GHANA ENERGY TRANSITION AND INVESTMENT PLAN

Foreword

The specter of climate change looms large, presenting a challenge that transcends borders and generations. Every corner of our planet, including the very lands and waters that cradle Ghana, is at risk. Rising sea levels, shifting weather patterns, increasingly erratic climatic phenomena and global geo-political uncertainties have made their presence felt, signaling the need for swift and decisive action.

Ghana stands resolute in joining the international community in combating this existential threat. Our motivation is twofold: It is both our ethical responsibility to safeguard our planet and a unique prospect to redefine our nation's trajectory towards sustainable growth and prosperity. We can chart a course that intertwines economic growth with environmental stewardship by harnessing the vast potential of renewable energy sources.

I am immensely proud to unveil the Ghana Energy Transition and Investment Plan that was built on Ghana's Energy Transition Framework. This pioneering blueprint maps out our nation's journey to achieve net-zero emissions by 2060 based on the latest data and evidence, ensuring that as our economy thrives, it does so in harmony with the environment. This plan is a testament to our dedication to fostering green industries, nurturing the evolution of cutting-edge low-carbon technologies, and propelling our nation towards a sustainable industrial revolution while giving equal growth opportunities to men and women.

Our vision projects that by pursuing this transformative path, we will unlock approximately USD 550 billion in investment opportunities by 2060. This is not just a domestic undertaking; the Ghana Energy Transition and Investment Plan is also a beacon for international collaborations, beckoning global stakeholders to share a vision of prosperity and sustainability.

I deeply thank the many stakeholders for their invaluable contributions and unwavering support, including government Ministries, Departments and Agencies, regional governments, the academic community, development allies, non-governmental organizations, and the private sector.

My heartfelt appreciation goes out to every government agency and partner, with a special mention of Sustainable Energy for All (SEforALL) for their invaluable contributions.

The journey ahead is both daunting and promising. Yet, if we stand united, each step we take will be a stride towards a future where our energy powers our nation and safeguards it. Let's come together, embrace the promise of tomorrow, and illuminate a prosperous, green, and just pathway.

NANA ADDO DANKWA AKUFO-ADDO

His Excellency the President of Ghana

Acknowledgement

The Ghana Energy Transition and Investment Plan emerges from Ghana's unwavering dedication to fighting the battle against climate change. Born out of robust collaboration, ingenuity, and a unified vision from pivotal players in both the public and private sectors, this plan paves the way for the energy sector to play a pivotal role in achieving Ghana's climate goal of net-zero emissions by 2060. Moreover, it aligns seamlessly with initiatives by various government bodies to expedite its rollout.

The Energy Transition and Investment Plan offers a consolidated strategy for the energy sector, encapsulating an all-encompassing approach that outlines the financial layout necessary for its fruition. It maps out the immediate journey and lays the groundwork for formulating energy-specific objectives to be integrated into upcoming policy and regulatory frameworks.

Core decarbonization technologies are pinpointed within this plan to facilitate a seamless transition. These technologies encompass renewable energy, energy efficiency, hydrogen, e-mobility, energy storage, and sustainable cooking solutions. Furthermore, the plan is geared towards project identification that can trigger funding from state-driven and private avenues.

The Ministry of Environment, Science, Technology & Innovation extends its heartfelt gratitude to Ministry of Energy and many stakeholders for their invaluable contributions and unwavering support. This includes government Ministries, Departments and Agencies, regional governments, the academic community, development allies, non-governmental organizations, and the private sector. Special thanks to Sustainable Energy for All (SEforALL) for their tireless and invaluable input in developing this plan.

We now turn our focus towards the plan's implementation, which will require broad engagement with local and international stakeholders alike. We look forward to working together towards realizing our vision for a sustainable and prosperous future for our beloved nation.

HON. DR KWAKU AFRIYIE (MP)

Minister for Environment, Science, Technology & Innovation

Context & Objectives

Objectives of the Ghana Energy Transition and Investment Plan

SEforALL is working with the Government of Ghana to build an Energy Transition and Investment Plan (ETIP)

The plan will help Ghana frame an energy transition agenda that will attract investment while at the same time ensuring a just transition and fully supporting Ghana's rapid economic growth trajectory

The plan will be presented at the Global Africa Business Initiative on the 21st of September and at subsequent events to engage the global investment and climate finance community

Ghana's Energy Transition and Investment Imperative

Internationally, the policy, business and investor communities are embracing net zero emissions.

Ghana is at a turning point and has the opportunity to increase its climate ambition, avoid the economic risks of a slower energy transition and secure its benefits

Ghana also has immense green growth opportunities that include carbon markets, green hydrogen, green manufacturing and localization of low-carbon technologies

- **Secure investment.** A slower transition will reduce investor appetite as fossil assets are increasingly difficult to finance. A net-zero target will position Ghana to secure investment capital and donor support, which is now primarily directed at low-carbon assets.
- **New growth sectors.** A slower transition presents a poor outlook for energy exports as international oil and demand fall. A net-zero target will create new economic opportunities for Ghana in global energy and technology markets..
- **Energy independence.** A carefully managed transition will reduce Ghana's energy independence as domestic demand grows and imports increase.

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CHAPTER ONE

Executive Summary

Ghana's path to Net Zero – Key Messages

GHANA'S EMISSIONS BASELINE AND FUTURE PATHWAYS

1. Without further action, Ghana's emissions could rise from 28 Mt CO2e in 2021 to over 140 Mt in 2050. Under Business As Usual (BAU), the bulk of emissions growth will come from transport, driven by population growth, GDP per capita growth, and vehicle ownership.

2. Alternative Net Zero pathways consider five country-level objectives or guiding principles: environmental sustainability, energy system costs, economic impact, social implications, and security of supply.

AN ORDERLY TRANSITION TO NET ZERO

3. Ghana could achieve Net Zero CO2 emissions by 2060, through the deployment of low-carbon solutions across all sectors. A 2060 target could achieve an orderly transition, balancing public-policy objectives.

4. Four main decarbonization technologies will anchor an Orderly Transition. Together, renewables, low-carbon hydrogen, battery electric vehicles and clean cookstoves cover over 90% of 2060 abatement.

