Climate Change, to share preliminary findings and insights. The study, finalized later in the year, identified waste-to-energy (alternative fuels) as the most feasible decarbonisation lever for immediate implementation, based on global practices and local assessments. These combined efforts are driving investment, action, and steering the industry toward a low-carbon future.

Key sectoral developments have taken place since the launch of the ETP (2022–2024) (2/2)

Transport

Since 2022, Nigeria has implemented significant policies to advance sustainability in its transport sector, aligned with the ETP and net-zero emissions goal by 2060. Key measures that have been put in place include the removal of fuel subsidies in 2023 to reallocate funds toward infrastructure development, tax and tariff reductions on EV) imports, and updates to the National Automotive Industry Development Plan (NAIDP) to support local EV manufacturing.

The government is developing an EV charging infrastructure program emphasizing renewable energy and establishing stricter vehicle emission standards. To ease adoption barriers, partnerships have been created to provide affordable EV financing options. As well as an initiative to deploy 100 e-buses to address the announcement of which came from his Excellency the President at COP28. The buses are to be deployed across 3 cities that have shown advancements and the ability to successfully adopt electric mass transit systems, Lagos, Abuja, and Ibadan. These initiatives mark crucial steps in decarbonizing Nigeria's transport sector and enhancing its sustainability.

While the ETP targets focus on electric vehicle adoption, the government is also promoting the use of Compressed Natural Gas (CNG) as a more accessible alternative through the Presidential CNG Initiative (Pi-CNG).

Buildings (Cooking)

In April 2024, the National Clean Cooking Policy was approved by the Federal Executive Council (FEC), a significant milestone in Nigeria's commitment to addressing access to clean cooking solutions. The policy outlines targets in line with meeting universal access by 2030 and the long-term vision of a carbon-neutral clean cooking future by the year 2060 in line with the ETP. The Nigeria Clean Cooking Forum, organized by the Nigerian Alliance for Clean Cooking, will continue to bring together key stakeholders, to discuss strategies and initiatives, and foster collaboration to accelerate the transition to clean cooking.

Oil and Gas

To reduce emissions and support decarbonization, Nigeria has introduced several measures. At COP28, the Nigerian Upstream Petroleum Regulatory Commission (NUPRC) launched a regulatory framework focused on energy transition, natural gas use, zero routine flaring, and methane reduction. Additionally, the Nigeria Gas Flare Commercialisation Programme (NGFCP) has begun allocating flare sites to private investors for conversion/utilisation of flared gas.

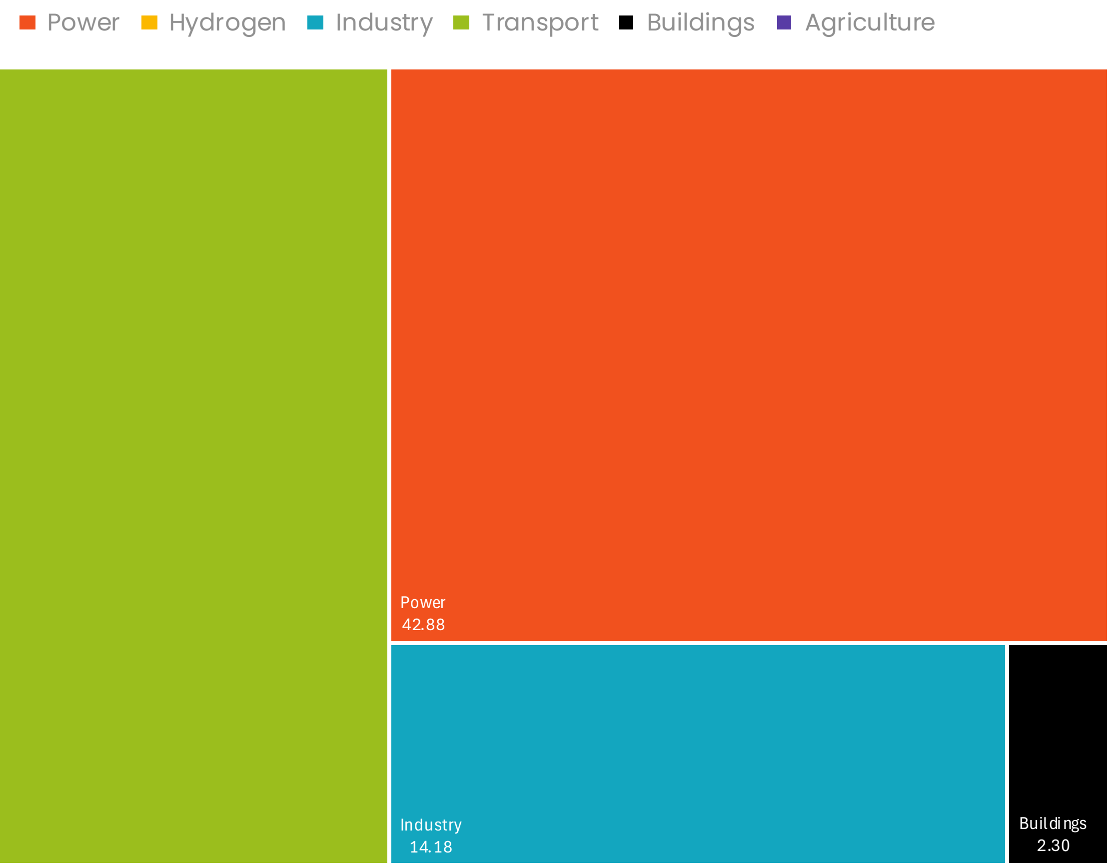
The ETP has been updated to strengthen implementation

- To reflect recent data and policy developments, a periodic update of the Energy Transition Plan was undertaken to develop the Nigeria Energy Transition and Investment Plan (ETIP) 2.0.
- This update was driven by collaborative efforts involving key MDAs, including the **National Council on Climate Change (NCCC)**, the **Ministry of Power**, **Ministry of Environment, Nigerian Electricity Regulatory Commission (NERC), Nigeria Sovereign Investment Authority (NSIA), Oando Clean Energy, etc**.
- Sector-specific stakeholder consultations were held with representatives, with their insights being critical in reviewing and refining the plan's assumptions and priorities.
- The updated plan utilizes advanced modelling tools to simulate current and future energy systems through linear optimization, providing a clear understanding of investment needs and the impact of energy transition projects across various sectors.
- Capacity-building efforts are ongoing to ensure ownership of the ETIP 2.0 by relevant stakeholders, enabling them to lead and sustain future iterations of the plan effectively.
- Future activities will focus on further capacity-building sessions with stakeholders to enhance implementation and monitor progress toward achieving energy transition objectives.

Nigeria Energy Transition & Investment Plan Update

Power and transport contributed to most of the energy-related CO_2 emissions, at roughly 84%

Greenhouse gas emissions per sector, 2020 (Mt CO_2e)[1]



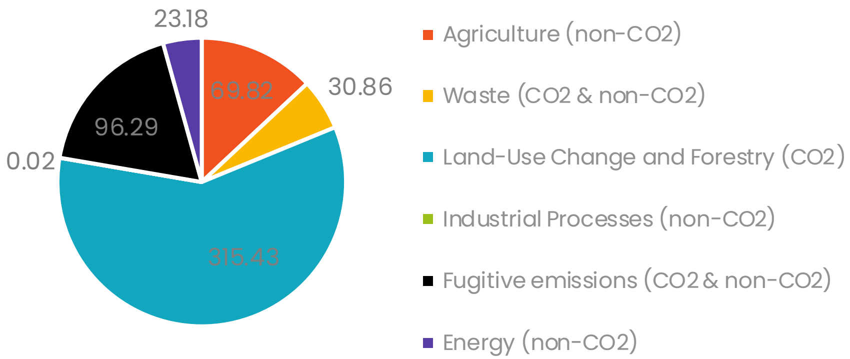
Source:

1. SEforALL analysis,
2. Nigeria GHG Inventory Report 2000-2017 (2021)

Key Insights

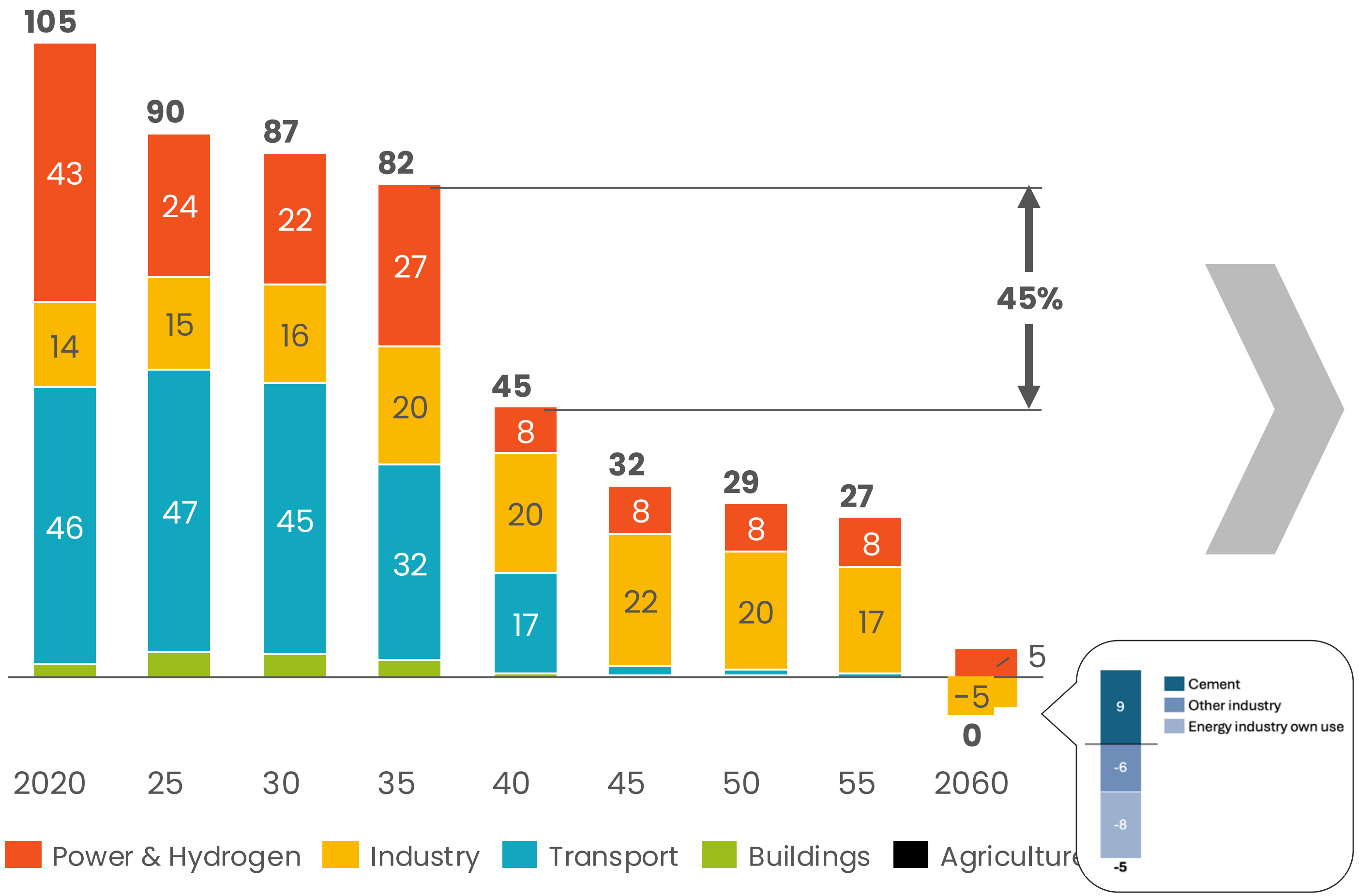
- **88.6 Mt CO2e** come from energy-related emissions, with around **84%** of from **power** and **transport** sectors alone.
- **535.6 Mt CO2e comes from non-CO2 energy-related and non-energy related emissions**, mainly livestock, managed soils, fugitives, waste, and LUCF – out of scope of this plan.
- **LULUCF emissions,** composed of **only CO2 emissions,** have a strong linkage with deforestation due to biomass use for cooking in buildings
- **Non-CO2 emissions** on energy sector are methane and nitrous oxide emitted from fuel combustion on transport, manufacturing and energy industries
- **Fugitive emissions**, are mainly sourced from oil and gas activities

Out of scope/not modelled emissions (Mt CO_2e)[2]



Achieving Net Zero Emissions by 2060 will require a rapid decline in total emissions between 2035 and 2040, along with negative emissions from industry

Projected CO_2e emissions under NZE by sector
Mt CO_2e, NZE, 2020-2060



Key Insights

- In the power sector, emissions are expected to peak in 2020, followed by a significant reduction anticipated between 2035 and 2040, driven by the rapid expansion of solar PV and increased investment in energy storage systems
- Emissions in the transport and buildings sectors are projected to peak by 2025 and gradually decline, while emissions in industry is projected to peak later, around 2045, before beginning to decrease
- By 2060, emissions across all sectors are expected to reach zero, except for the power sector, where residual emissions will be offset by utilization of BECCS in industrial applications.

Underlying drivers

- By 2030, diesel stand-alone is fully replaced by decentralized technologies (decentralized solar PV, solar home system, and hybrid diesel-solar)
- Industry sector will have negative emissions through Biomass CCS (including for energy own use) to offset small volume of CO2 emissions from power sector
- Traditional biomass stoves in urban areas are phased out in 2030
- EV makes up at least 80% of fleet by 2050

Nigeria Energy Transition & Investment Plan Update

Power sector's energy transition includes universal electrification in 2030 with improvement of electricity access quality and increasing grid access

5 Mn

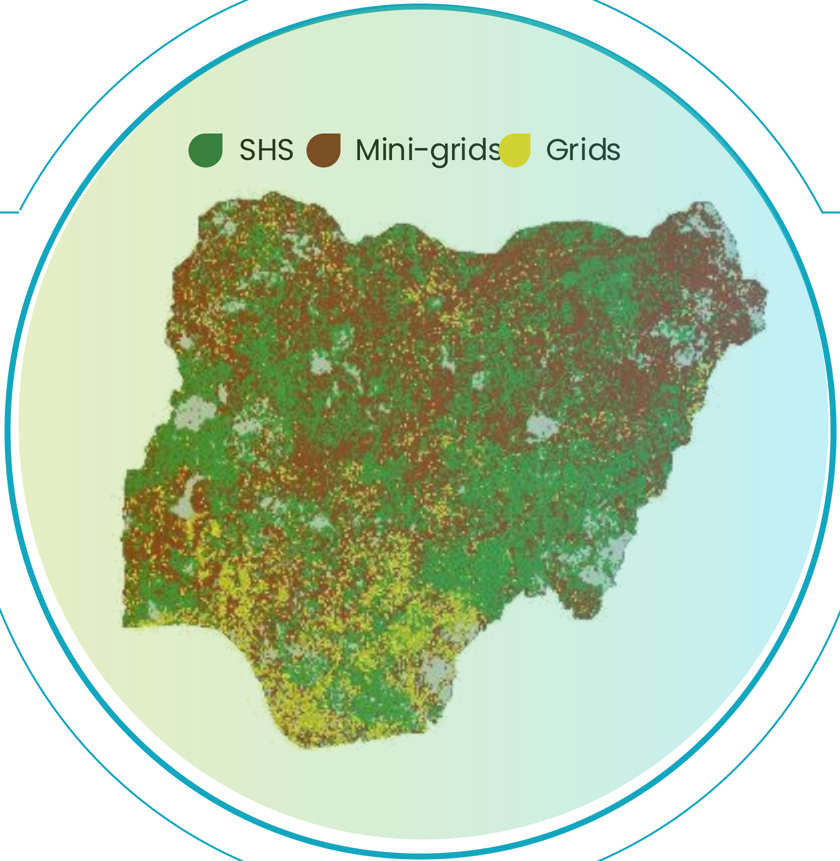
Solar home systems connections, mostly in sparsely populated areas

5.4 Mn

Grid connections in densely populated areas within close proximity of existing grid infrastructure

8.9 Mn

Mini-grid connections (104.8k mini-grids) in densely populated areas further from existing grid infrastructure



USD 25.8 Bn

Total nominal investment needed for universal access

8400 GWh p.a. & 3.6 GW

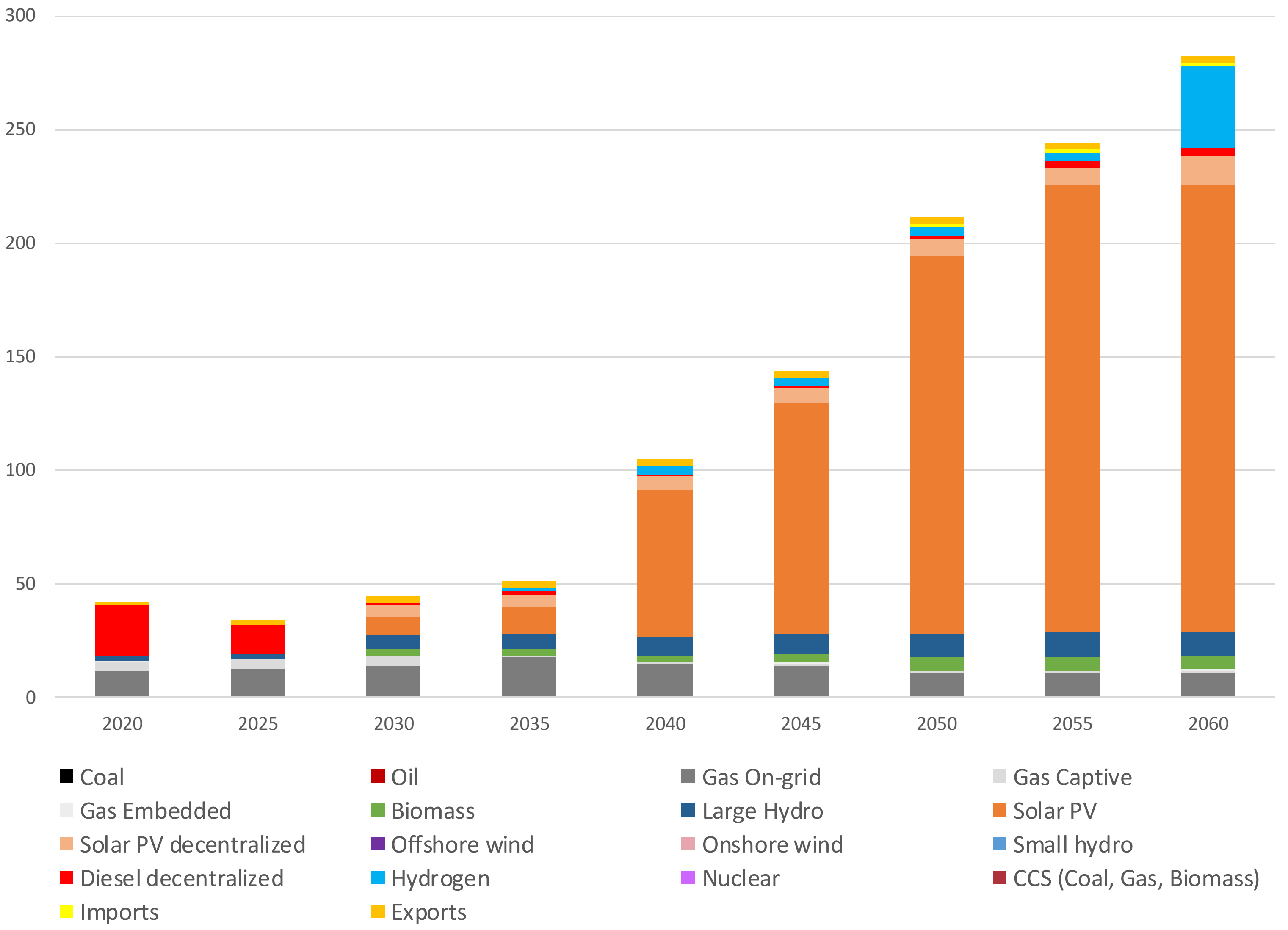
Total electricity supplied to unelectrified residential households

106 Mn & 19.3 Mn

Additional people and residential households reached respectively

Power | Installed capacity mix (GW) – driven by a high share of solar, gas and hydrogen