SOCIOECONOMIC IMPACTS AND FINANCING NEEDS

5. In a Net Zero scenario, Ghana would need around USD 550 bn in capital investment to 2060 (USD 140 bn more than under BAU), with the majority of investment going to the power and transport sectors. Delivering this investment could drive new economic activity in the energy sector and beyond, potentially supporting an additional 400 thousand net new jobs by 2060.

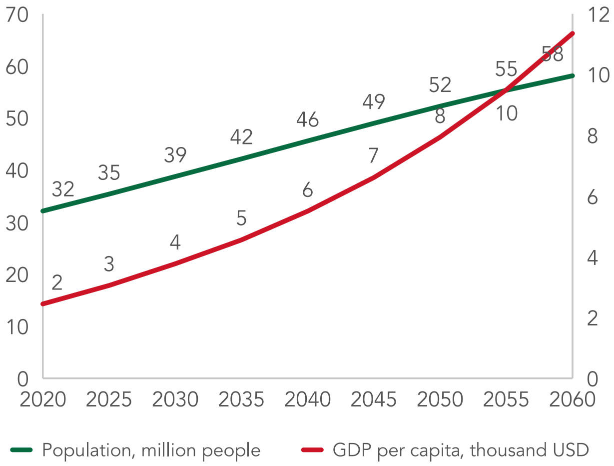
6. Capital markets could provide the largest funding pool, but tapping these sources will require de-risking interventions.

THE PATH FORWARD

7. There is a set of clear next steps to drive the implementation of a pathway, underpinned by strong governance, a clear timeline and cadence of interaction, and supportive policies.

Economic growth will drive significant energy emissions growth, even under current policies

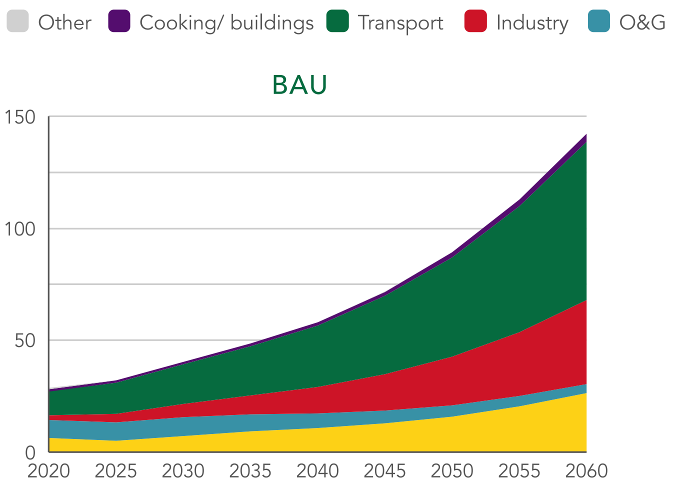
PROJECTED UNDERLYING GROWTH

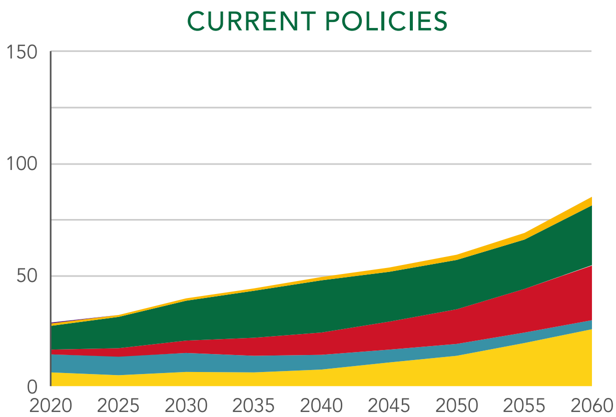


Population and income projected to grow substantially to 2060:

- Population expected to grow 1.7x, at 1.5% CAGR[1]
- GDP per capita expected to grow 4.4x, at 4% CAGR[1]

PROJECTED CO2 EMISSIONS GROWTH, MtCO2 Only energy CO2 emissions included





Demand growth drives 5x growth in CO2 emissions to 2060

- Road transport: car travel grows 18x
- Residential electricity grows 3X
- Substantial expansion of manufacturing base

Low-carbon technologies limit emissions growth to 2x by 2060

- Emissions reduced by ~70% renewables in power mix[2], and 100% EV car sales by 2060.
- Remaining emissions driven by rise of gas in the power; continued use of diesel trucks in transport and limited industry decarbonization.

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[1] Compound Annual Growth Rate

[2] 45 GW generation capacity from RES (Nuclear, Geothermal, Hydro power, Solar PV, Offshore wind, Onshore wind) out of 65 GW total capacity in 206

Source: GDP - IIASA SSP database, Population - World Bank, SEforALL analysis

Ghana's pathway design is dependent upon the weight attributed to different objectives

GUIDING PRINCIPLES

A. Investment

Create conditions for investment into Ghana's energy system by pursing an energy mix that is aligned with international investor appetite.

B. New growth sectors

Optimize for macroeconomic benefit, supporting economic activity in the energy sector and wider economy.

C. Energy security and trade balance

Ensure system security through self-sufficiency, system stability, and low-risk access to supplies, e.g., free-up a greater share of Ghana's oil and gas consumption for export under Net Zero vs BAU.

D. Employment impact

Solve for job retention and future job creation potential from decarbonizing Ghana's economy.

E. Environmental sustainability

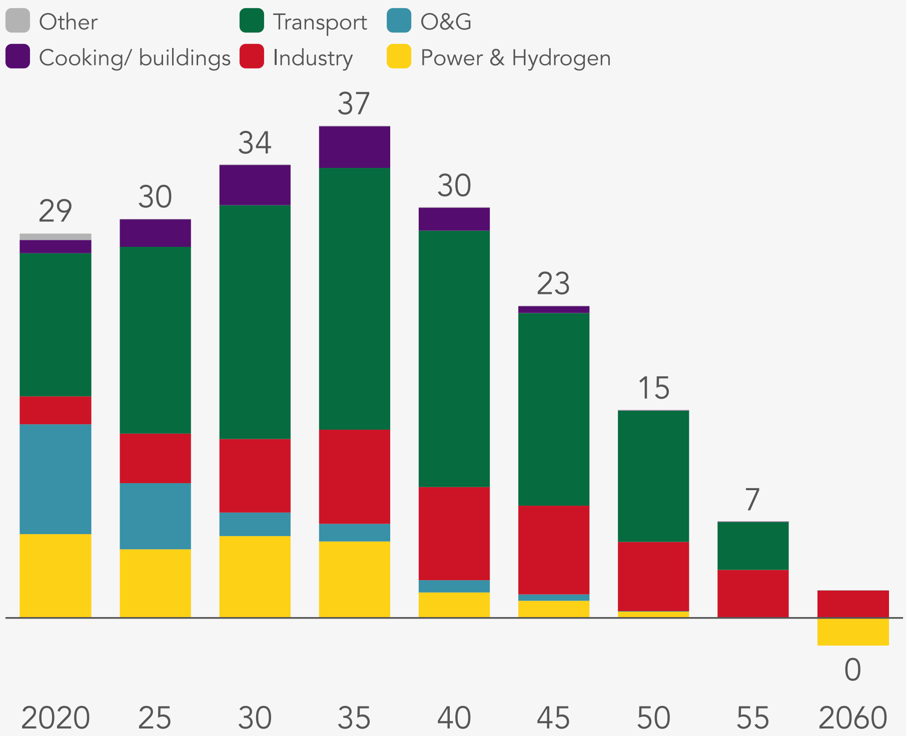
Reduce carbon emissions to reach Net Zero and minimize the overall carbon budget for Ghana to align with international investor expectations.

F. Affordability

Minimize energy costs to the Ghanaian population and energy-dependent domestic sectors.

Achieving Net Zero Emissions by 2060 will require emissions to peak around mid 2030s and begin a rapid decline thereafter

CO2 EMISSIONS BY SECTOR, MtCO2e 2020-2060



Source: SEforALL analysis

KEY OUTCOMES

- Both industry and transport sector emissions peak between 2035 and 2040
- Power CO2 emissions fluctuate, as demand growth offsets the declining CO2 intensity of the grid
- By 2060 emissions are close to zero in all sectors, with negative emissions in power offsetting a small volume of residual emissions in the industry

Source: SEforALL analysis

Six main decarbonization technologies will anchor an Orderly Transition pathway, with transport electrification driving around 40% of abatement

TECHNOLOGY					
ELECTRIFICATION & RENEWABLES	CARBON CAPTURE & STORAGE	LOW-CARBON HYDROGEN	BATTERY ELECTRIC TECHNOLOGIES	CLEAN COOKING TECHNOLOGIES[1]	NEGATIVE-EMISSION SOLUTIONS
CONTRIBUTION					
Replace fossil fuels through electrification; power provided by solar, wind, geothermal and potentially nuclear energy in combination with energy storage	**Decarbonize industrial and/or high temperature heating processes by capturing energy and process-related CO_2** streams (e.g., in steel BFBO, cement or chemicals)	**Substitute fossil fuels as a heat source and/or feedstock with green and blue hydrogen** and hydrogen derivatives (e.g., ammonia, synfuels) in Industry and Transport	**Replace internal combustion engines with electric batteries**, primarily for passenger cars, 2/3 wheelers and light trucks	**Replace traditional biomass and oil-derivatives** (e.g., LPG and kerosene) **with improved biomass and electric cookstoves** in buildings	**Implement technology-driven solutions such as BECCS[2]**
CONTRIBUTION TO CO2 ABATEMENT UNDER NET ZERO VS BAU IN 2060					
26%	5%	12%	40%	16%	2%

[1] Abatement for clean cooking accounts for estimated associated deforestation emissions

[2] Bioenergy with carbon capture and storage. Although nature-based solutions also deliver negative emissions, using nature-based solutions to offset energy sector emissions would reduce the scope to monetise these solutions in international carbon markets

Source: SEforALL analysis

Net Zero 2060 will convey benefits across a full range of public policy objectives

INVESTMENT

USD 24 Bn

Near-term investment opportunities in clean energy infrastructure, with \$500 billion of overall investment opportunities to 2060

NEW GROWTH SECTORS

USD 650 Bn

Global market for clean technologies by 2030, with opportunity to create new domestic industries in solar PV, electric vehicles, lithium-ion batteries and clean cookstoves

ENERGY SECURITY & TRADE BALANCE

~90%

Reduction in domestic oil and gas consumption in 2060 Net Zero vs BAU, releasing these commodities for export

EMPLOYMENT IMPACT

400,000

Net additional jobs, of which 80% is directly stimulated by Net Zero investments in solar PV, and EV charging / hydrogen fuelling stations

ENVIRONMENTAL SUSTAINABILITY

2 $GtCO_2$

Emissions avoided under Net Zero path vs BAU over the next 40 years

1 $GtCO_2$

Total carbon budget of the Net Zero pathway over the next 40 years

AFFORDABILITY

<0.2% of GDP

As average additional spending[1] required to decarbonize the economy to 2060 Net Zero vs BAU (total incremental system cost to 2060 is USD 24 bn)

[1] Includes CAPEX, O&M costs and fuel costs

Source: SEforALL analysis

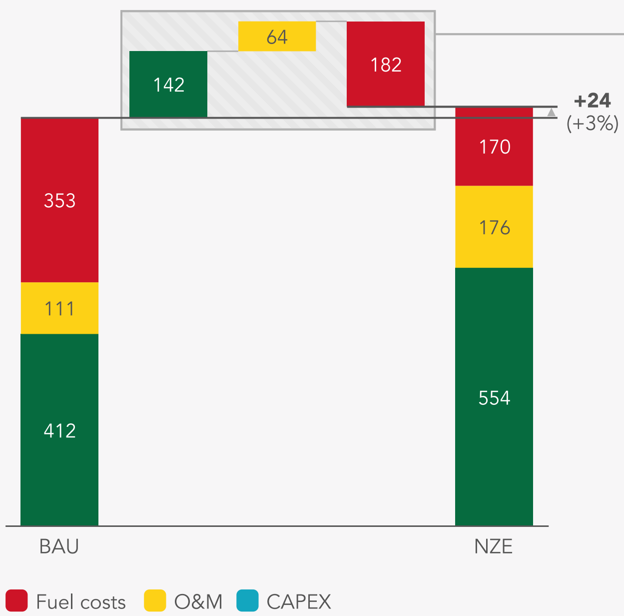
A set of technology transitions will be needed to achieve Net Zero