Installed capacity mix (GW)



Key insights

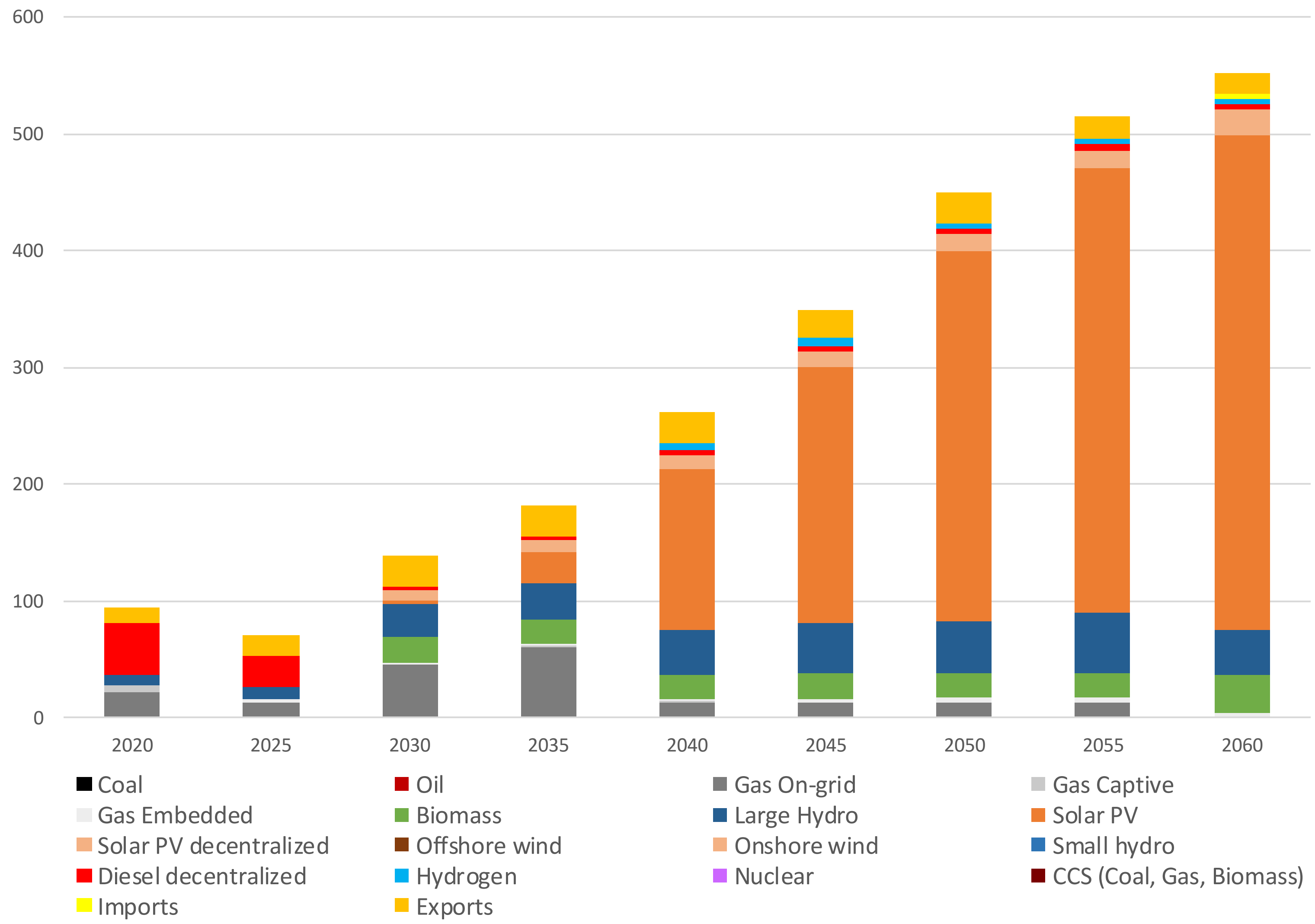
- Total installed capacity increases by 6.8 times between 2020-2060.
- High increase of **centralized** technologies from 34% in 2020 to 94% in 2060 with an annual growth rate of 8%
- Diesel **decentralized** technologies are gradually phased out from 23 GW in 2020 to 3.5 GW (mini-grids) in 2060
- **Renewable energy technology** share increases from 5% in 2020 to 82% in 2050, excluding hydrogen.
- Significant uptake of **solar PV** in 2050, reaching to 209 GW while **hydropower** reaches to 11 GW in 2060 from 2 GW in 2020 due to need to dispatchable power
- Uptake of **biomass** (6 GW) and **hydrogen** (36 GW) in replacement of **gas** (11.8 GW) by 2060, due to zero emission constraints in 2060 and need of dispatchable power
- Increased penetration of **battery storage** (130 GW), and **hydrogen storage** (35 GW) for security of supply due to penetration of renewables by 2060

Overall assumptions

- There is enough renewable energy potential of solar PV, hydropower and biomass in the country

Power | Generation mix (TWh) – driven by a high share of solar and hydropower

Power generation mix (TWh)



Key insights

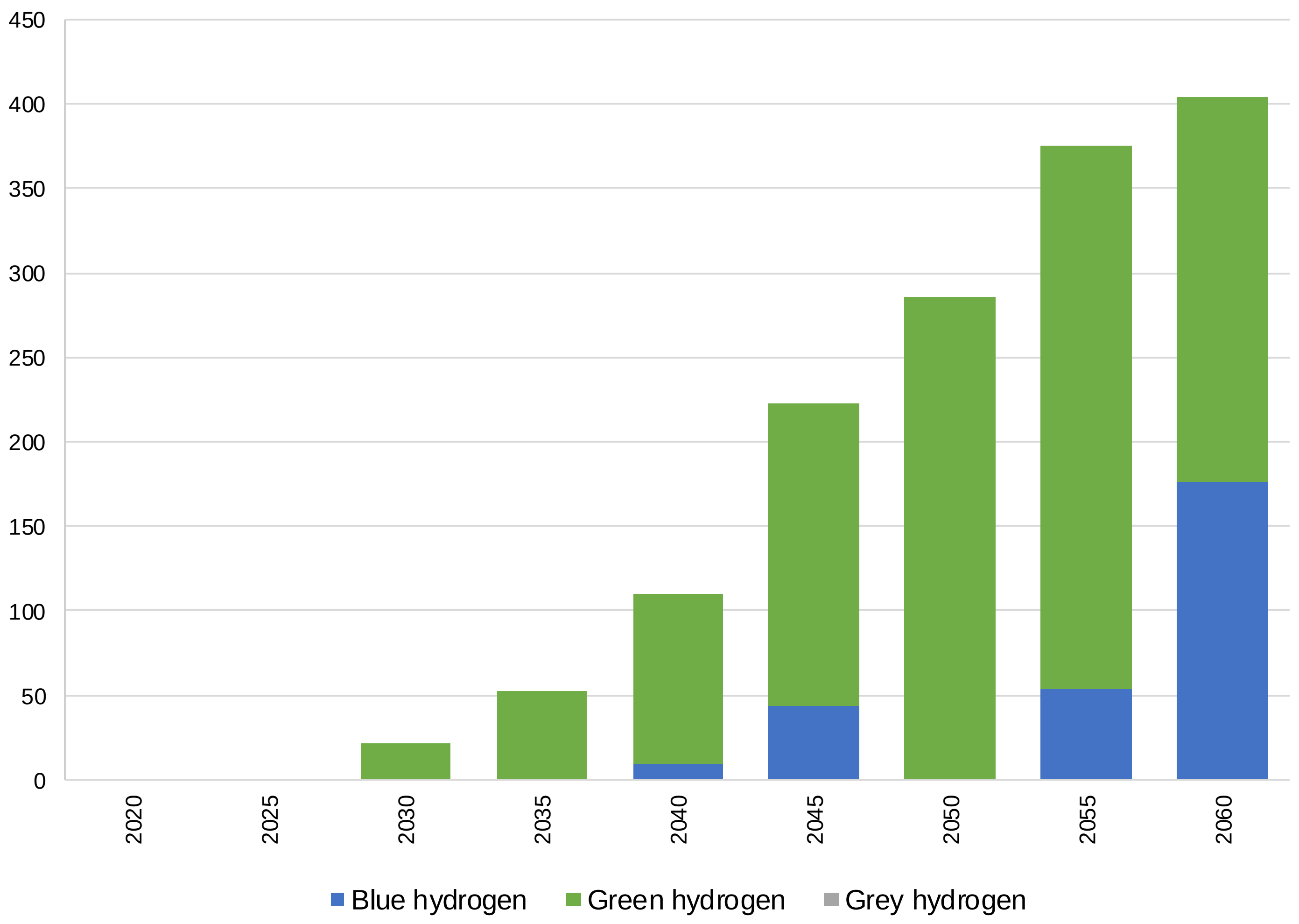
- Electricity generation increases by **6.5 times** between 2020-2060, with an annual growth rate of 32% due to **universal electrification** in 2030
- Oil and gas **decentralized** generators replaced by **centralized technologies** due to achievement of universal electrification in 2030 and decarbonization objective in 2060
- Significant uptake of **solar PV** in 2060 of 446 TWh due to replacement of gas to achieve net zero emissions
- Increase of **biomass** reaching to 32 TWh in 2060 in replacement of gas and need of dispatchable power
- Increase of **hydropower** generation, 39 TWh in 2060 and **hydrogen** of 4 TWh due to limited fossil fuel generation and need of dispatcable power
- Increased penetration of **battery storage** (0.5 TWh) and **hydrogen storage** (0.14 TWh) for security of supply due to increased penetration of renewables and hydrogen

Overall assumptions

- There is enough renewable energy potential of solar PV, hydropower and biomass in the country

Power | Hydrogen Production mix (PJ) – driven by a high share of green hydrogen

Hydrogen production mix (PJ)



Key insights

- Increased penetration of **hydrogen** reaching to 404 PJ in 2060
- Uptake of hydrogen for **replacement of gas and decentralized diesel** due to zero emissions target in 2060 and security of supply
- Increased penetration of renewables in the future leads to **green hydrogen** growth from 2030 onwards, reaching to 228 PJ in 2060
- **Blue hydrogen** generation reaches to 176 PJ in 2060, replacing gas due to Net zero emission trajectory

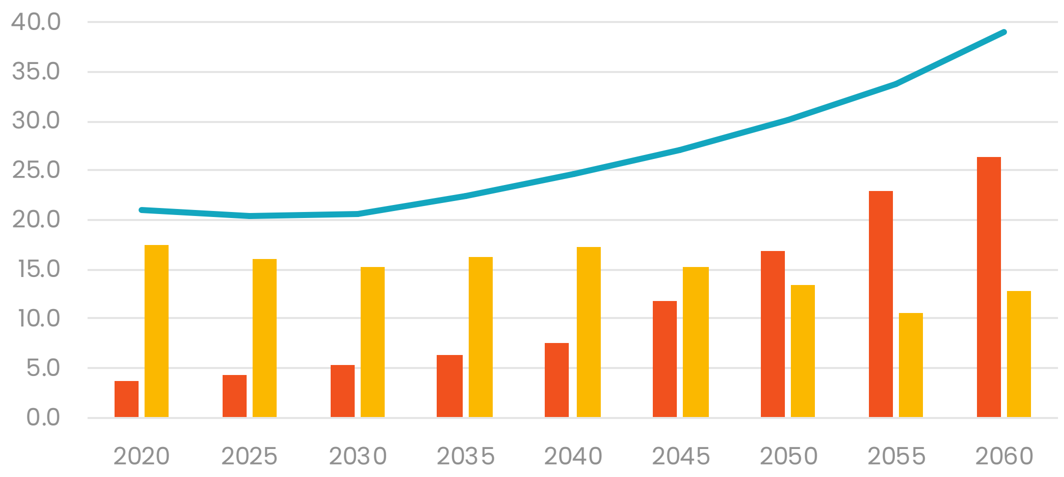
Overall assumptions

- There is enough renewable energy potential in the country for production of green hydrogen
- Gas could be used for blue hydrogen production
- Development of an efficient hydrogen infrastructure

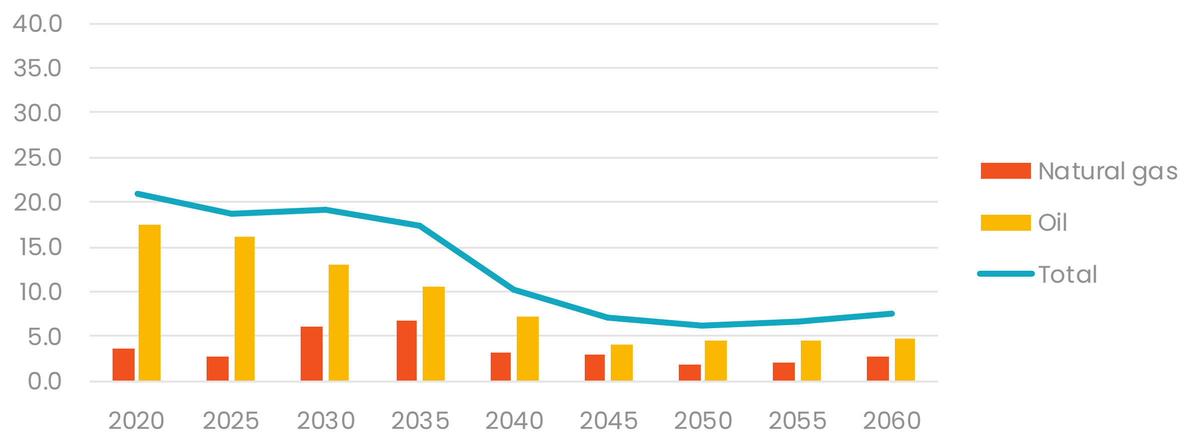
Nigeria Energy Transition & Investment Plan Update

Emissions from the Oil and Gas sector (Upstream) remain positive even in 2060

Oil and gas emissions in BAU, *MtCO2eq*



Oil and gas emissions in NZE 2060, *MtCO2eq*



Source: SEforALL analysis

Key insights

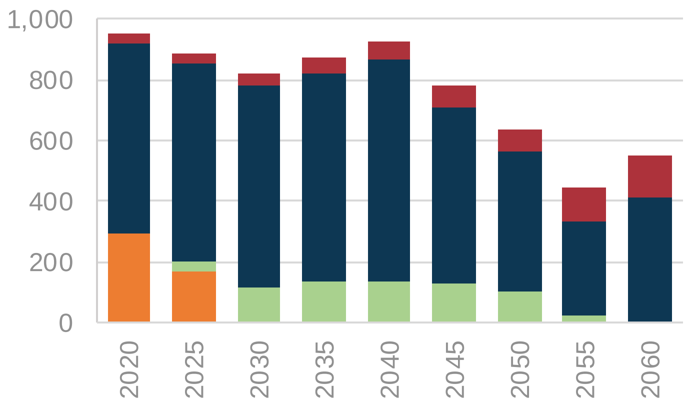
- In BAU, **emissions from the O&G sector (upstream) almost double from 2020 to 2060**, reaching around 39.1 MtCO2eq in 2060.
- In NZE, **emissions from the O&G sector remain positive (7.5 MtCO2eq) even in 2060**, mainly from the production of oil.
- The upstream O&G sector **emissions abatement in the NZE** in comparison to BAU is 31.6 MtCO2eq, or **around 80%** of the O&G sector emissions under BAU.

Overall assumptions

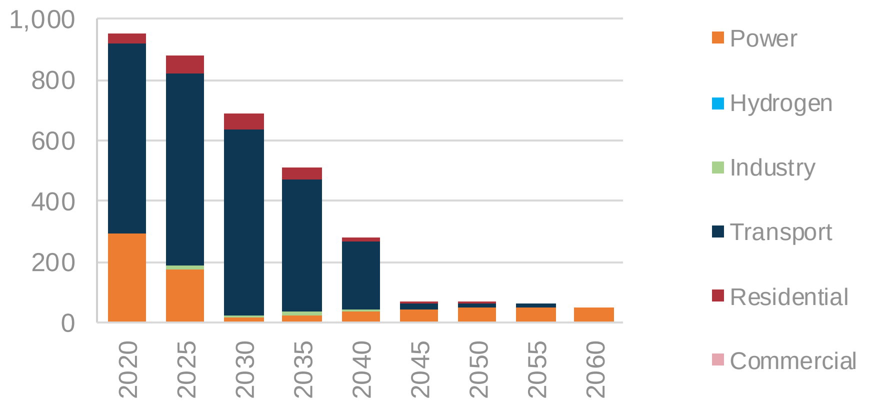
- Upstream emission factor for natural gas (natural gas production) considered is 0.0108 Mt CO2eq/PJ
- Upstream emission factor for oil (oil production) considered is 0.0158 Mt CO2eq/PJ)
- Oil and gas activity values (total demand) are multiplied by their respective emission factors to obtain the total emissions from the O&G sector.

Oil and Gas demand - Downstream

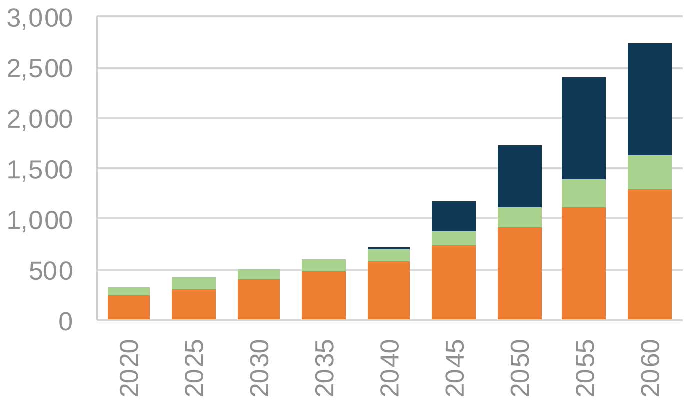
Oil demand by source in BAU, *PJ*



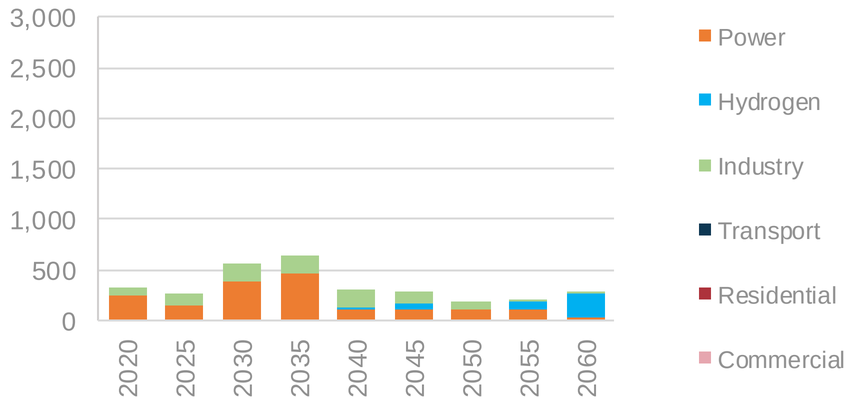
Oil demand by source in NZE, *PJ*



Gas demand by source in BAU, *PJ*



Gas demand by source in NZE, *PJ*



Source: SEforALL analysis

Key insights

- **Oil demand** in both scenarios is mainly from the **transport** sector, while **gas demand** is mainly from the **power** sector.
- In **BAU**, the oil demand is almost halved by 2060 in comparison to 2020 (550 PJ in 2060), while **natural gas demand increases** by more than **8 times** (2,740 PJ in 2060) within this period.
- This is due to a **shift of demand from oil to natural gas** observed for the **industry** (from 2040), **transport** (from 2040) and **power** (from 2030) sectors, resulting in an overall demand reduction in oil and a significant increase in natural gas demand.
- In **NZE**, **oil demand drops sharply** by 2045, owing to growth of **electric vehicles.**
- In **NZE**, **gas demand remains less** in comparison to BAU (650 PJ in 2035). The major demand is from the power and industrial sectors for security of supply and hard to abate industries.

Note – NZE scenario is least cost optimized.