SECTOR		2020 – 2030 – 2040 – 2050 – 2060
O&G	Upstream	Flaring and venting are reduced by around 80% by 2030 through cost competitive solutions[1] Reach complete flaring phase-out by 2060 through solutions that require policy support
	Refining	Application of CCS in the refining sector
Industry	Steel	Improve energy and materials efficiency Decarbonize future steel production through hydrogen DRI starting 2040 to reach 80% of production mix by 2060
	Cement	Improve energy and materials efficiency Decarbonize future cement production starting 2040 through gas with CCS to dominate by 2060
	Chemicals and other industries	Improve the efficiency of industrial processes Decarbonize low- and medium-temperature heat through industrial heat pumps starting 2040 Decarbonize high temperature heat through gas CCS starting 2040
Transport	Cars and motorcycles	Improve new cars efficiency standards and encourage public transport usage Shift the market of new cars and 2/3 wheelers to electric with ~30% CAGR Shift the whole fleet to electric as old cars and motorcycles retire
	Freight trucks and buses	Improve new efficiency standards on freight trucks and buses Shift trucks and buses to electric and hydrogen
	Aviation and shipping	Implement new efficiency improvements Introduction of biofuels in 2055
Buildings	Cooking	Replace traditional biomass cookstoves by oil-derived and improved biomass ones by 2030 Roll-out greater volumes of electric and improved biomass cookstoves to fully replace oil-derived ones by 2050
Power and hydrogen	Power	Deployment of solar PV starting 2020 to reach 26 GW by 2040 Fast deployment of solar PV starting 2040 at 5GW/yr in average to reach 146 GW by 2060 Deployment of nuclear units starting 2045 to each 3 GW by 2060
	Hydrogen	Production of green and blue hydrogen starting 2045 to reach 85% and 15% respectively from over 90 PJ production by 2060

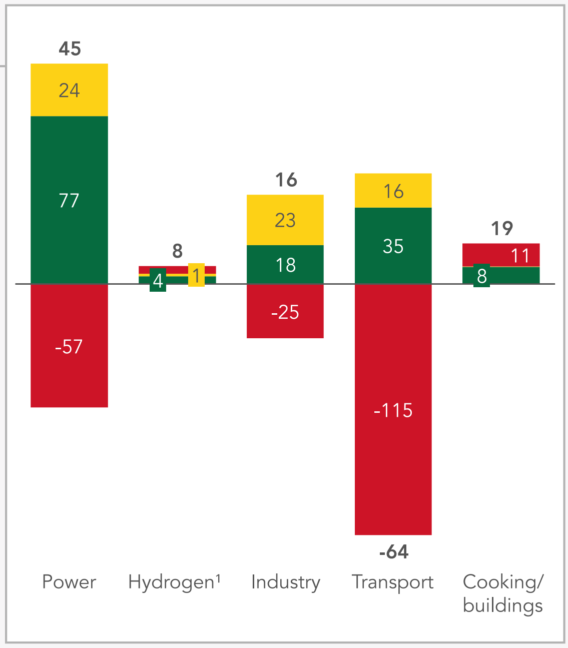
[1] Through re-use, Vapor Recovery Unit (VRU) or Leak detection and repair for fugitives (LDAR)

Net zero requires around USD 24bn in cumulative additional spending over BAU between 2020 and 2060

CHANGE IN CUMULATIVE SPENDING NZE VS BAU
2020-2060, USD bn



CHANGE IN CUMULATIVE SPENDING NZE VS BAU
2020-2060, sectorial view, USD bn



KEY INSIGHTS

- Total capex and O&M are around USD 140 bn and USD 65 bn higher than under BAU, respectively; while fuel costs are around USD 180 bn lower
- The majority of the additional capex spending occurs in the power and transport sectors, with some additional capex spending in the industry and buildings sectors
- The majority of the fall in fuel costs occurs in the transport and power sectors. In the power sector spending is around USD 45 bn higher than under BAU; while in the transport sector the fuel cost savings outweigh the increased capex, with spending in this sector around USD 65 bn less than under BAU

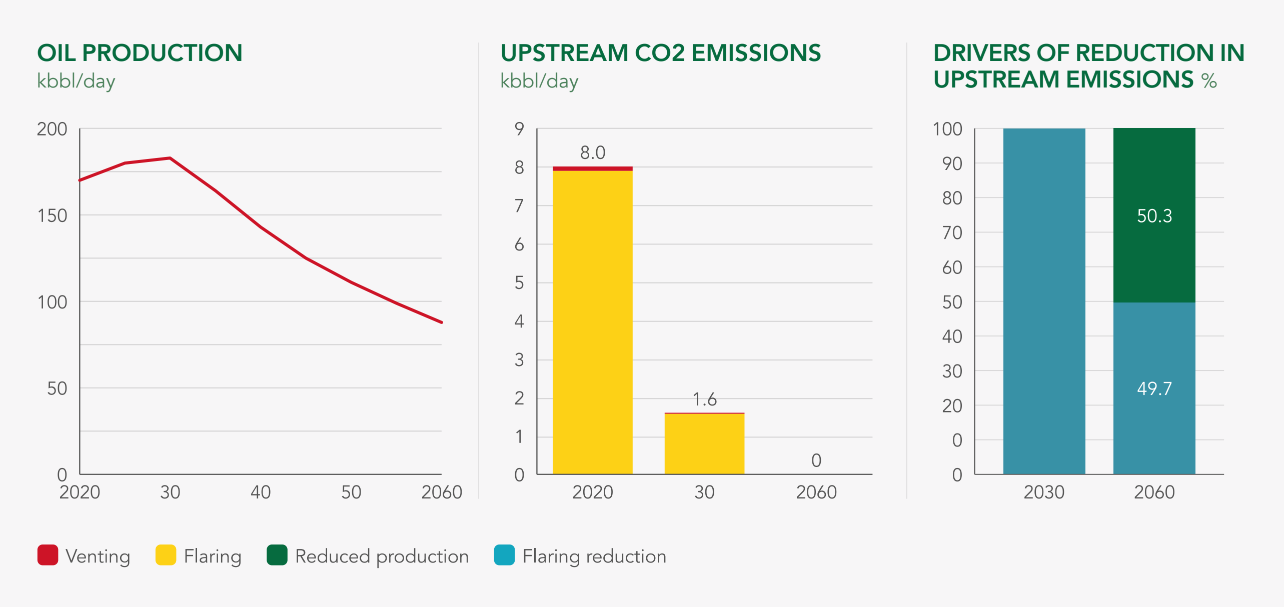
[1] Electricity and hydrogen are not allocated to end-uses
Source: SEforALL analysis

CHAPTER TWO

Sector Insights

Oil & Gas

Reducing oil and gas flaring offers the greatest emissions reduction potential



KEY MESSAGES

Oil production is expected to decline over the period to 2060 as the energy transition dampens global oil demand

Flaring accounts for 97% of oil and gas emissions, and around 25% of total CO2 emissions:

- Flaring and venting are reduced by around 80% to 2030, and to zero by 2060

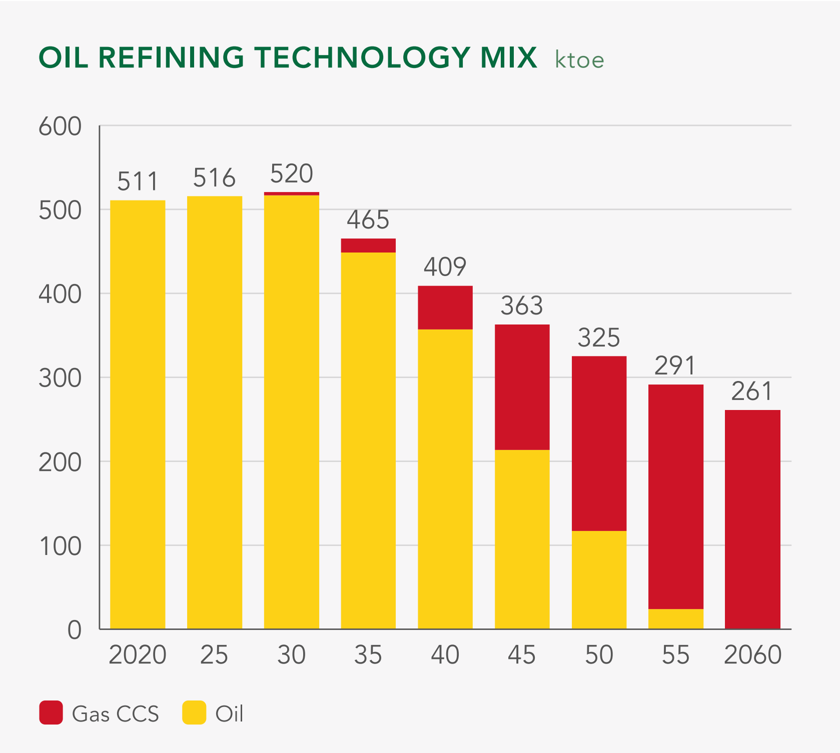
Reducing flaring is the primary lever to reducing oil and gas emissions:

- **Flaring and venting:** Cost positive abatement options include improving flaring efficiency and exporting gas through pipeline; repurposing gas can deliver additional abatement, though carries a cost premium

Note: Oil production assumed to change in line with global oil demand in the IEA Announced Policies Scenario

Source: SEforALL analysis

CCS is the main solution to decarbonise refining operations



KEY OUTCOMES

- Refining activity falls by around half over the period to 2060 as domestic oil demand decreases
- Oil remains the key fuel for oil refining processes for the next two decades
- From the mid-2030s new oil refinery plant fueled by gas with carbon capture are delivered to reduce emissions from oil refining processes
- By 2060 all refinery processes use CCS to minimise CO2 emissions

UNDERLYING DRIVERS OF THE PATHWAY

- Due to the cost premium of carbon capture and storage, this technology only emerges in the mid-2030s to achieve the Net Zero target