Just transition perspectives in the Oil and Gas sector

- The **global net zero emissions movement** and the resulting global oil demand reduction can **impact the O&G sector**:
  - **110 k low-qualified direct, indirect and induced jobs potentially lost in 2050** compared to 2020

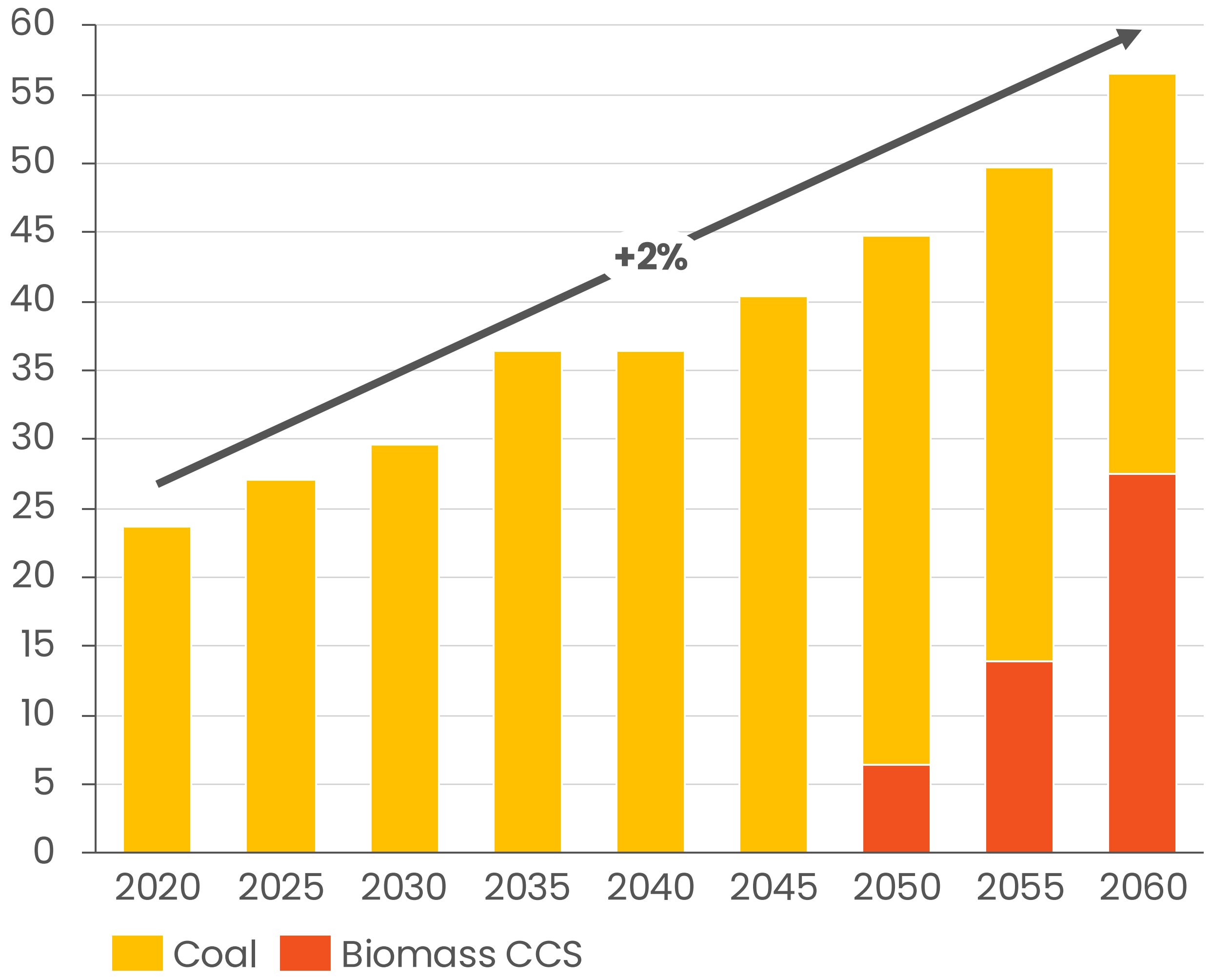
- However, the **net zero transition in Nigeria will also create several jobs** in the renewable and other sectors:
  - **840 k incremental full-time equivalents in 2050** compared to 2020 across sectors
  - Most job creating sectors include **power sector with decentralized technologies**, and **transport sector with electric vehicles**

- Preparing for a just transition could be enabled by **reskilling the affected workforce**, creating **local value chains**, and creating a **national just transition policy** outlining clear pathways for workers and communities affected by the shift to a low-carbon economy.

Nigeria Energy Transition & Investment Plan Update

Cement as the largest industrial emitter has significant decarbonization potential

Total Cement Production - Mtpa



Key insights

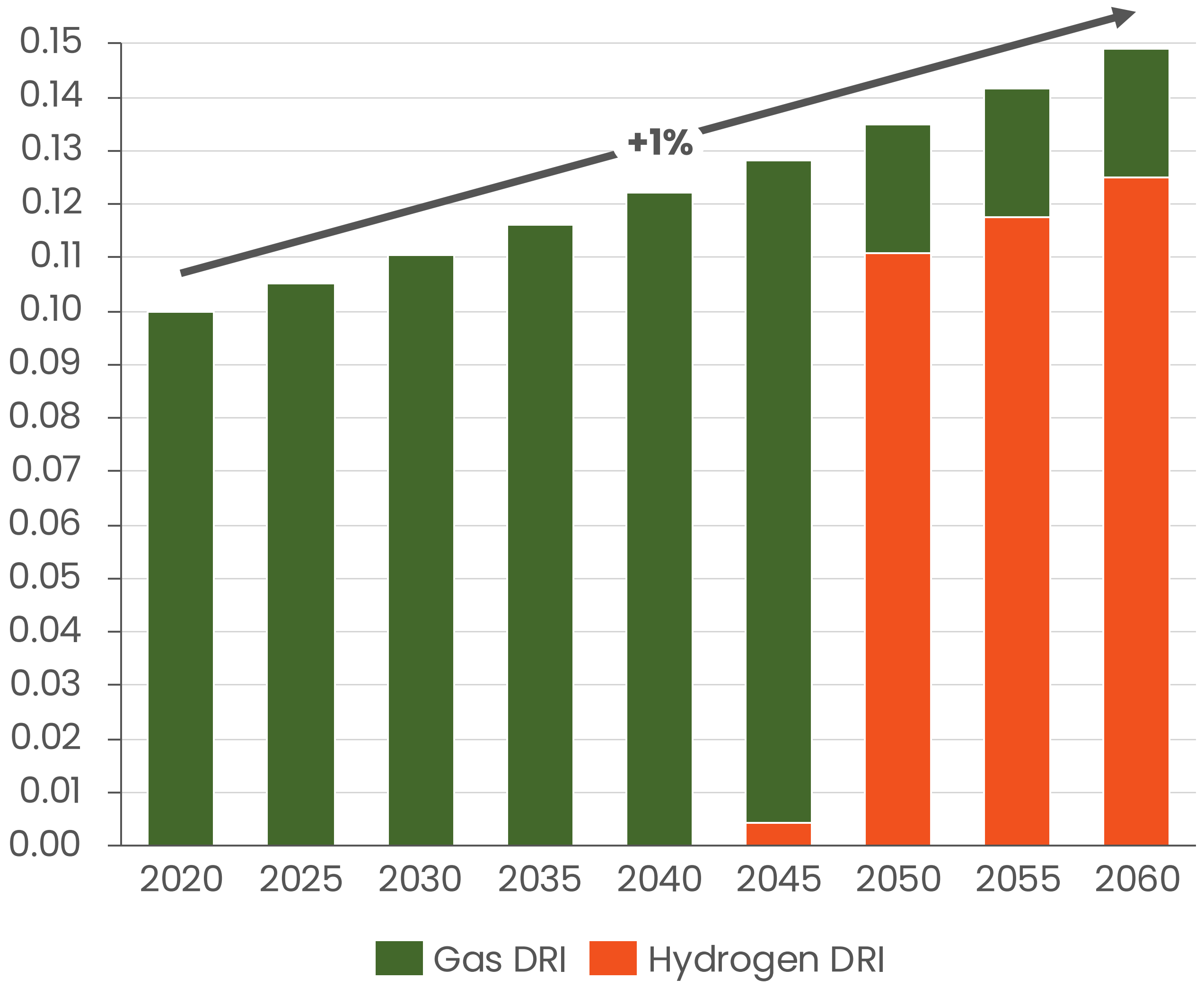
- Coal dominates cement production until 2050, after which biomass CCS starts to significantly increase.
- Cement production is projected to increase steadily, with a growth rate of 2% per year.
- The transition from coal to biomass CCS signals a late but important move toward cleaner production methods.
- Biomass with CCS only takes off after 2050, indicating delayed but necessary adoption of carbon capture to meet emissions targets.
- Use of Calcinated clay for clinker process can reduce upto 50% of the emissions.

Underlying assumptions

- Sustained demand for cement due to infrastructure development, supporting a steady production growth.
- Delayed implementation of cleaner technologies: The assumption is that there will be little incentive or investment in clean technology until closer to mid-century.
- Technological breakthroughs in biomass CCS will become economically viable post-2050.

Hydrogen can drive future steel production

Total Steel Production - Mtpa



Key insights

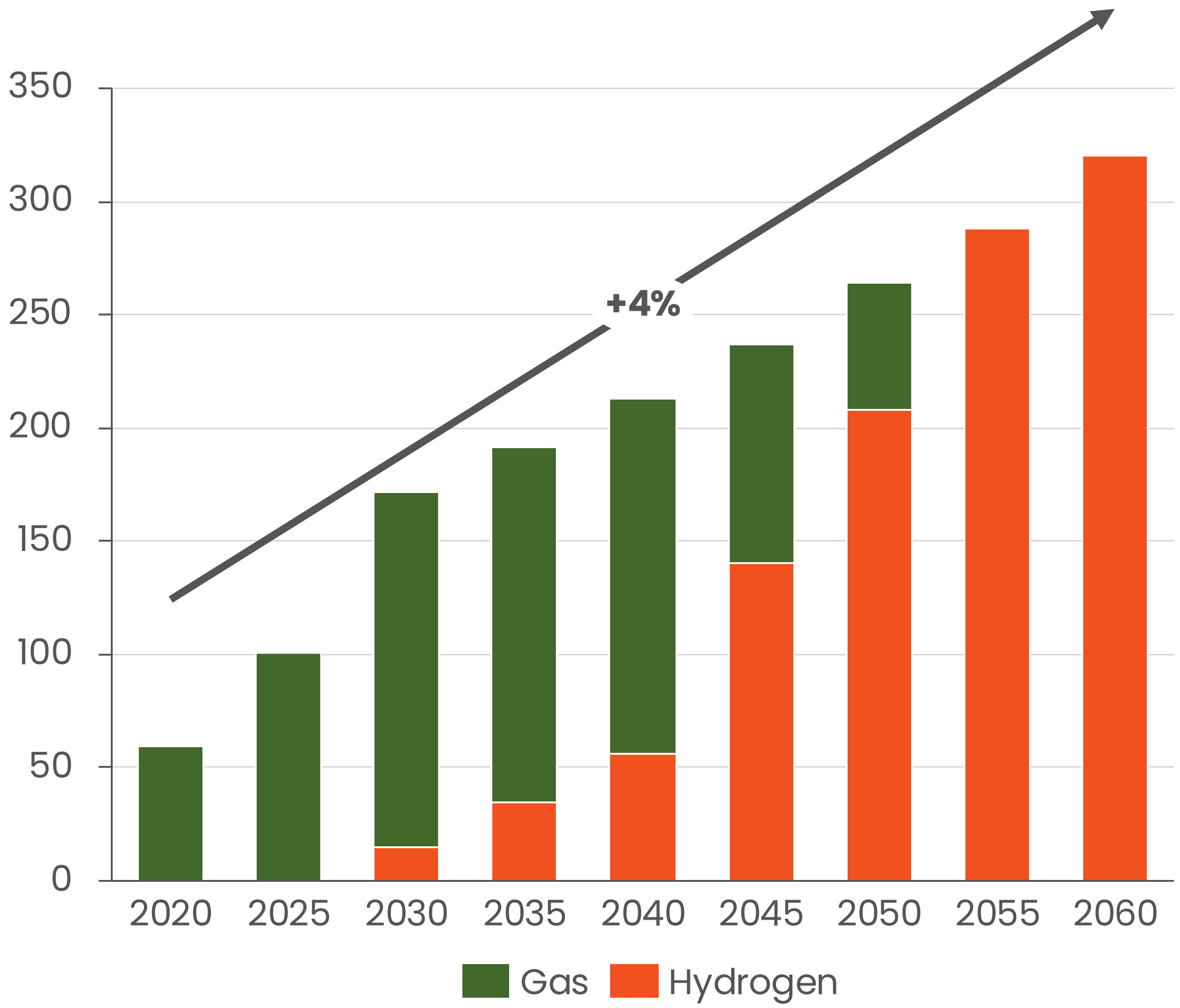
- Gas DRI dominates steel production up to 2045, but Hydrogen DRI takes over after 2050.
- Steel production is projected to grow slowly, with an annual increase of 1%.
- The steel industry shifts toward hydrogen-based technologies to meet emissions targets post-2045.
- Gas DRI remains the primary method until hydrogen technologies mature.

Underlying assumptions

- Technological readiness of Hydrogen DRI will take decades, likely due to infrastructure and cost barriers.
- Steel demand remains high but transitions to more sustainable production methods over time.
- Gas DRI technologies will remain economically viable until hydrogen technologies become cost-competitive.

Ammonia/Chemicals

Total Energy Demand for Chemical Production - PJ



Key insights

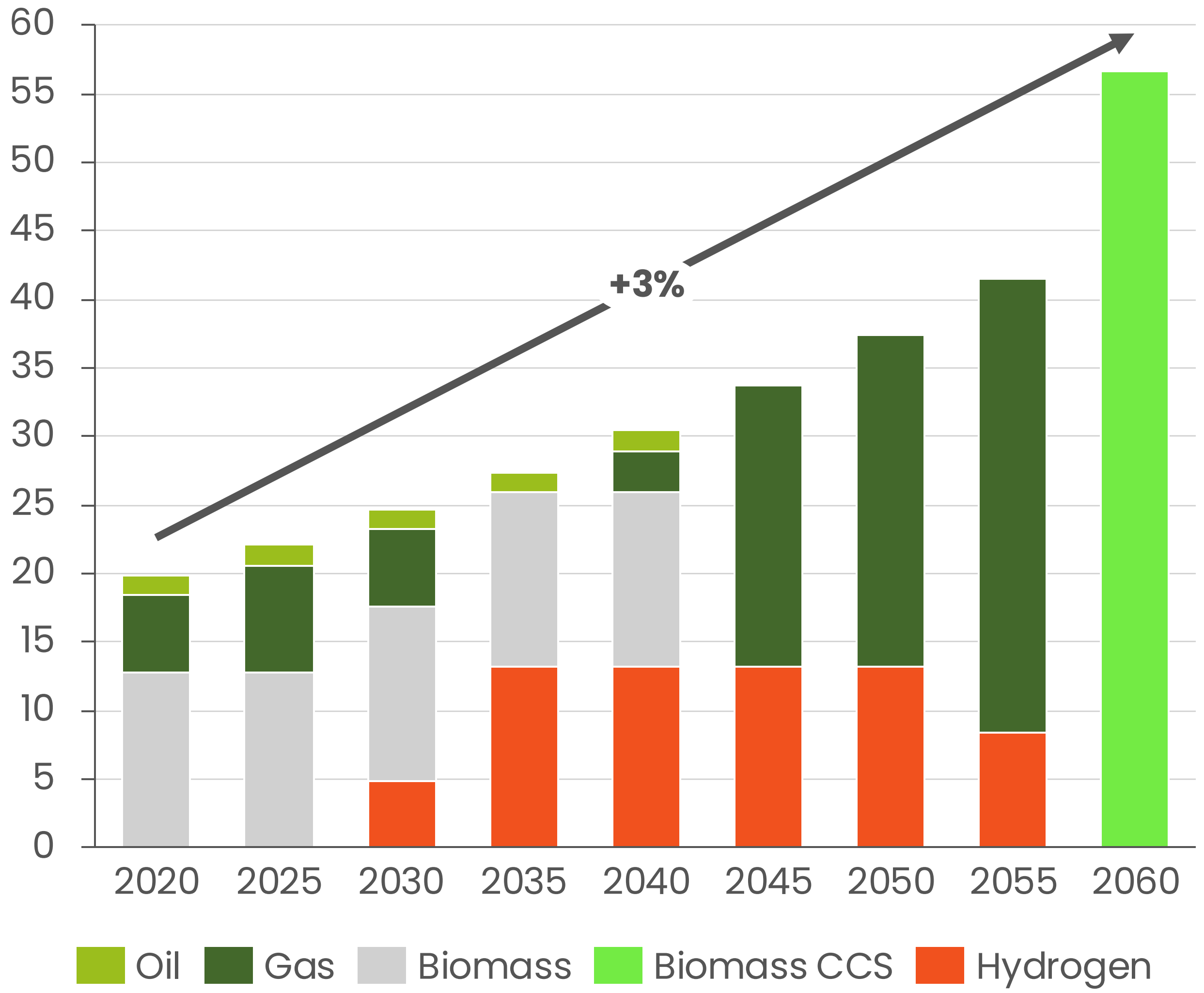
- Energy demand for chemical production is expected to grow significantly over the next decades.
- Gas remains the primary energy source for chemical production until hydrogen takes over post-2045.
- Hydrogen use increases significantly after 2045, signaling a shift to decarbonized chemical production.
- The switch to hydrogen will help decarbonize the chemical industry, aligning with emissions reduction targets.

Underlying assumptions

- Increased demand for chemicals driven by industrial and consumer needs globally.
- Delayed transition to hydrogen due to technological, infrastructure, and cost barriers in the chemical industry.
- Hydrogen infrastructure will become widely available and economically viable post-2045.

Other Industry – High Temperature applications

Total energy demand for High Temperature applications - PJ



Key insights

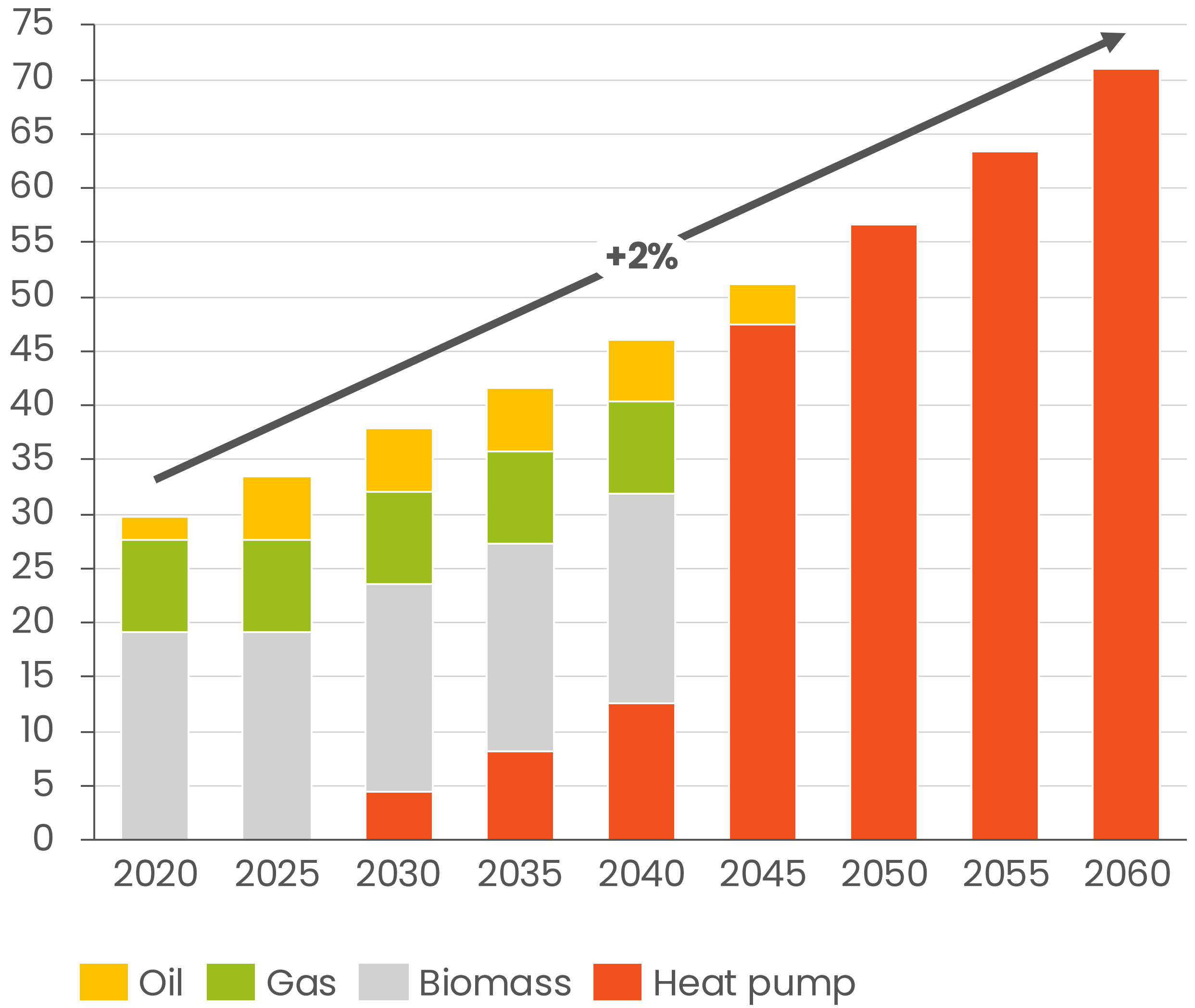
- Energy demand for high-temperature industrial applications will grow steadily.
- The use of biomass and hydrogen increases post-2045, replacing gas and oil.
- By 2060, hydrogen will be the dominant energy source for high-temperature applications.
- Fossil fuels remain dominant until hydrogen becomes the leading energy source post-2055.