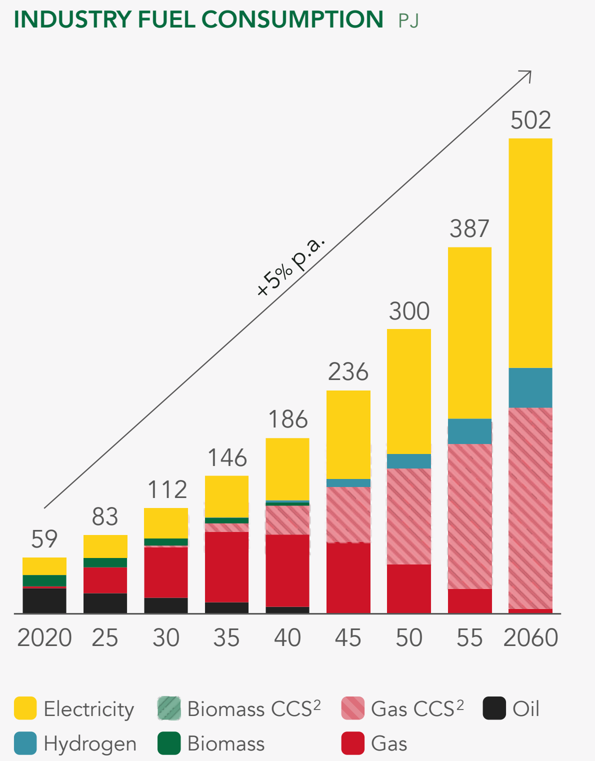
ALTERNATIVE SOLUTIONS

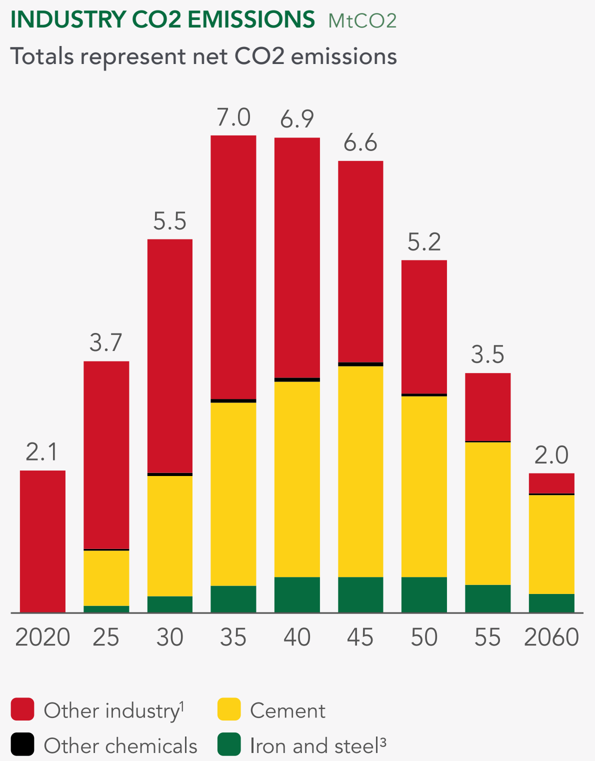
- Depending on the rate of innovation, hydrogen could also provide a cost-effective solution for decarbonising refining operations
- While biomass could also play a role in decarbonizing low- and high-temperature heat, it is likely that sustainable biomass will be in limited supply, and will be prioritized by sectors such as aviation and shipping with fewer viable alternatives

Source: SEforALL analysis

Industry

Low-emissions technologies and clean fuel sources will allow Ghana to decarbonize a rising industrial production





KEY OUTCOMES

- Decarbonisation of industry drives a shift in the fuel mix, with strong roles for electricity, hydrogen, gas with CCS, and a smaller role for biomass

[1] Includes equipment and machinery manufacturing, food and tobacco, paper and wood products, textile and industry not elsewhere specified

[2] Carbon capture and storage;

[3] Direct reduced iron technology

Source: SEforALL analysis

UNDERLYING DRIVERS OF THE PATHWAY

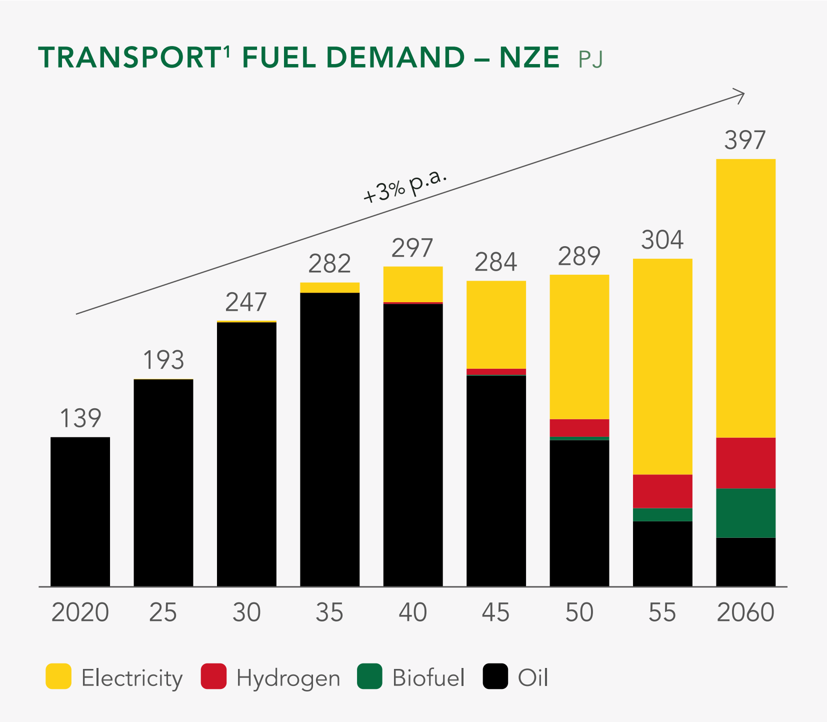
- Heat pumps replace fossil heating at low temperatures, driving up the use of electricity though with high efficiency. Heat pumps account for around half of electricity demand, while the other half is to power appliances in industrial facilities.
- Hydrogen demand is driven by its use in the steel sector, which uses H2-based direct reduced iron
- CCS emerges as the least-cost solution to decarbonise the cement sector as well as other high temperature heating in chemicals and other industries
- A small amount of biomass CCS is used to offset residual emissions (chiefly from fossil CCS)

ALTERNATIVE SOLUTIONS

- There is high confidence that electrification will be key decarbonisation solution for low temperature heat processes
- Hydrogen or innovative electric technologies such as electric cement kilns are alternative solutions to decarbonise high temperature heat

Transport

Electrification, hydrogen fuel cell vehicles and biofuels replace oil-based transport to decarbonise the sector