Underlying assumptions

- Increased industrial energy demand driven by economic growth and expanding industrial sectors.
- Biomass and hydrogen technologies will only become cost-effective and scalable post-2045.
- Fossil fuel reliance remains strong until alternative energy sources can compete on cost and availability.

Other Industry – Low Temperature applications

Total energy demand for Low Temperature applications - PJ



Key insights

- Energy demand for low-temperature industrial processes is projected to increase steadily.
- Heat pumps and hydrogen become the primary energy sources for low-temperature applications, replacing biomass and fossil fuels.
- Fossil fuels are used less in favor of cleaner technologies like heat pumps and hydrogen.
- Significant changes in energy mix only happen post-2040.

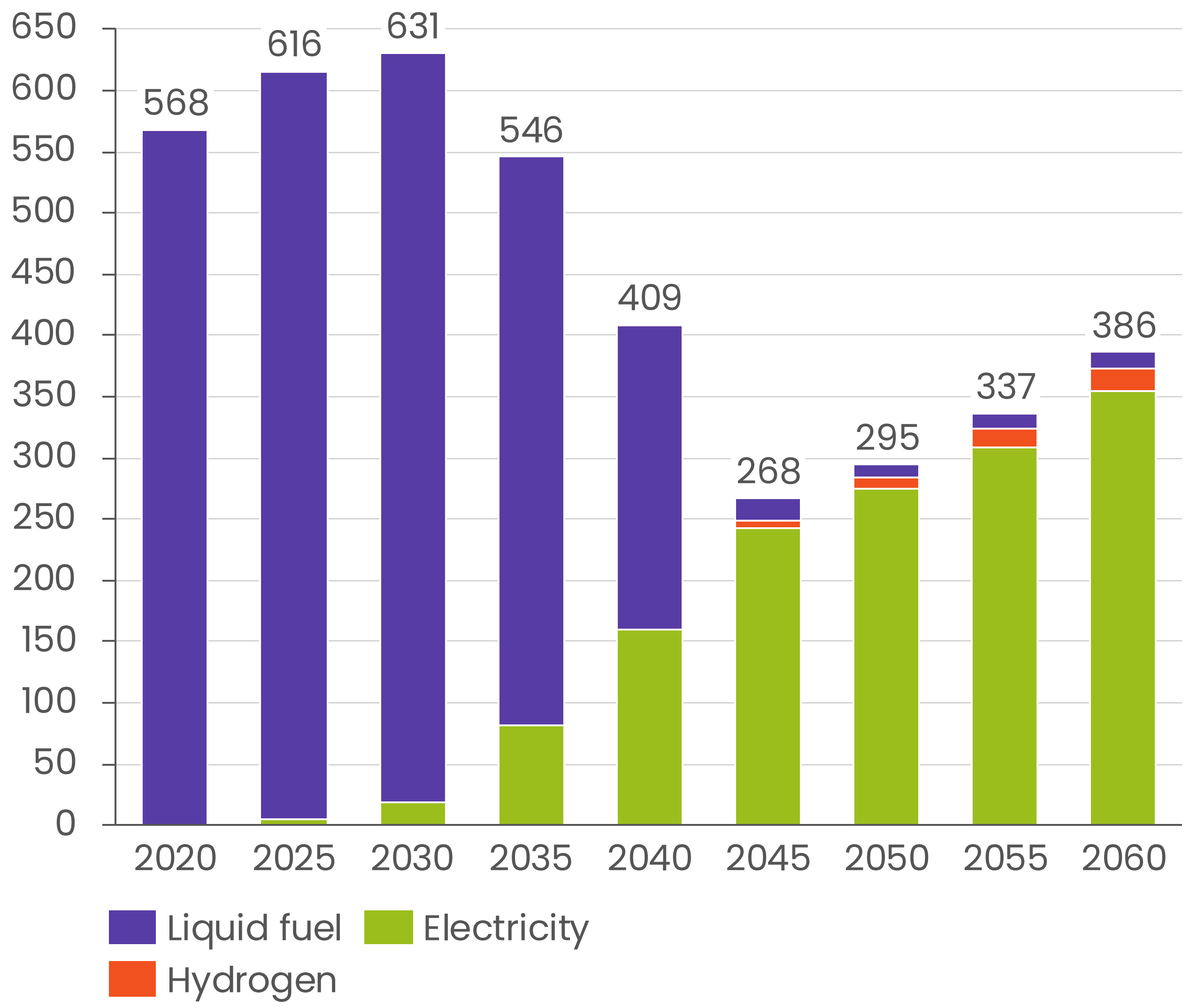
Underlying assumptions

- Technological advancements in heat pumps and hydrogen will make them more cost-effective for low-temperature processes.
- Biomass and fossil fuels will remain competitive until renewable energy technologies mature.
- Steady energy demand growth for low-temperature applications in sectors like food processing and manufacturing.

Nigeria Energy Transition & Investment Plan Update

Fuel Consumption in Transport Sector

Total Fuel Consumption in Transport Sector – PJ



Key insights

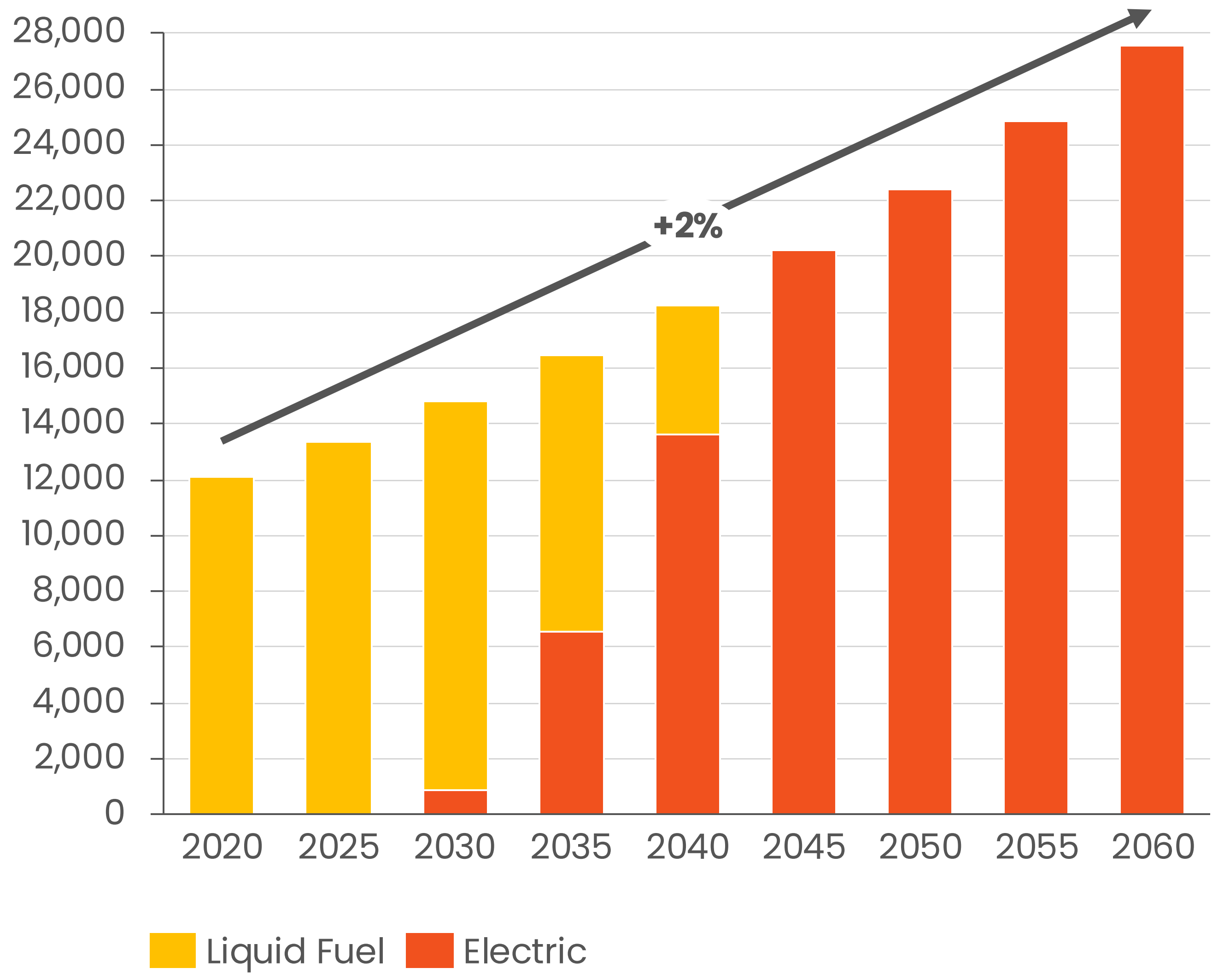
- By 2040, liquid fuel use drops significantly, while electricity and hydrogen use grows.
- Most transport energy will come from electricity, with hydrogen playing a supporting role.
- The sector sees a massive shift from fossil fuels to renewable energy sources.
- Efficiency improvements lead to a reduction in overall energy demand despite growing transportation needs.

Underlying assumptions

- Widespread adoption of electric vehicles (EVs) across all transport modes by 2050.
- Hydrogen infrastructure will grow to support sectors like heavy-duty trucking and aviation.
- Efficiency gains in EV technology will help reduce overall fuel consumption.

Electric cars would drive the transition in 4 wheelers

Total Cars by engine type – '000 units



Key insights

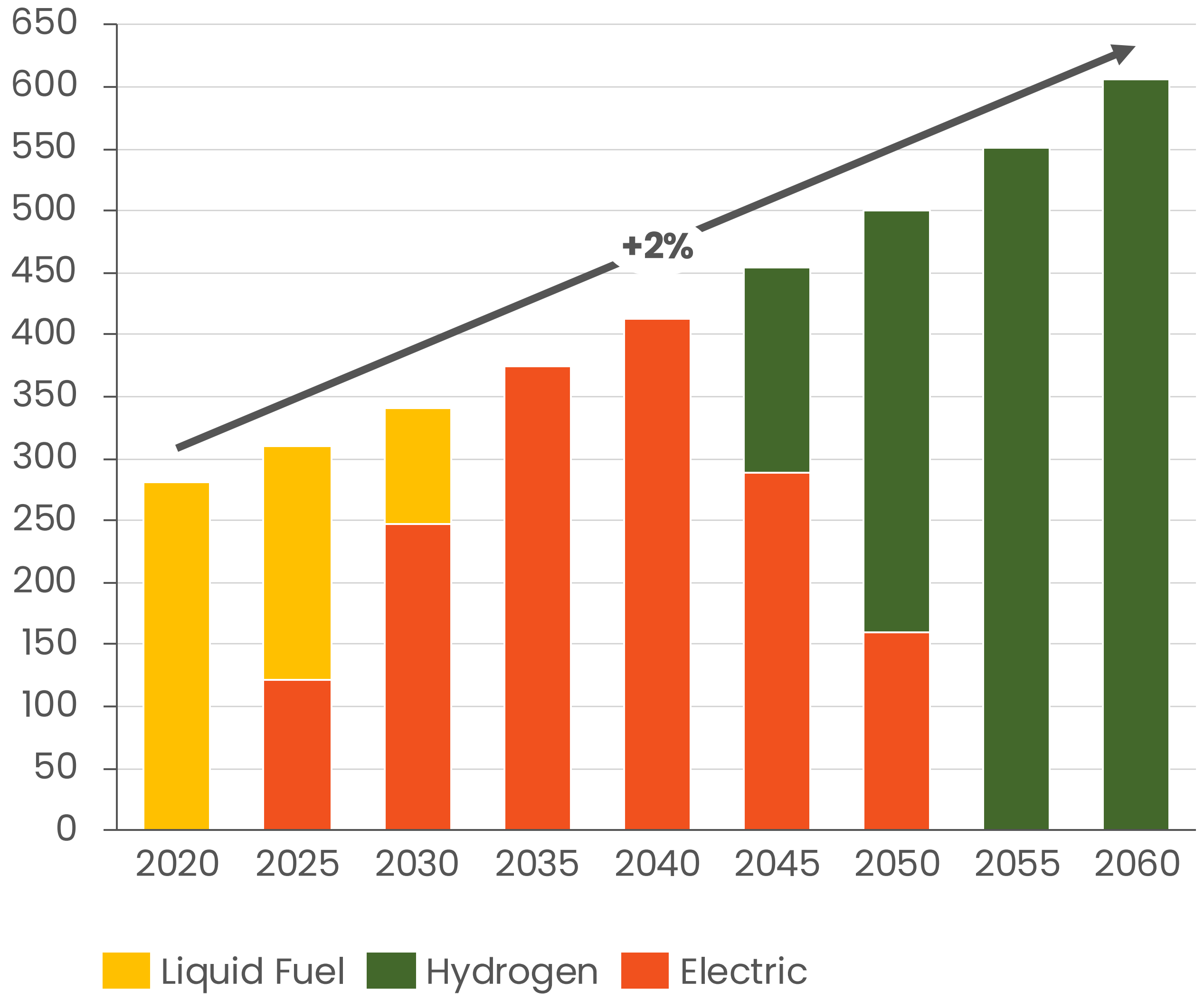
- The number of cars will continue to grow, with a significant shift toward electric vehicles (EVs) by 2060.
- By 2060, nearly all cars will be electric, with fossil fuel cars phased out after 2045.
- Fossil fuel-based cars rapidly decline post-2035 as EV technology becomes mainstream.
- The transition reflects strong support for EV infrastructure and policies.

Underlying assumptions

- Incentives, regulations, and charging infrastructure investments will drive the transition.
- Advances in battery technology will make EVs more accessible to a broader market.
- Fossil fuel-based cars will be phased out as stricter emissions regulations take effect.

Freight trucking needs could be supported by both electric and hydrogen fuel cell vehicles

Total Trucks by engine type – ‘000 units



Key insights

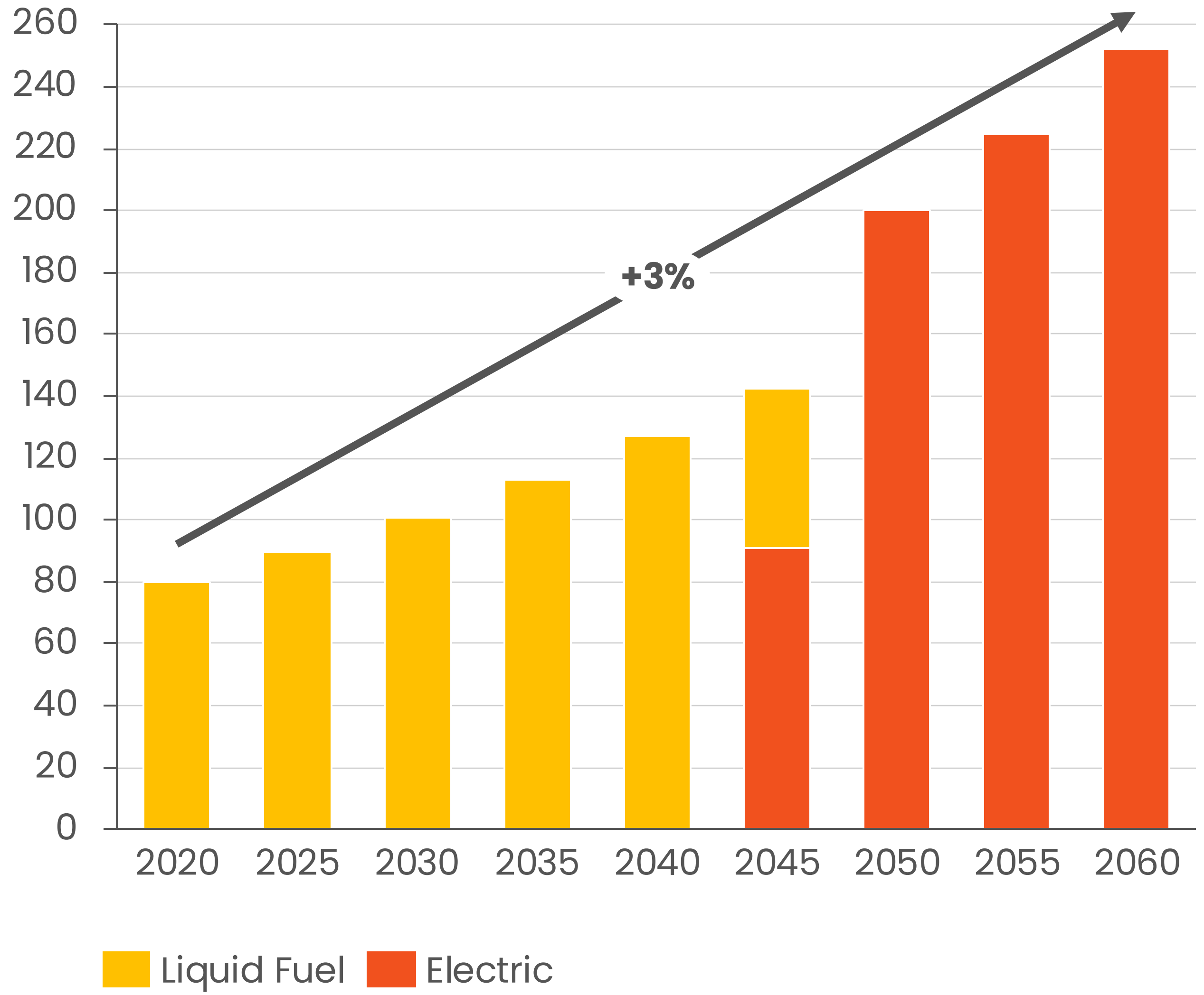
- Hydrogen and electric trucks increase steadily from 2035, replacing fossil fuel-based trucks.
- Hydrogen dominates heavy trucking by 2060, with full electrification for light trucks.
- Truck ownership increases steadily, supporting growing freight demands.
- Fossil fuel-based trucks are phased out after 2045, reflecting stricter emissions targets.

Underlying assumptions

- Hydrogen trucks will be necessary for long-haul and heavy-duty applications.
- EV and hydrogen infrastructure will expand to support the growing fleet of clean trucks.
- Regulatory pressure on truck emissions will drive fleet transitions.