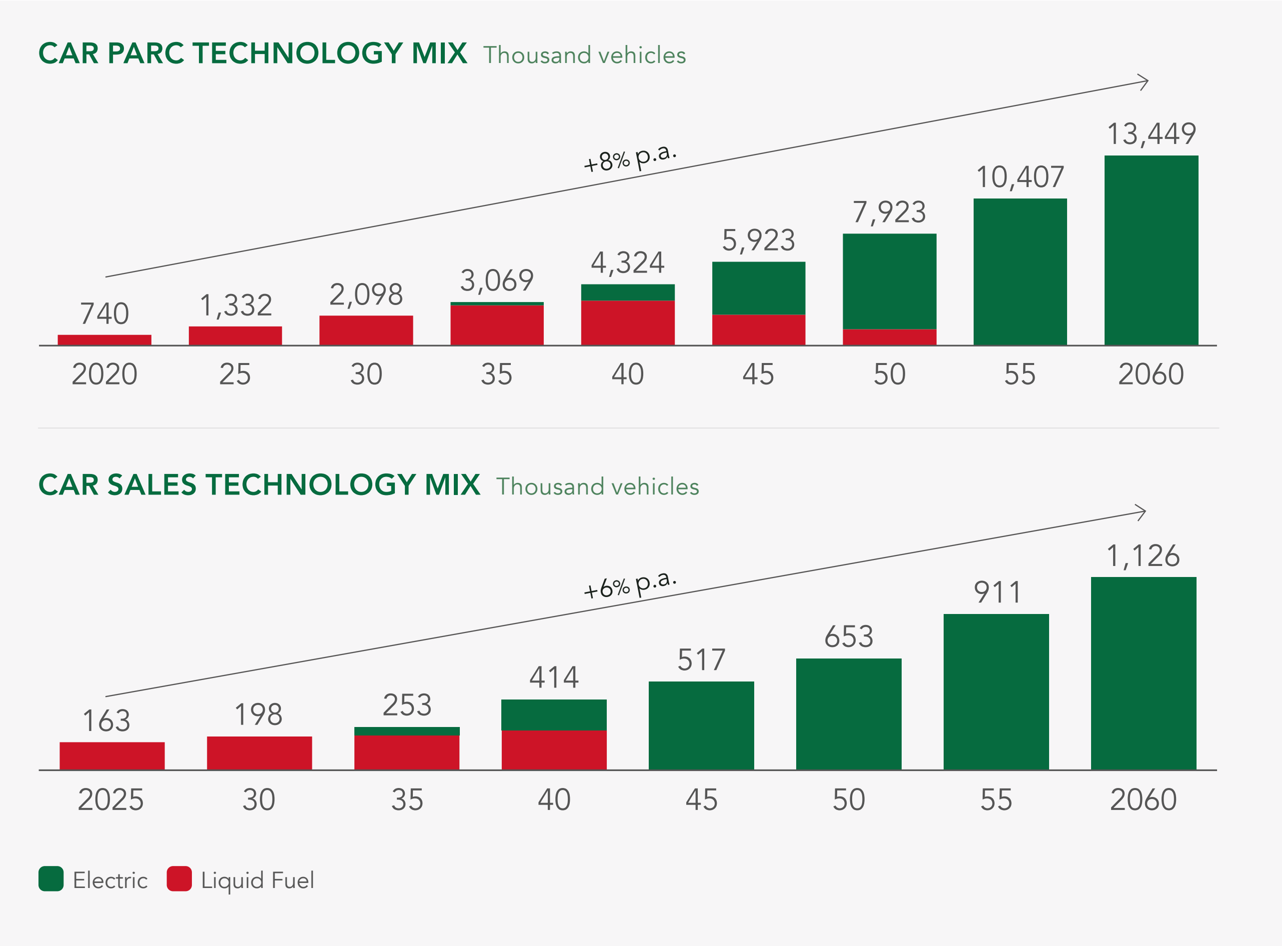
KEY OUTCOMES

- Economic growth drives 3-4x increase in transport sector energy demand, with growth in all modes
- Roll out of hydrogen-powered heavy trucks in heavy trucks drives a shift to hydrogen as a fuel
- Biofuels replace oil-derived fuels in aviation and shipping
- Overall fuel demand levels out from around 2040 as the increased efficiency of electric and hydrogen vehicles offsets the effect of rising demand for travel

[1] The scope considers domestic aviation and shipping and road transport

Source: SEforALL analysis

Electric cars dominate the fleet by the mid-2050s even under current policies and fully replace fossil vehicles by 2060



KEY OUTCOMES

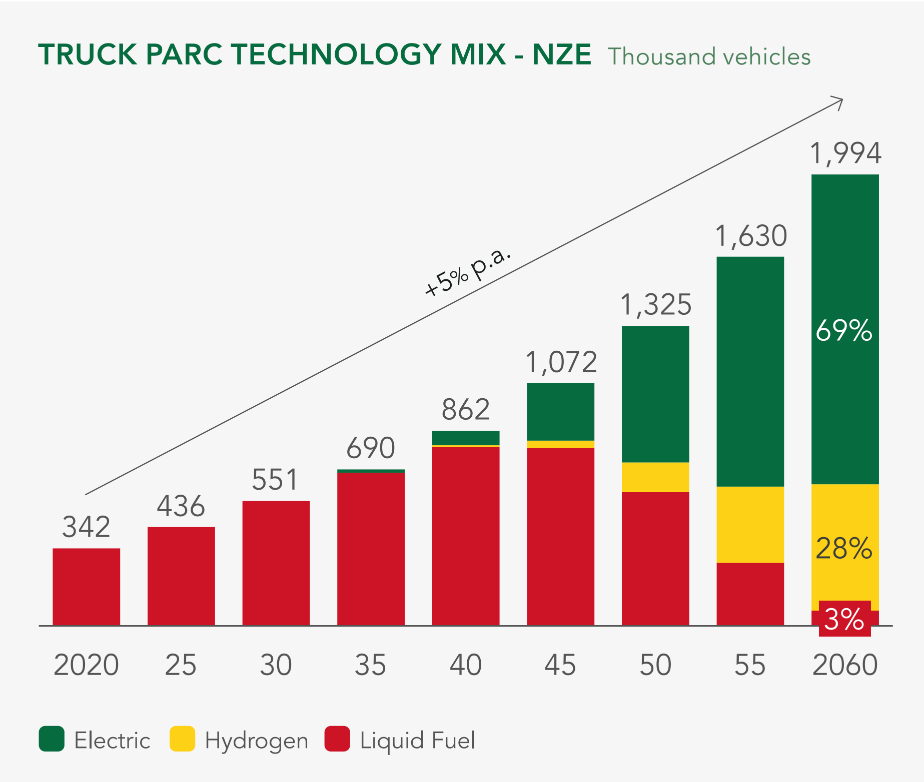
- Passenger car ownership grows 18x 2020-60 as incomes rise
- Initially the vast majority of cars are ICE due to the current EV cost premium and low volumes of EVs in the used vehicle market
- By the mid-2030s, used EVs are cost-competitive and are available in the market
- By the mid-2030s, annual EV sales increase sharply, doubling between 2045 and 2060 to reach >1 mn per year
- By 2050 electric vehicles dominate the fleet and fully replace fossil vehicles by 2060