Buses

Total Buses by engine type – ‘000 units



Key insights

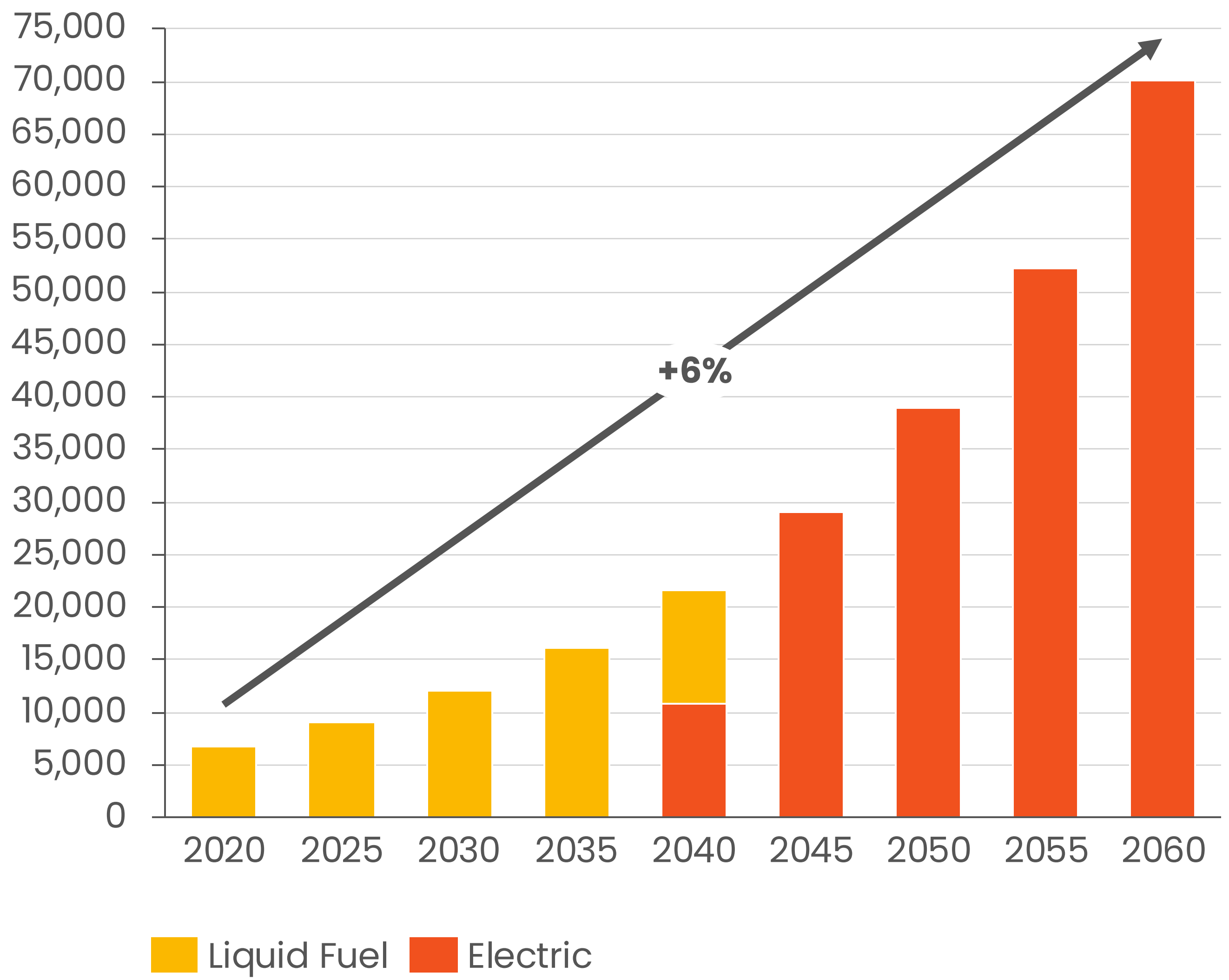
- Public transportation demand continues to grow, with electric buses dominating by 2060.
- All buses are projected to be electric by 2055, phasing out fossil fuel buses.
- The share of electric buses increases significantly from 2035 onwards.
- The bus sector becomes a major player in transport decarbonization efforts because of modal shift and improvement in the public transportation.

Underlying assumptions

- Government investment in electric bus infrastructure will drive adoption.
- Public transit policies will support the shift to electric buses through incentives and stricter emissions regulations.
- EV technology will continue improving, making electric buses more reliable and cost-effective than liquid-fuel alternatives.

2/3 Wheelers

Total 2/3 wheelers by engine type – ‘000 units



Key insights

- Electric 2/3 wheelers grow significantly from 2040 onward, surpassing fossil fuel models by mid-century.
- Total units increase rapidly, driven by electrification and growing demand for 2/3 wheelers.
- The shift to electric vehicles is clear after 2040, with fossil fuel 2/3 wheelers phased out by 2055.
- Electric 2/3 wheelers are likely to be favored in urban areas due to affordability, efficiency, and reduced emissions.

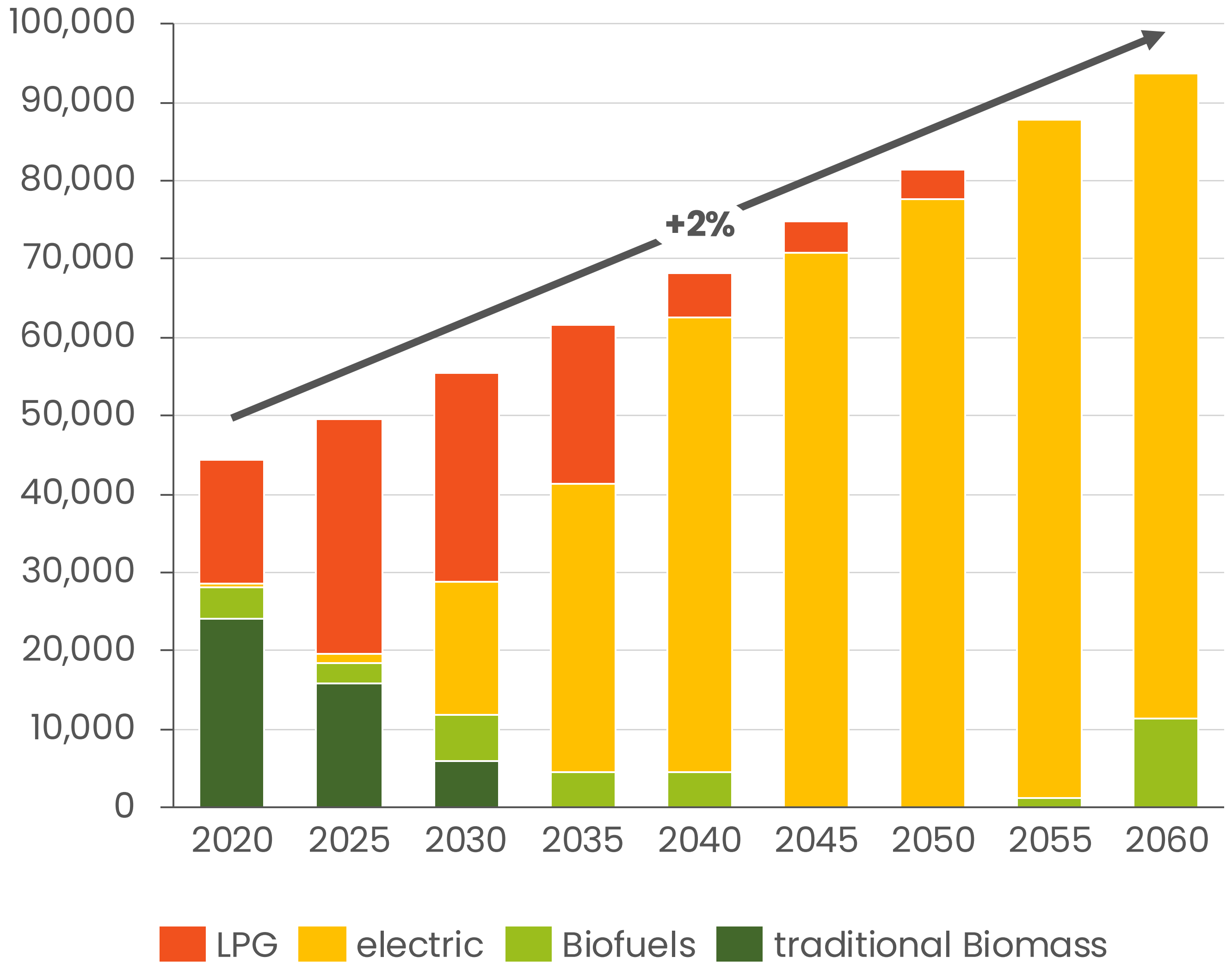
Underlying assumptions

- Support for EV infrastructure and incentives for electric 2/3 wheelers will accelerate adoption.
- Improvements in battery range and charging infrastructure make electric 2/3 wheelers more viable for consumers.
- Increased urbanization drives demand for cost-effective, clean transportation solutions like electric 2/3 wheelers.

Nigeria Energy Transition & Investment Plan Update

Adoption of e-stoves drives decarbonization of cooking sector

Total cooking demand ('000 Units)



Key insights

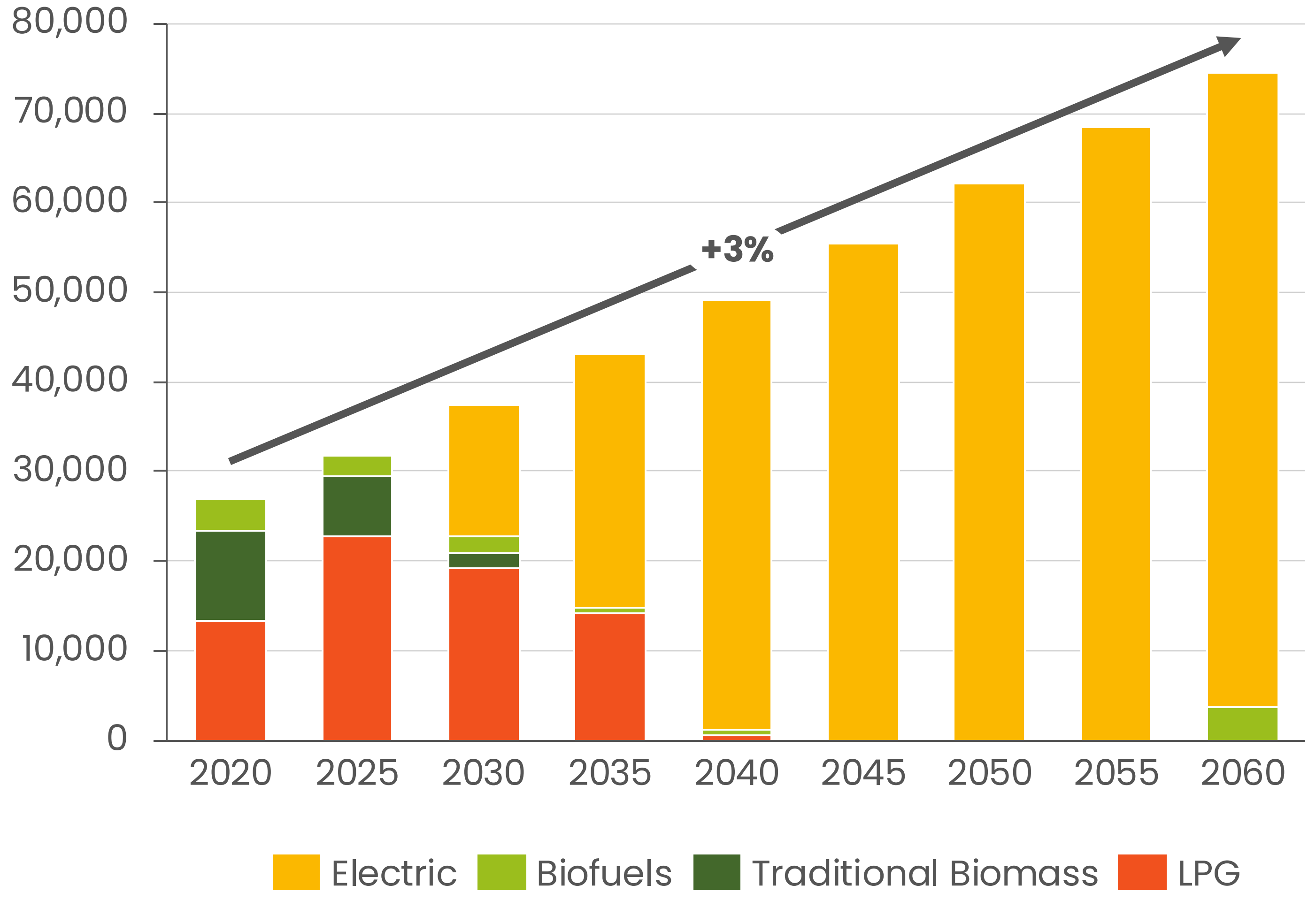
- Demand for electric grows 3-fold between 2030-2060, as universal access to electricity is being achieved
- Demand for LPG stoves peaks in 2030 and is phased out in the early 2050's, as e-cooking becomes more available
- Demand for biofuels is limited, but constant throughout the decade, as they serve as a cheaper alternative to LPG and E-stoves.
- Traditional biomass is phased out in 2030, and is mostly prevalent in rural areas

Underlying assumptions

- Universal access to energy is achieved by 2030
- Reliable infrastructure for LPG and electricity distribution in urban and rural areas
- Policy and financial incentives to offset high premium cost of LPG and e-stoves
- Latest population projection is based on UN SSP2 scenario, which estimates a population growth by 2-fold between 2020-60.

Total cooking demand in urban areas increase by ~65% over the three decades

Urban Cooking demand, (‘000 units)



Key insights

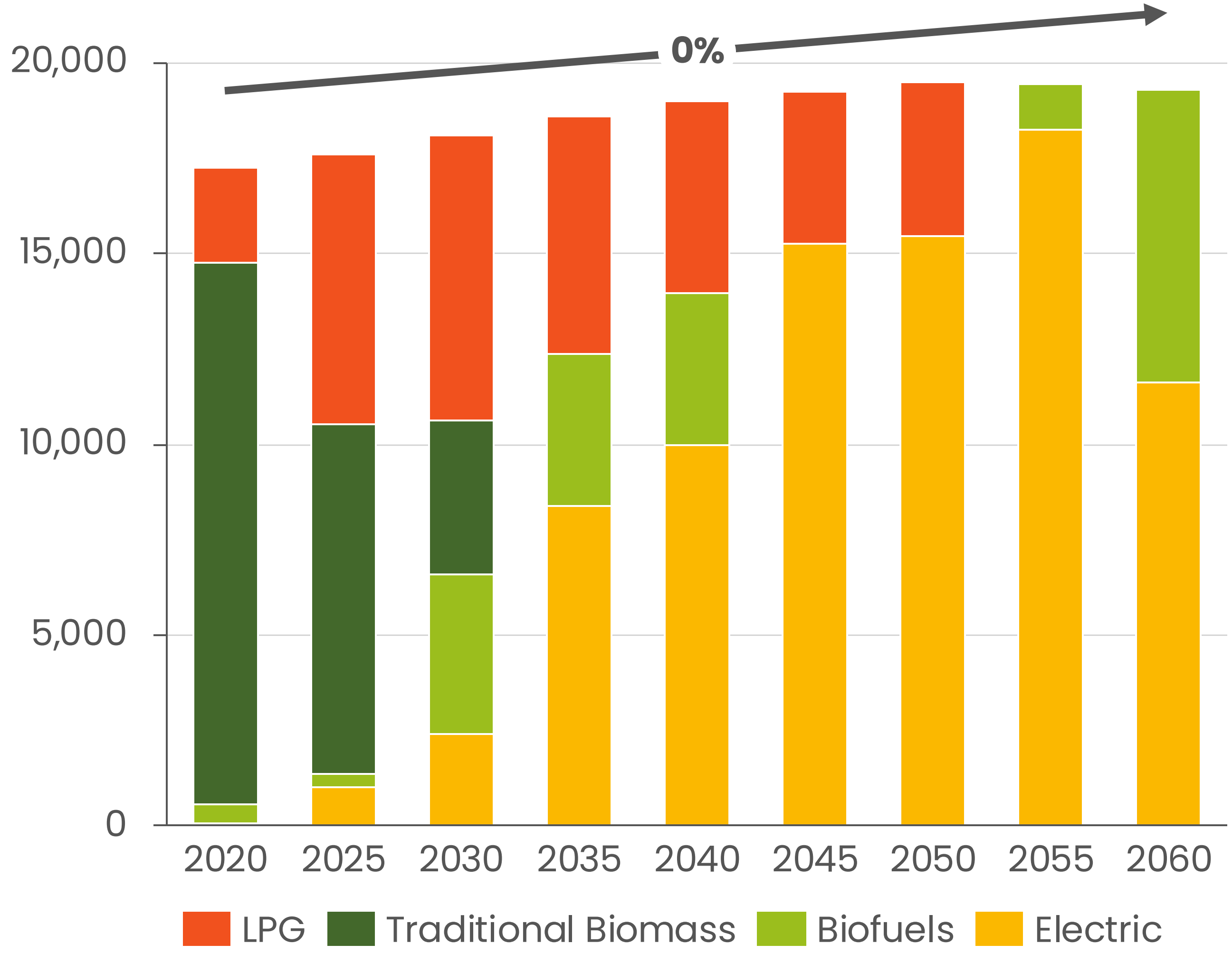
- Total cooking demand in urban areas grows in line with expected population growth
- By 2060, **90% of urban households are supplied by electric stoves**.
- A minority of the population likely leaving in peri-urban areas, is still using biofuels until 2060, likely as a cheaper alternative to LPG and e-stoves.
- **LPG stoves are phased out by 2040** in line with goals of NZE by 2060 but play an important role as a transition technology in the first decade
- **Traditional biomass stoves are phased out in 2030**, as LPG and e-stoves becomes more available.

Underlying assumptions

- 100% electricity in urban and peri-urban areas by 2030.
- Reliable and stable grid in urban areas to accommodate e-cooking load demand
- Financial incentives to reduce the premium of high costs stoves, especially in the first two decades

Cooking demand in rural areas sees a limited demand due to a high urban migration rate

Rural cooking demand ('000 units)



Key insights

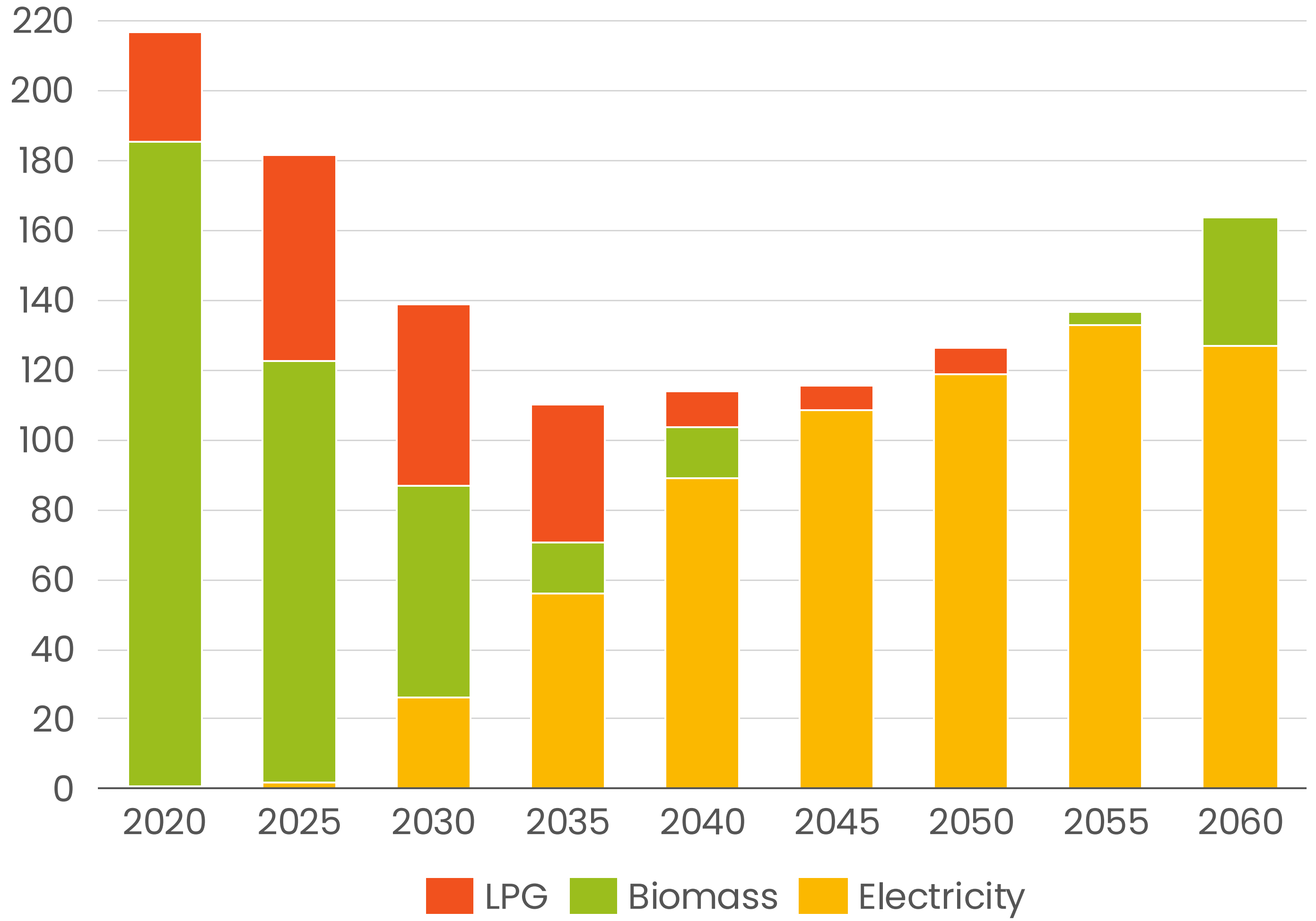
- From 2040 and onwards, **>50% of the total rural households are using e-stoves**
- LPG stoves are phased out by 2050, but **plays an important role as alternative to the more expensive e-stoves** in the earlier decades
- Biofuels also play an important role as **affordable alternative to e-stoves and serves 40% of total rural population in 2060**.

Underlying assumptions

- Urbanization rate of 70% by 2050s, as estimated by UN Habitat, pointing to a high urban migration
- Reliable infrastructure to LPG distribution in rural areas.
- Financial incentives to enable the affordability of high costs stoves, especially in the first two decades

Total fuel consumption decrease by 20% driven by more efficient stoves in the market

Total Fuel demand (Pj)



Key insights

- Electricity takes the lion's share of cooking fuel consumption, **and grows 3-fold between 2030-60**, as universal electrification is achieved.
- **LPG peaks at 58 PJ in the mid-20's and is phased out by 2050**, as households move towards cleaner options
- **Biomass consumption is an important fuel until 2030,** mainly due to rural households' reliance on traditional biomass.
- **After 2030, biomass consumption is driven by biofuels** (biogas, ethanol, improved charcoal …etc), peaking at 36 PJ in 2060.

Underlying assumptions

- Enabling policy and financial incentives for energy efficient stoves.
- 100% electricity in urban and peri-urban areas by 2030.
- Reliable and stable grid in urban areas to accommodate e-cooking load demand

Nigeria Energy Transition & Investment Plan Update

A green leap forward: approx. $ 500 billion USD will be required in capital investments across different sectors for Nigeria to reach Net-Zero by 2060 above BAU

Investment, selected projects (Net-Zero)		Cumulative Total Investment, Billion USD	
Sector	Project archetypes	2020-2040	2040-2060
Power	Grid and off-grid generation technologies incl. renewables, O&G; battery storage	138.4	264.3
Transmission and Distribution	Transmission and distribution extension and upgrades	77.5	162.5
Industry	Clean high and low-temperature heating processes including in steel and cement industries	7	34
Clean Cooking	Clean cookstoves and fuels	6.7	8.7
Transport	Electric two-wheelers, cars, buses, trucks including heavy road machinery for agriculture	193.9	410.2
Hydrogen	Green & Blue hydrogen for storage and industrial processes	9.2	56
Total		**432.7**	**935.7**

Financing a Net-Zero 2060 Pathway

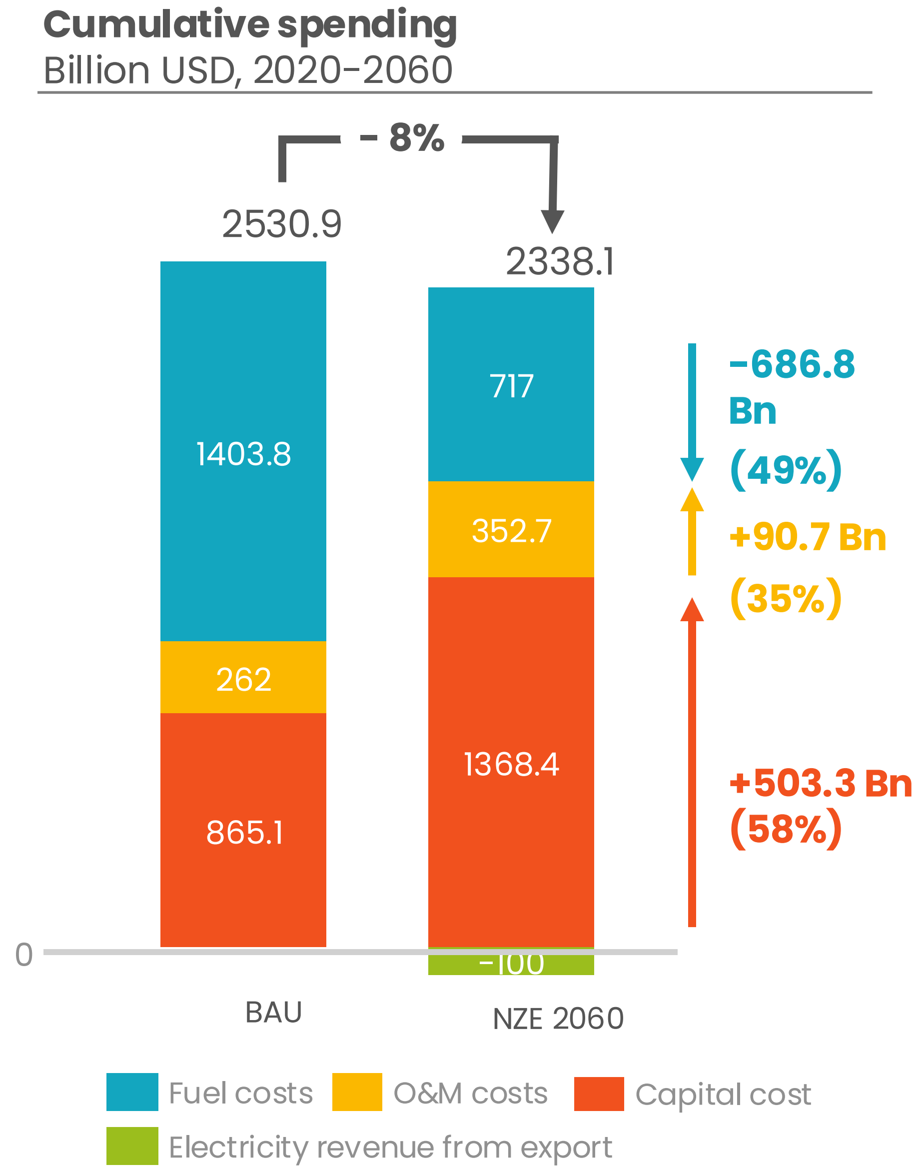
Nigeria will require approx. 500 Bn USD (above BAU) to achieve Net-Zero emissions in the power sector and sustainably power various sectors to meet social and development targets in industry, transport and clean cooking.

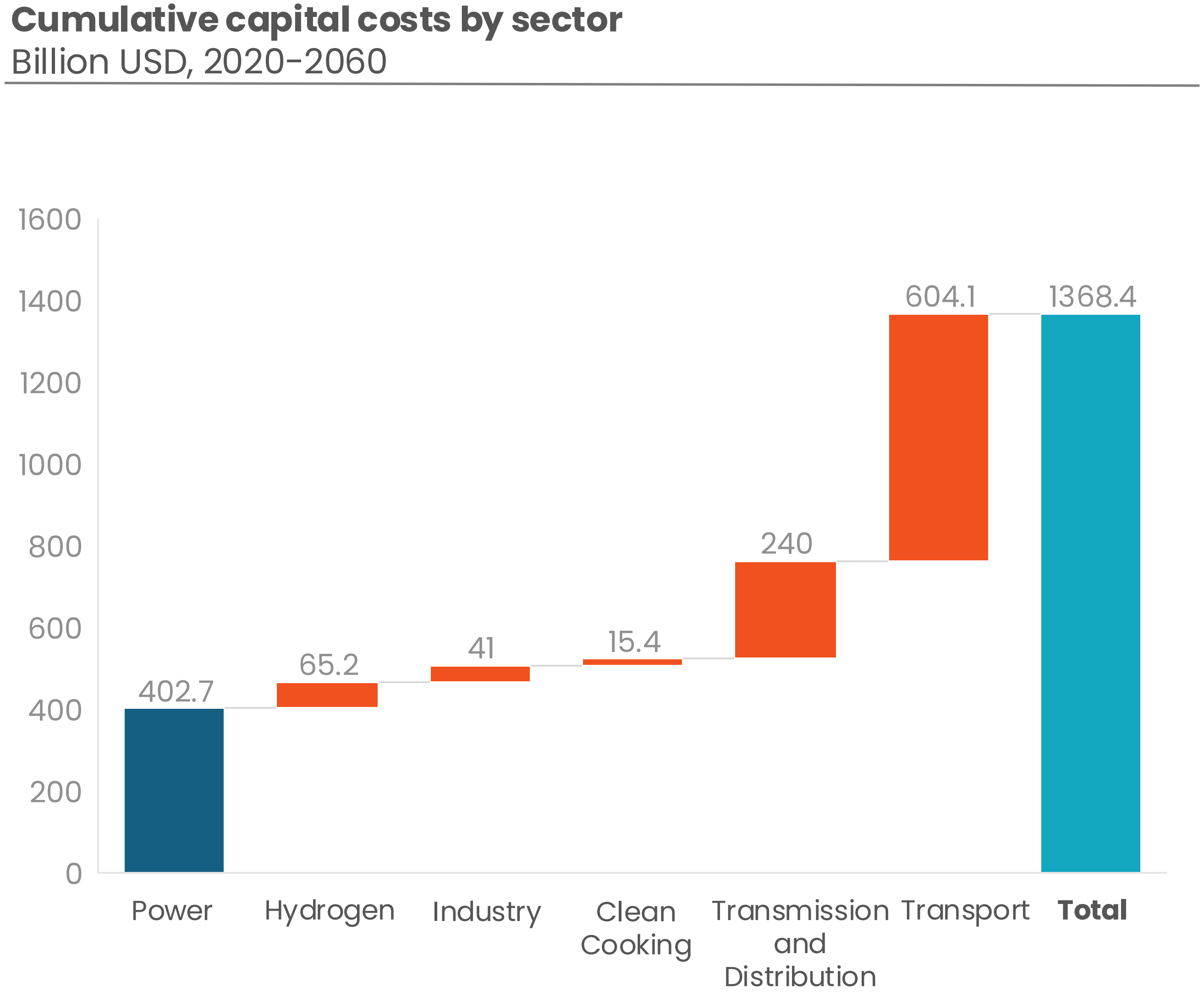
Financial Partnerships

Core finance providers and de-risking instruments from international institutions

- Households and individuals
- Corporate and Private Sector
- Public institutions
- Green finance funds and pension funds
- Private foundations

Net Zero Pathway Requires 56% More Investment But Saves $686B in Fuel Costs compared to BAU.





Smart Capital: Unlocking Value in Nigeria's Net Zero Investment Plan

Nigeria's transition to Net Zero presents a distinctive investment opportunity that requires careful financial structuring. While the transition demands significant front-loaded investments, it delivers substantial long-term savings compared to a Business as Usual (BAU) scenario. This financial dynamic creates unique opportunities for innovative financing approaches while requiring careful risk management.

Investment Profile

Financing would need to be structured across two major phases with a majority of efforts required in the power and transport sectors. The initial phase focused on universal energy access, running from 2020 to 2040, requires a mobilization of $432 billion to establish critical and foundational infrastructure and systems. This would then need be scaled up with an additional $935 billion through 2060 for Nigeria to successfully transition to Net-Zero by 2060. This phased approach allows for gradual market development while recognizing the urgency of early action in expanding critical infrastructure and propel Nigeria’s development trajectory.

Cost-Benefit Analysis

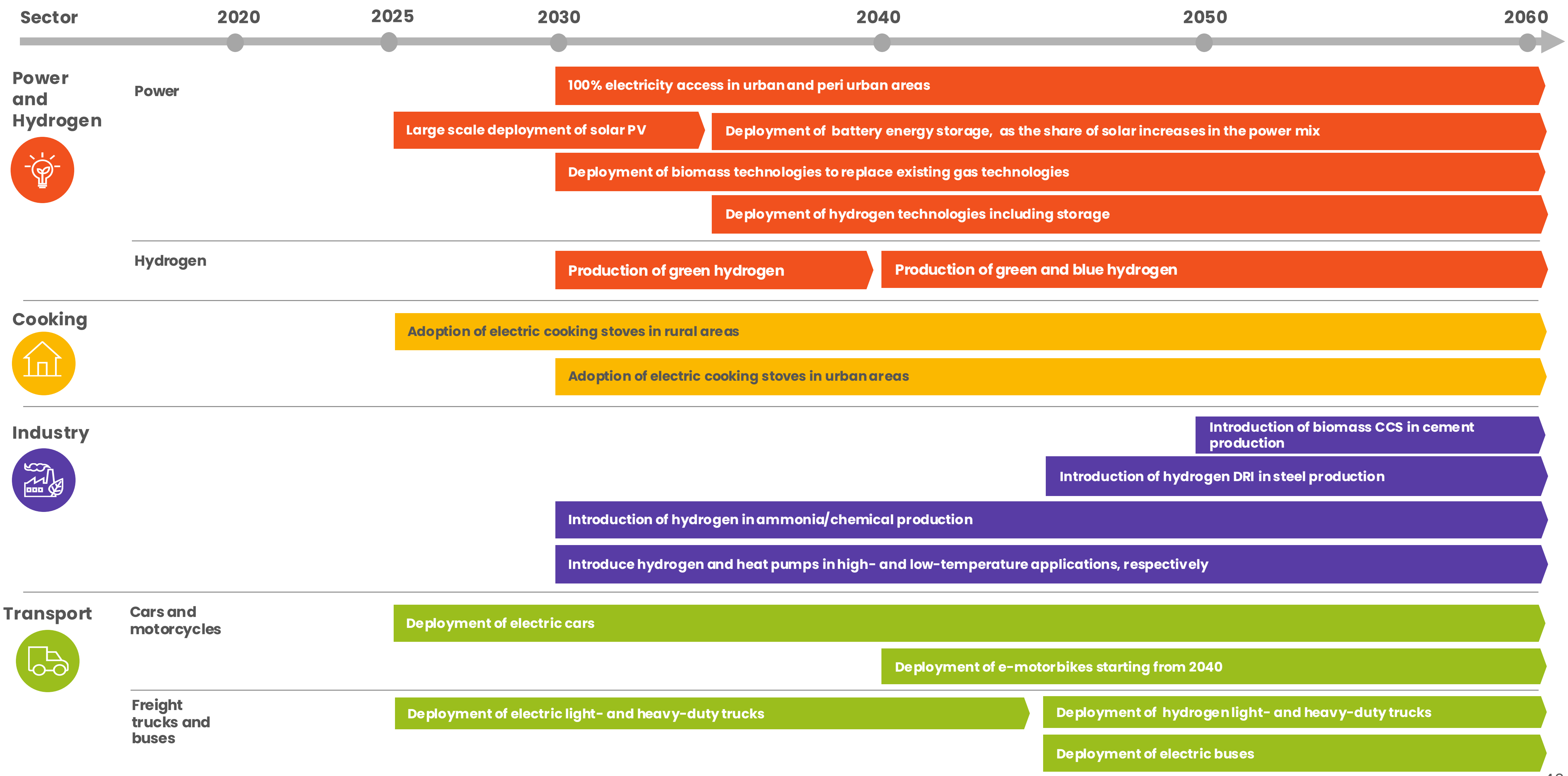
Despite the higher capital requirement, the economic case for this transition is compelling and promotes massive fuel savings. The investment generates $686 billion in fuel cost reductions over the period, delivering a net saving of 8% on total expenditure. These operational savings provide a strong foundation for structuring long-term financing mechanisms and demonstrate the commercial viability of the transition.

Financial Structuring and implications

Successfully raising the capital will require different approaches and will be dependent on several risk mitigating factors. Blended finance approaches will be essential to manage risk-return profiles across different project types. Phased capital deployment strategies would also be required to align with technology maturity curves and market development. Sector-specific financing instruments will need to accommodate varying project scales and revenue models. Risk-sharing mechanisms will be crucial for attracting private capital, particularly in early-stage technologies. Finally, the long-term nature of returns requires patient capital with appropriate governance structures.

Nigeria Energy Transition & Investment Plan Update

Major technology and policy milestones to be met for Nigeria's Energy Transition to be achieved by 2060



There are barriers to be addressed across sectors to enable a Green Growth Future (1/7)

Sector	Barriers	Potential Actions

Oil & Gas	• Global O&G demand shifts
	• Upfront costs for reducing upstream emissions
	• Perceived reduction in Govt revenue decrease
		▪ Global oil and gas demand reduction due to the global net zero emissions movement
		▪ Reduce fugitive emissions in oil and gas
		  • Instrument air systems
		  • Vapor recovery unit(VRU) on storage tanks
		  • Replace compressor rod packaging
		  • Quarterly leak detection and repair (LDAR)
		▪ Reduce flaring and venting in oil, driven by the Nigeria Gas Flare Commercialization Programme (NGFCP)
		  • Improve flaring efficiency
		  • Export gas through pipeline
		  • Repurpose gas
		▪ Fuel use efficiency in oil and gas production
		  • Increase run time of key equipment
		  • Equipment optimization through AI
		  • Upgrade simple cycle gas turbine (SCGT) to combined cycle gas turbine (CCGT)
		  • Steam boiler electrification
		  • Process electrification
		  • Electric motor
		▪ Deploy CCUS in refining

There are barriers to be addressed across sectors to enable a Green Growth Future (2/7)

Sector	Barriers	Potential Actions
Power	• Significant electricity access gap • Unreliable grid supply and affordability • High transmission and distribution losses and lack of capacity • High system costs and low investor attraction • Regulatory uncertainties for project development • Lack of energy transition planners	**Capacity and Generation expansion plan:** ▪ Accelerate the deployment of mini-grids, SHS , and grid densification for 100% electricity access by 2030. ▪ Install decentralized technologies in locations closer to the demand load centers to decrease distribution costs and provide more reliable electricity and closer to the national grid to be connected in the future ▪ Deploy T&D capacity and extension particularly to service manufacturing and industrial zones ▪ Implement a national losses reduction program on reducing the transmission and distribution losses, ▪ Streamline the permitting process for power projects development , particularly focus on clean energy technologies ▪ Deploy a smart metering program for accurate billing and load management by the utilities. ▪ Develop an energy and climate resilient power system that has diverse energy sources and can withstand extreme weather events. ▪ Develop a National Green Hydrogen Mission ▪ Improve the utilization of existing power plants

There are barriers to be addressed across sectors to enable a Green Growth Future (3/7)

Sector	Barriers	Potential Actions
Power	• Significant electricity access gap • Unreliable grid supply and affordability • High transmission and distribution losses and lack of capacity • High system costs and low investor attraction • Regulatory uncertainties for project development • Lack of energy transition planners	**Enhance Policy, Strengthen Regulations and Institutional Framework:** ▪ Develop clear, transparent regulations for energy generation and distribution, encouraging competition and investment in the sector. ▪ Develop standards and labeling program for main energy consuming appliances such as motors, pumps, air-conditioners, fans, cookstoves etc. ▪ Examine a comprehensive policy for developing sustainable biofuels in the country ▪ Develop policies that encourage private sector participation in renewable energy projects, such as tax incentives, subsidies, or guaranteed power purchase agreements (PPAs). ▪ Ensure that electricity tariffs are cost-reflective but also consider affordability for low-income households. ▪ Educate consumers about energy-saving practices and the benefits of energy-efficient appliances. ▪ Strengthen capacity of the energy transition planning within the energy planning units of the government.

There are barriers to be addressed across sectors to enable a Green Growth Future (4/7)

Sector	Barriers	Potential Actions
Cement	• Calcined clay adoption for clinker production • High upfront investment for improving process efficiency • High captive power generation using fossil fuels assets	▪ Create incentive-based programs for cement producers to switch to calcined clay clinker substitution. For example, a technical standard in public procurement or projects. ▪ Support cement industries to undertake periodic energy audits and implement energy efficiency projects. ▪ Introduce national energy efficiency standards for boilers, motors and compressed air systems for easier adoption of such equipment in the industries ▪ Incentivize captive power generation in cement industries ▪ Supporting waste to heat energy projects for process heat applications ▪ Demonstrating CCS projects in the cement industries with international cooperation
Steel	• Scrap steel-oriented industry profile • Virgin steel is not produced	▪ Incentivize virgin steel production with green steel technologies ▪ Scrap steel industry energy efficiency roll-out program to improve process efficiency

There are barriers to be addressed across sectors to enable a Green Growth Future (5/7)

Sector	Barriers	Potential Actions
Other Industry	• Insufficient investment capacity of small industries • Dependence on diesel generators • High operational costs • Unreliable grid electricity	▪ Further the development of industrial zones and special economic zones (SEZ) to attract investment and boost industrial production along with incentives for energy and resource efficiency manufacturing ▪ Industrial Energy Efficiency Program developed and deployed ▪ National grid expansion plan prioritizing industries and also incentivizing renewablee captive generation could reduce reliance on diesel generators and lower operational costs, making industries more competitive. ▪ Incentives for adopting clean heat technologies in the manufacturing sector is crucial for reducing carbon emissions and enhancing sustainability. ▪ Developing skilled labor to support modern industries. Investment in education, vocational training, and technical skills will be necessary to build a workforce capable of handling advanced technologies and higher-value industrial production.

There are barriers to be addressed across sectors to enable a Green Growth Future (6/7)

Sector	Barriers	Potential Actions

Cooking	• High capital costs to e-cooking and social reluctance
	• Dependence on traditional biomass in rural area
	• Vulnerability of LPG price volatility
	• Low consumer awareness
	• Limited market for biofuels
	• Lack of financial mechanisms
		▪ A holistic clean cooking strategy that reviews the various solutions available that is viable for adoption and can be balanced to also provide co-benefits associated to clean cooking (e.g.: support to a better health, climate & environment, and gender & livelihood).
		▪ Prioritize the implementation of the Electricity Sector Reform Roadmap to facilitate a switch to e-cook stoves.
		▪ Develop national strategies and targets for the following:
		  o Securing supply chains of modern and cleaner fuels through an integrated resource planning approach.
		  o Support the development of a market for biofuels such as ethanol or biogas, via R&D of local opportunities for conversion and distribution of biowaste to energy.
		▪ Develop regulations and frameworks to enable a carbon credit financing targeting private sector, to empower them to invest in cleaner, efficient and more affordable cooking technologies.

There are barriers to be addressed across sectors to enable a Green Growth Future (7/7)

Sector	Barriers	Potential Actions
Transport	• High initial costs of EVs • Limited public transport options • Inadequate charging infrastructure • Poor vehicle fuel economy • Skills gap in EV technology • Limited job opportunities in green industries	▪ Introduce tax incentives for purchase of electric vehicles, particularly in the 2/3-wheeler segment to be competitive to 2/3 wheelers based on ICE (internal combustion engine). ▪ A public e-bus transport policy with additional incentives for public transport operators to transition to electric buses. ▪ Provide tax deductions or exemptions for companies that invest in developing EV charging stations and related infrastructure. ▪ Introduce fuel efficiency standards for passenger cars to be aligned with major export markets to ensure that new and used vehicles in the country meet certain minimum fuel economy standards. ▪ Introduce biofuel mixing into conventional fuels with progressive standards ▪ Policy on quality checking of import of used vehicles ▪ Partner with technical institutes and universities to create specialized certification programs for EV technology, renewable energy systems, and green infrastructure development..

Nigeria Energy Transition & Investment Plan Update

How we build an Energy Transition and Investment Plan

An optimized pathway that delivers a tangible implementation and investment plan

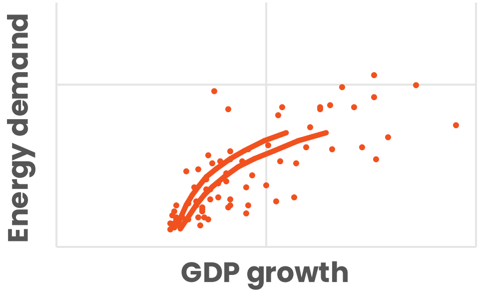
Simplified

The Energy Transition and Investment Plan...

Applies cost-effectiveness analysis to identify the clean tech options across all major demand-supply sectors...

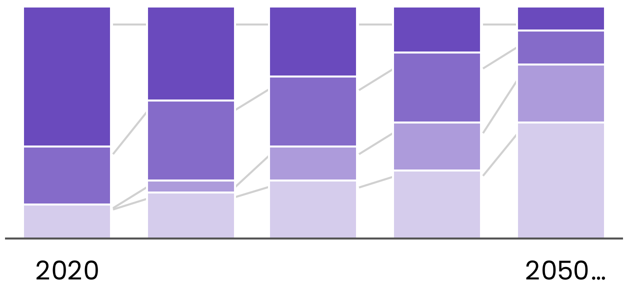
- Power
- Hydrogen
- Industry
- Transport
- Buildings and other energy

...to lay out how to achieve GDP and population growth in a low-emission way...



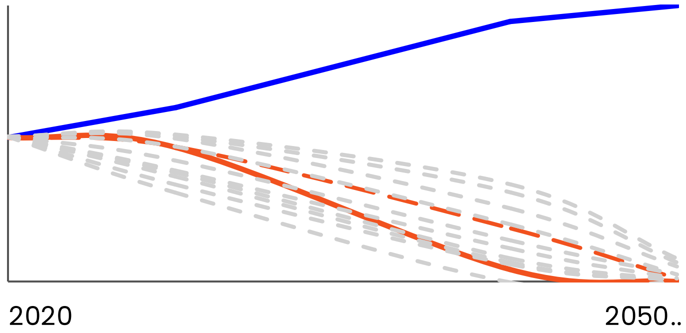
...assessing the implications of rapid innovation in clean tech for optimized adoption rates and technology mix per segment...

Technology penetration over time, per segment



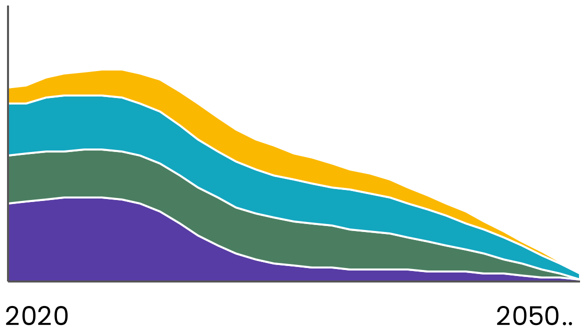
...and testing alternative scenarios to explore more rapid climate action...

Emissions, per scenario



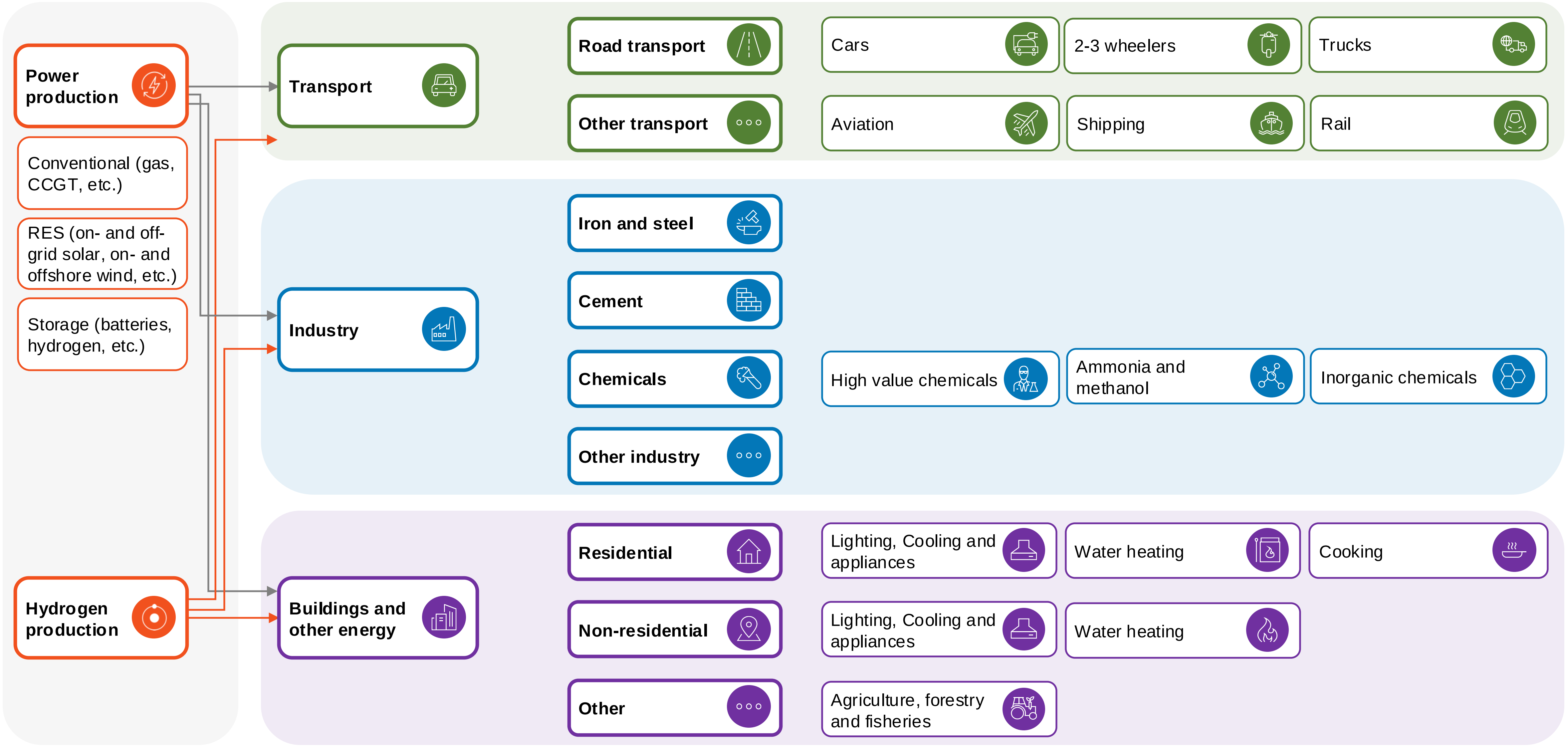
...to output the total GHG emissions and fuel demand of the optimized pathway...

Emissions, per sector



... as well as a tangible implementation and investment plan, compared with investment needs under business-as-usual

Insights through a comprehensive energy system model (SEforALL energy model) that is robust , fast learning curve, and open-source approach



*SEforALL energy model (SEM) is based on OSeMOSYS

ETP approach – Oil & Gas (O&G) Sector

Scope of evaluation from emissions perspective

Upstream production supplies the downstream uses.

Upstream:

Extraction, processing, transportation to end users

Downstream:

Combustion by end users

- The ETP approach for the O&G sector is to decouple the reliance on imported fossil fuels by diversifying the economy using cheaper renewable sources.
- This allows more O&G resources available for export ambitions
- BAU scenario is no domestic decarbonization policy but that does not mean there are no global shifts.

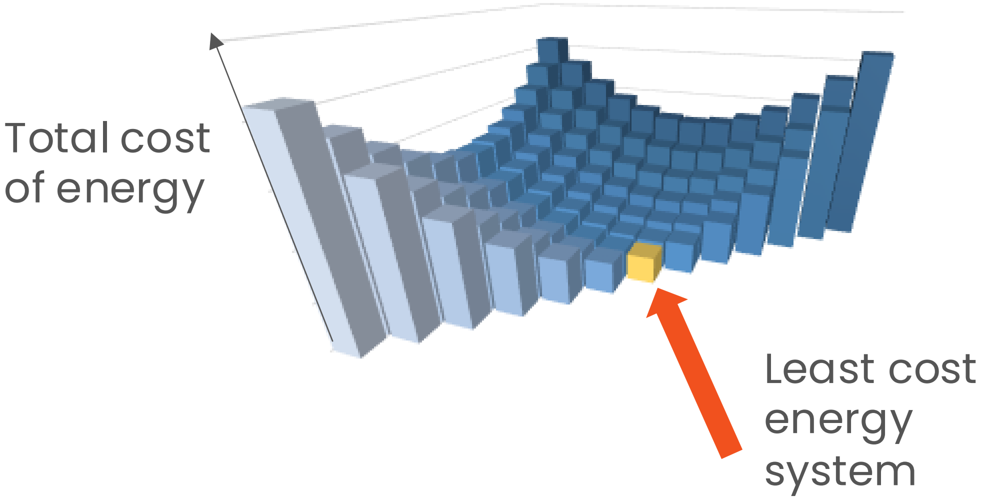
- Upstream emission factor for natural gas (natural gas production) considered is 0.0108 Mt CO2eq/PJ
- Upstream emission factor for oil (oil production) considered is 0.0158 Mt CO2eq/PJ
- Oil and gas activity values (total demand) are multiplied by their respective emission factors to obtain the total emissions from the O&G sector.

SEM develops realistic and coherent scenarios for the global energy system

SEM simulates the current and future global energy system through linear optimisation.

- uses linear optimisation to simulate how policymakers and markets will drive economic energy outcomes
- embeds socio-political and techno-economic feasibility into the scenarios
- based on OSeMOSYS (open-source energy modelling system)

Solution space



SEM minimises the cost of simultaneously meeting energy demand and climate outcomes

- Capital costs
- Energy costs
- Carbon costs

While ensuring a high degree of feasibility and realism

Socio-political preferences

- Most likely climate policies
- Public opinion on key technologies e.g. carbon capture and storage

Technoeconomic feasibility

- Market and supply chain scale up (e.g. hydrogen)
- Resource availability (e.g. biomass)

ETP approach – Cooking Sector

Prevalence of stove type

- To understand baseline scenario and potential future demand.
- Considers energy efficiency, CO_2 emissions and costs (CAPEX/OPEX)

Population growth

- Projected population based on the Shared Socio-economic Pathway scenario 2.
- This is a 'middle-of-the-road scenario' where developing countries reach today's average income levels of the OECD by around 2060–2090

GDP per Capita growth

- Used to sense check our assumption and make sure our projected data is on a par as the global GDP per capita growth

SEM Demand Forecasting Methodology

There are different approaches for forecasting, shown through the relationship between a country's GDP per capita and the variable to be forecasted.

- Polynomial fit: Captures the relationship between demand and income (GDP per capita).
- GDP and population growth method: Based purely off GDP and population growth of a country and may lead to values outside international norms.
- International experience-based method: Aligns forecasts with global trends.

SEM Methodology: Forecasting Based on Polynomial Fit:

1.Identify Relationship Between Demand and Income (GDP per capita)

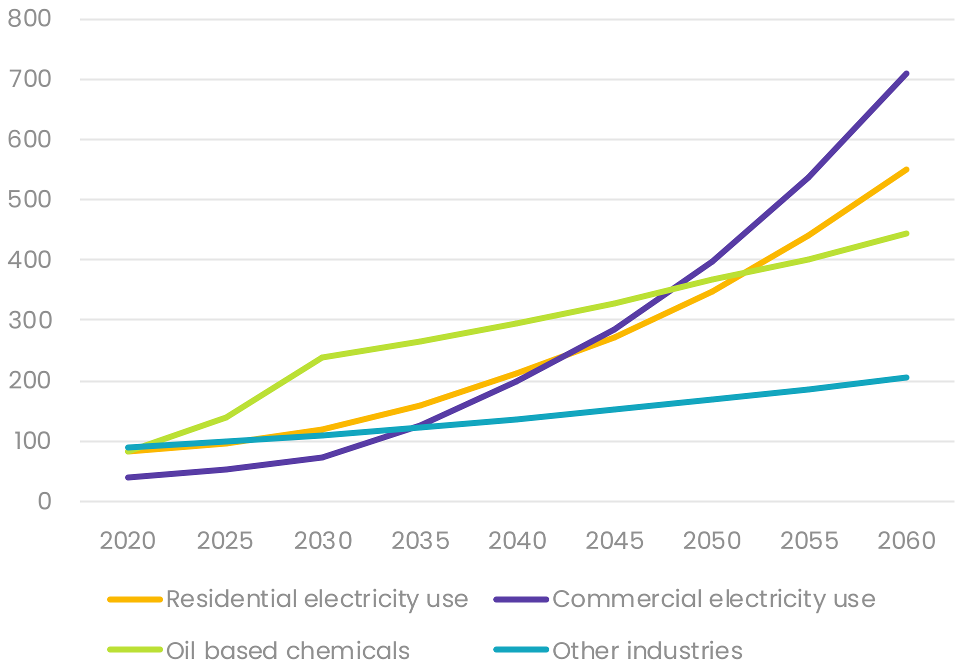
1. Find the relationship between the variable to be forecasted and GDP per capita.
2. The polynomial fit equation with an R^2 value indicates the level of fit between these two factors.
3. This relationship helps to estimate future demand based on a given GDP per capita value.

2.Forecast Demand

1. Derive future GDP per capita (IIASA, World Bank etc.) and assume the growth rate follows that of a typical country.
2. Use the delta to the polynomial fit to calculate changes in demand.
3. The "delta" here refers to the absolute change in demand for a given GDP per capita increase, based on the trend line from the polynomial equation.

Power Sector demand growth in buildings and industries would be driven by GDP

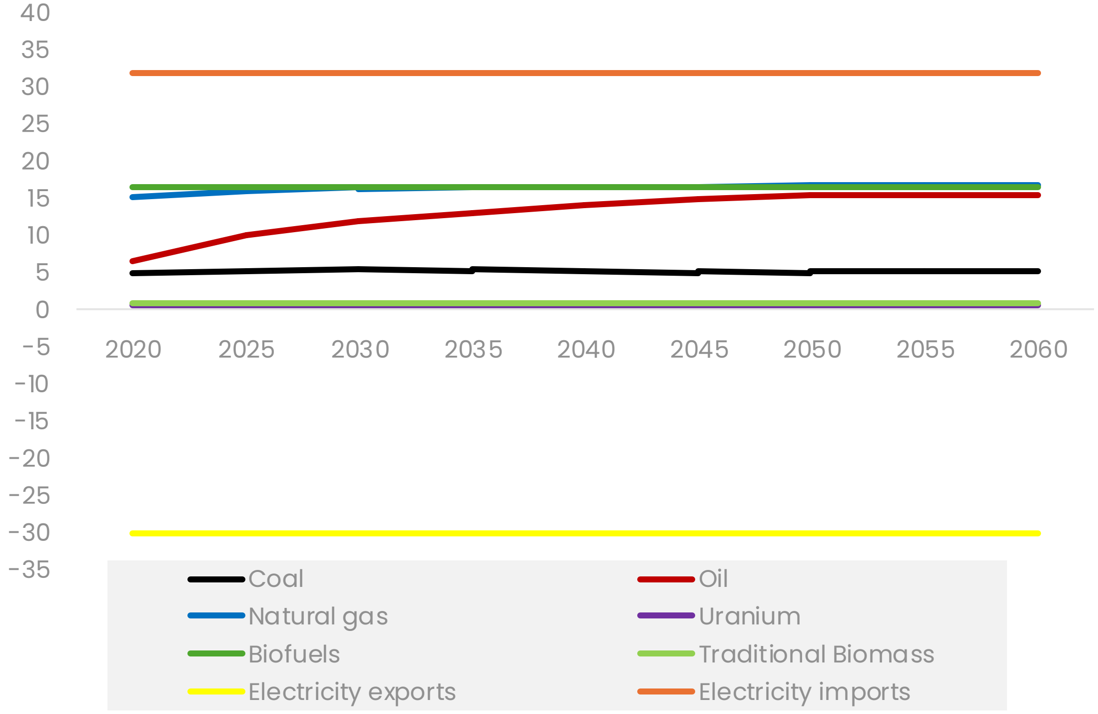
Demand projections per sector, (TWh)



- Population projections are estimated to reach to 474.5 million by 2060
- GDP per capita projections to reach to 8,726 USD
- Total electricity demand in residential, commercial, oil-based chemicals and other industries will reach to 1,910 TWh by 2060

Source: SEforAll analysis

Fuel cost, USD/GJ

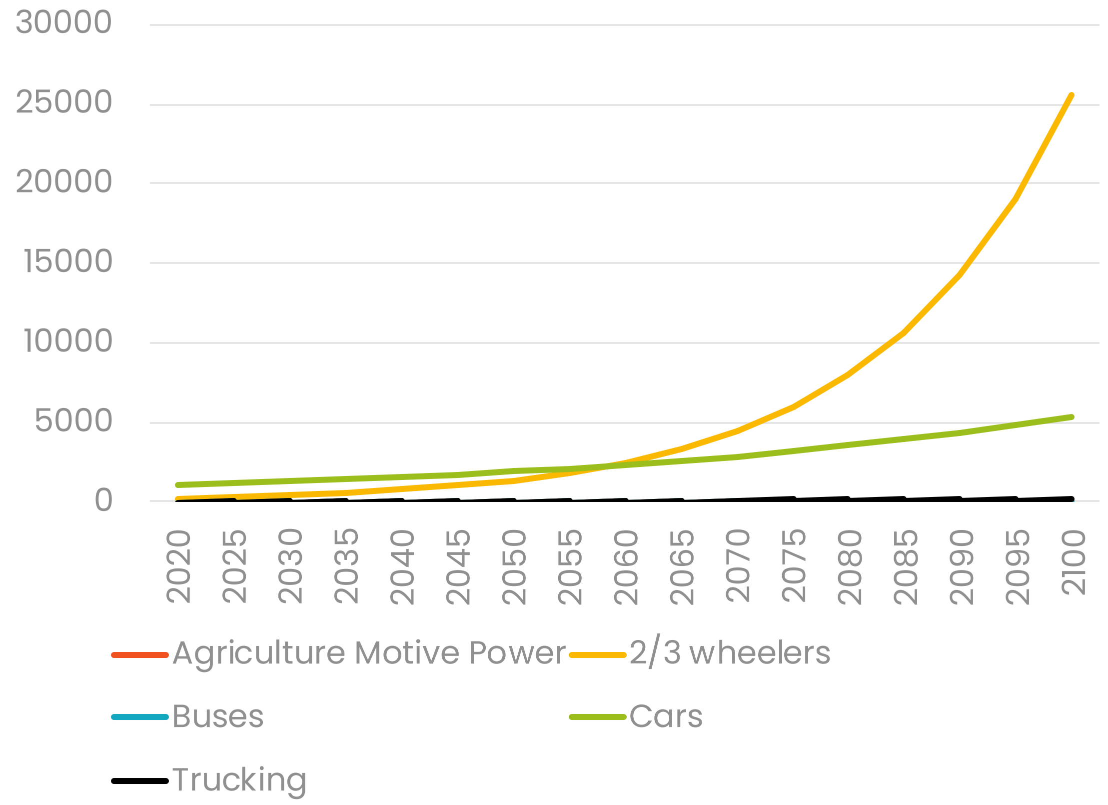


- The fuel costs of natural gas and coal are expected to increase at a similar rate over the modelling period
- Oil prices show an increased growth in the future
- Overall, natural gas and biofuels have the highest fuel costs
- Electricity imports and exports are assumed to be constant over the modelling period

Source: EIA -Annual Energy Outlook

Transport demand to increase with more urbanization and industrialization with increasing GDP per capita

Demand projections per transport mode, bVKM



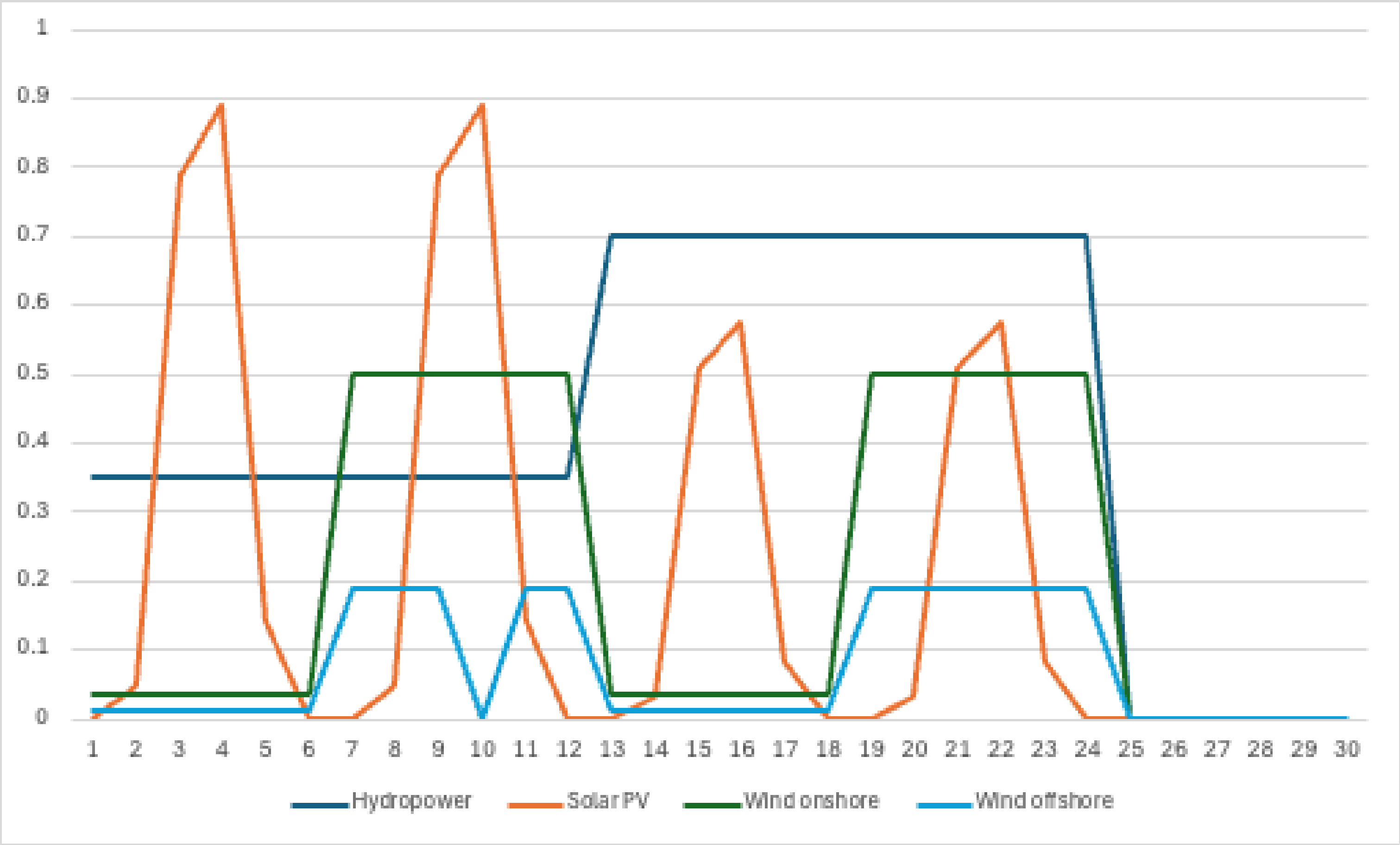
- The transport demand is projected to come mainly from 2/3 wheelers and cars in 2060.
- The demand from agriculture motive power and buses in insignificant.

Parameter	2020	2030	2050
Emissions (MTCO2)	45.71	47.14	28.41
Fuel (PJ)	623.39	651.38	717.58
Emissions for Passenger Cars (MtCO2)	37.38	36.97	18.32
Vkm Passenger Car (billion km)	205.74	252.11	381.20
Vkm 2/3 Wheelers (billion km)	47.00	84.49	272.88
Vkm Trucks (billion km)	9.00	10.91	16.00
Vkm Buses (billion km)	2.00	2.52	5.00
Number Cars (million)	12.10	14.83	22.42
Number 2/3 Wheelers (million)	6.71	12.07	38.98
Number Trucks (million)	0.28	0.34	0.50
Number Buses (million)	0.08	0.10	0.20

Source: SEforAll analysis

Capacity factor of solar PV and wind power plant technologies

Maximum capacity factor of power plant technologies, %



Key insights

- **Time slices** are accounted as:
  - **Dry season** (1-12): December – April, from 1-6 high wind operation while 7-12 low wind operation
  - **Wet season** (13-24): May – November, from 13-18 high wind operation while 19-24 low wind operation
  - **Worst day** (25-30): 1 day no RET
- Overall, hydropower technologies are expected to have a higher maximum capacity than the other RET, at 21% (solar PV), 21% (wind onshore) and 7% (wind offshore) at various timeslices.
- From timeslice 24 onwards, the maximum capacity for RET technologies are expected to be 0%. It is assumed that one day of the year renewables are not available to see how the system will balance the supplied electricity.

Source: SEforAll analysis

Techno-economic assumptions in the power sector

Technologies	Capital Cost (USD/kW)			Fixed operational cost (USD/kW)			Efficiency (%)			Availability factor (%)	Lifetime (yrs)	Resource potential
	2020	2040	2060	2020	2040	2060	2020	2040	2060			
Blue hydrogen production from natural gas	1,680	1,320	1,280	312	215	202	0.7	0.7	0.7	0.95	25	
Electrolyser	923	446	399	50	40	38	0.6	0.7	0.7	0.95	25	
Grey hydrogen production from coal	2,670	2,670	2,670	4	4	4	0.6	0.6	0.6	0.95	25	
Grey hydrogen production from natural gas	910	910	910	134	134	134	0.8	0.8	0.8	0.95	25	
Biomass	3,793	3,594	3,527	110	105	105	0.3	0.3	0.3	0.85	25	29800 PJ
Biomass with CCS	4,485	4,485	4,485	43	43	43	1.0	1.0	1.0	0.85	25	
Coal	1,500	1,500	1,500	377	377	377	0.3	0.4	0.4	0.7	25	
Coal with CCS	5,192	4,384	3,750	45	45	45	0.4	0.4	0.4	0.7	25	
Distributed solar PV	6,510	6,510	6,510	175	145	125	-	-	-	0.95	25	
Hydrogen	900	575	450	14	9	7	0.6	0.6	0.6	0.95	25	
Large hydro	3,200	3,200	3,200	50	50	50	-	-	-	0.95	50	24 GW
Natural gas combined cycle	1,590	1,590	1,590	75	75	75	0.4	0.5	0.6	0.4	25	
Natural gas combined cycle with CCS	2,826	2,336	1,961	85	73	60	0.4	0.5	0.5	0.4	25	
Nuclear	4,615	4,615	4,615	170	170	170	0.4	0.4	0.4	0.8	40	
Nuclear with small modular reactor (SMR)	6,115	6,115	6,115	170	170	170	0.4	0.4	0.4	0.8	60	
Oil	1,300	1,300	1,300	40	40	40	0.4	0.4	0.4	0.85	25	
Utility scale solar PV	1,000	773	773	18	16	16	-	-	-	0.95	25	210 GW
Stand-alone solar PV	6,510	6,510	6,510	110	110	110	-	-	-	0.95	25	
Offshore wind	6,327	2,899	2,899	105	70	60	-	-	-	0.95	25	
Onshore wind	2,650	2,343	2,343	46	43	42	-	-	-	0.95	25	3.2 GW
Small hydropower	3,900	3,900	3,900	65	65	65	-	-	-	0.95	30	3.5 GW
Stand-alone diesel	325	325	325	23	23	23	0.4	0.4	0.4	0.85	25	
Mini-grid hybrid solar&diesel	3,400	3,287	3,174	110	110	110	0.4	0.4	0.4	0.85	25	
Mini-grid wind onshore	5,956	5,421	4,885	46	43	42	-	-	-	0.95	25	
Transmission network	1500	1500	1500	-	-	-	0.95%	0.95%	0.95%		60	
Distribution network	2815	2815	2815	-	-	-	0.91%	0.93%	0.95%		60	

Source: EU-EU Reference scenario 2020, IEA – WEO 2022

Techno-economic assumptions in the transport sector

	2020	2030	2050	2020	2030	2050	
Transport Mode	Capital Cost (MUSD/ 1000 vehicles)			Fixed operational cost (MUSD/ 1000 vehicles / year)			Lifetime (yrs)
2/3-wheeler: electric	2.51	1.75	1.4	0.3	0.3	0.3	8
2/3-wheeler: liquid fuel	0.88	0.88	0.9	0.0	0.0	0.0	10
2/3-wheeler: natural gas	0.88	0.88	0.9	0.0	0.0	0.0	10
Bus: electric	142.39	108.59	101.1	10.9	8.0	7.6	10
Bus: hydrogen	144.13	104.21	97.2	11.0	7.6	7.3	10
Bus: liquid fuel	75.01	82.29	86.7	5.6	6.2	6.5	10
Bus: gas	75.01	82.29	86.7	5.6	6.2	6.5	10
Car: electric	20.45	15.26	5.5	1.5	1.1	1.1	15
Car: hydrogen	12.28	6.65	5.9	2.5	1.3	1.2	15
Car: liquid fuel	4.97	5.17	5.2	1.0	1.1	1.1	15
Car: gas	4.97	5.17	5.2	1.0	1.1	1.1	15
Heavy truck: electric	136.69	98.68	88.9	10.4	7.2	6.7	15
Heavy truck: hydrogen	159.26	102.31	90.9	12.2	7.4	6.8	15
Heavy truck: liquid fuel	57.22	67.49	72.2	4.2	5.1	5.4	15
Heavy truck: natural gas	57.22	67.49	72.2	4.2	5.1	5.4	15
Light truck: electric	12.66	8.87	7.5	2.1	1.6	1.5	15
Light truck: hydrogen	17.95	9.26	8.1	3.6	1.9	1.6	15
Light truck: liquid fuel	5.91	6.20	6.3	1.3	1.3	1.4	15
Light truck: gas	5.91	6.20	6.3	1.3	1.3	1.4	15

Source: SEforAll analysis, IEA

Techno-economic assumptions in the industry sector

Technology	Unit	2020	2030	2050	2060	Lifetime
Iron and steel high temperature heating system: biomass	MUSD/GW	762.1	727.4	667.2	665.7	25
Iron and steel high temperature heating system: biomass with CCS	MUSD/GW	1,844.2	1,662.5	1,359.9	1,348.2	25
Iron and steel high temperature heating system: coal	MUSD/GW	614.2	580.2	543.2	542.4	25
Iron and steel high temperature heating system: coal with CCS	MUSD/GW	1,696.3	1,515.3	1,235.9	1,224.9	25
Iron and steel high temperature heating system: hydrogen	MUSD/GW	166.9	166.9	166.9	166.9	25
Iron and steel high temperature heating system: natural gas	MUSD/GW	150.4	150.4	150.4	150.4	25
Iron and steel high temperature heating system: natural gas with CCS	MUSD/GW	1,232.5	1,097.1	855.4	845.2	25
Iron and steel high temperature heating system: oil	MUSD/GW	293.0	293.0	293.0	293.0	25
Cement kiln: biomass	MUSD/Mtpa	289.7	289.7	289.7	289.7	25
Cement kiln: biomass with CCS	MUSD/Mtpa	532.1	532.1	532.1	532.1	25
Cement kiln: coal	MUSD/Mtpa	289.7	289.7	289.7	289.7	25
Cement kiln: coal with CCS	MUSD/Mtpa	532.1	532.1	532.1	532.1	25
Cement kiln: hydrogen	MUSD/Mtpa	289.7	289.7	289.7	289.7	25
Cement kiln: natural gas	MUSD/Mtpa	289.7	289.7	289.7	289.7	25
Cement kiln: natural gas with CCS	MUSD/Mtpa	532.1	532.1	532.1	532.1	25
Cement kiln: oil	MUSD/Mtpa	289.7	289.7	289.7	289.7	25
Oil based chemicals high temperature heating system: biomass	MUSD/GW	762.1	727.4	667.2	665.7	25
Oil based chemicals high temperature heating system: biomass with CCS	MUSD/GW	1,844.2	1,662.5	1,359.9	1,348.2	25
Oil based chemicals high temperature heating system: coal	MUSD/GW	614.2	580.2	543.2	542.4	25
Oil based chemicals high temperature heating system: coal with CCS	MUSD/GW	1,696.3	1,515.3	1,235.9	1,224.9	25
Oil based chemicals high temperature heating system: coal with Hydrogen	MUSD/GW	166.9	166.9	166.9	166.9	25
Oil based chemicals high temperature heating system: natural gas	MUSD/GW	150.4	150.4	150.4	150.4	25
Oil based chemicals high temperature heating system: natural gas with CCS	MUSD/GW	1,232.5	1,097.1	855.4	845.2	25
Oil based chemicals high temperature heating system: oil	MUSD/GW	293.0	293.0	293.0	293.0	25
Other industry high temperature heating system: biomass	MUSD/GW	762.1	727.4	667.2	665.7	25
Other industry high temperature heating system: biomass with CCS	MUSD/GW	1,844.2	1,662.5	1,359.9	1,348.2	25
Other industry high temperature heating system: coal	MUSD/GW	614.2	580.2	543.2	542.4	25
Other industry high temperature heating system: coal with CCS	MUSD/GW	1,696.3	1,515.3	1,235.9	1,224.9	25
Other industry high temperature heating system: hydrogen	MUSD/GW	166.9	166.9	166.9	166.9	25
Other industry high temperature heating system: natural gas	MUSD/GW	150.4	150.4	150.4	150.4	25
Other industry high temperature heating system: natural gas with CCS	MUSD/GW	1,232.5	1,097.1	855.4	845.2	25
Other industry high temperature heating system: oil	MUSD/GW	293.0	293.0	293.0	293.0	25
Other industry low temperature heating system: biomass	MUSD/GW	762.1	727.4	667.2	665.7	25
Other industry low temperature heating system: coal	MUSD/GW	614.2	580.2	543.2	542.4	25
Other industry low temperature heating system: electricity	MUSD/GW	894.1	803.6	716.5	715.0	20
Other industry low temperature heating system: hydrogen	MUSD/GW	166.9	166.9	166.9	166.9	25
Other industry low temperature heating system: natural gas	MUSD/GW	150.4	150.4	150.4	150.4	25
Other industry low temperature heating system: oil	MUSD/GW	293.0	293.0	293.0	293.0	25
Virgin steel produced from blast furnace and basic oxygen furnace	MUSD/Mtpa	597.7	597.7	597.7	597.7	30
Virgin steel produced from blast furnace and basic oxygen furnace with CCS	MUSD/Mtpa	1,204.2	1,204.2	1,204.2	1,204.2	30
Virgin steel produced from direct reduced iron using hydrogen and electric arc furnace	MUSD/Mtpa	590.0	590.0	590.0	590.0	30
Scrap steel produced from Electric Arc Furnace	MUSD/Mtpa	271.5	271.5	271.5	271.5	30

Techno-economic assumptions in the cooking sector

Input parameters

	2020	2040	2060	2020	2040	2060	2020	2040	2060	
Stove type	Capex (MUSD/1000 stove unit)			Opex (MUSD/1000 stove unit)			Efficiency			Lifetime
Electric	0.075	0.075	0.075	0.0049	0.0049	0.0049	95%	95%	95%	15 years
Biofuels	0.032	0.032	0.032	0.025	0.025	0.025	22%	22%	22%	15 years
LPG	0.075	0.075	0.075	0.0032	0.0032	0.0032	60%	60%	60%	15 years
Traditional Biomass	0.0025	0.0025	0.0025	0.0027	0.0027	0.0027	18%	18%	18%	15 years

Cumulative costs

	2020	2030	2050	2060	2020	2030	2050	2060
Stove type	CAPEX (MUSD)				OPEX (MUSD)			
Electric	0.15	1,266	8,571	12,751	0.21	10.20	46.53	49.40
Biofuels	0.74	147	147	509	2.44	3.60	-	6.86
LPG	21.11	1,803	2,153	2,153	9.53	15.96	2.40	-
Total	**22**	**3,217**	**10,872**	**15,414**	**12.18**	**29.76**	**48.93**	**56.26**