Source: SEforALL analysis

UNDERLYING DRIVERS OF THE PATHWAY

- Battery cost reductions drive a shift to electric vehicles in the international auto market
- In Ghana, second hand electric vehicles are cost-competitive with internal combustion vehicles by 2030, though market availability is limited
- A shift away from used vehicles in the auto market would be needed to accelerate the EV transition

A mix of battery electric and hydrogen fuel cell trucks decarbonize the road freight sector



KEY OUTCOMES

- Truck fleet grows around 6x to 2060 as rising incomes and population drive a greater volume of freight
- Conventional liquid fuel trucks dominate for the next two decades as the global market for low-carbon trucks remains small and the vehicles carry a significant cost premium
- Deployment of electric and hydrogen trucks begins in the 2040s, and dominate the fleet by 2060

Source: SEforALL analysis

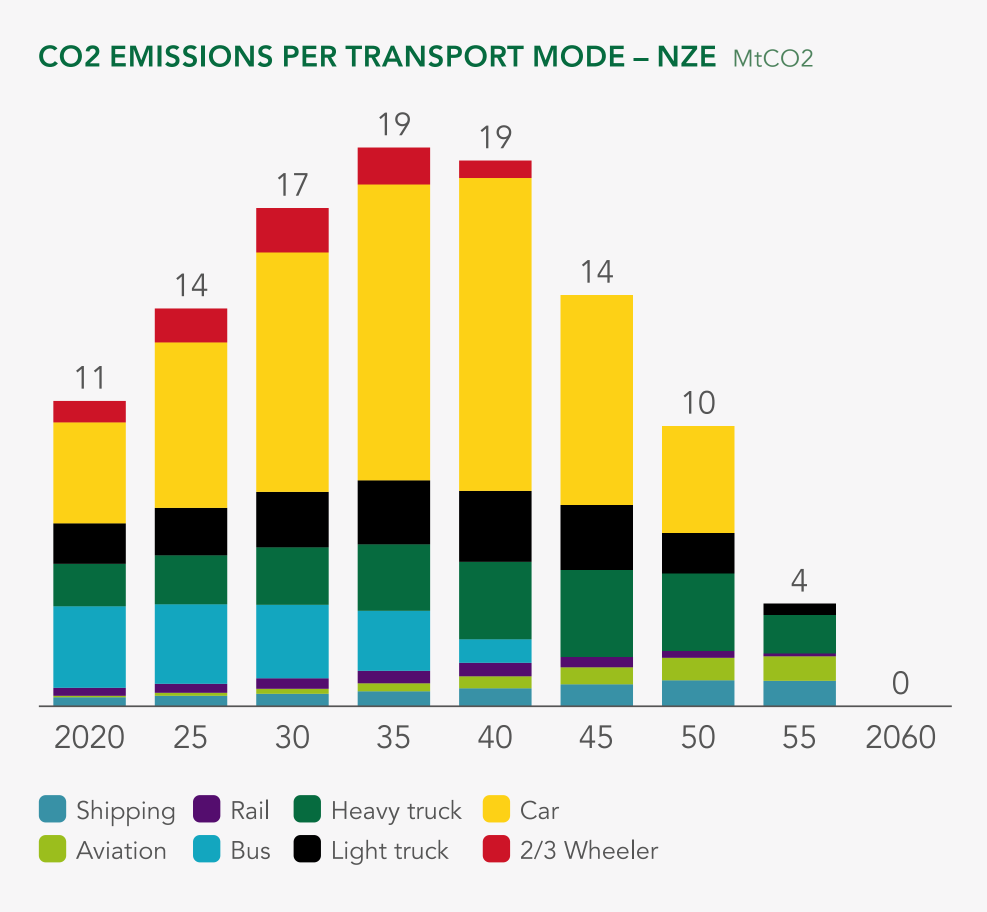
UNDERLYING DRIVERS OF THE PATHWAY

- Low-carbon trucks continue to carry a significant cost premium and strong policy support will be needed to deliver them at the scale needed
- Hydrogen is the preferred solution for long-distance trucking due to greater range, while battery trucks are preferred for shorter distances due to their greater efficiency

ALTERNATIVE SOLUTIONS

- There is high confidence in wide transition to EV and H2-fuel cells for long-distance trucks
- The specific mix of battery vs hydrogen vehicles will depend on improvements in battery cost and vehicle range

Emissions could peak in 2035 before falling back, with cars driving the largest growth and largest reduction in carbon emissions



KEY OUTCOMES

- Transport CO2 emissions peak around 2035 before falling back as all modes decarbonise
- Emissions from passenger cars account for the majority of CO2 emissions in all years
- Trucks also an important contributor to CO2 emissions, though smaller due to their lower distance travelled and fuel consumption

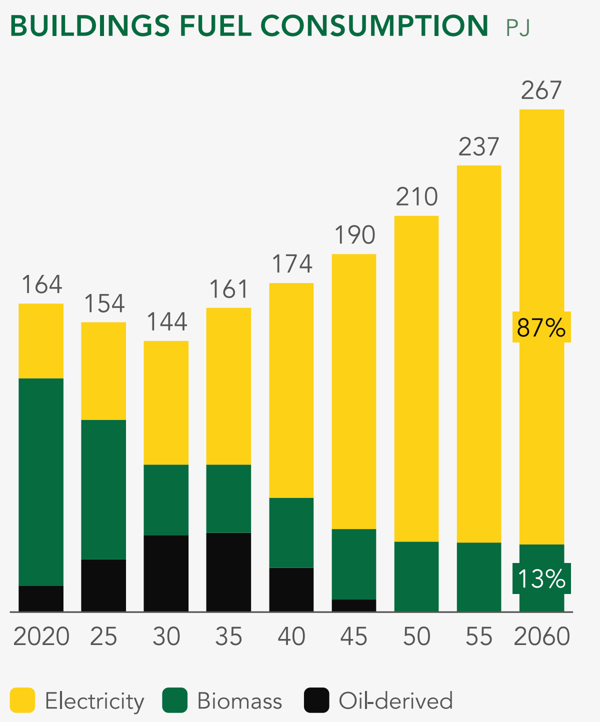
UNDERLYING DRIVERS OF THE PATHWAY

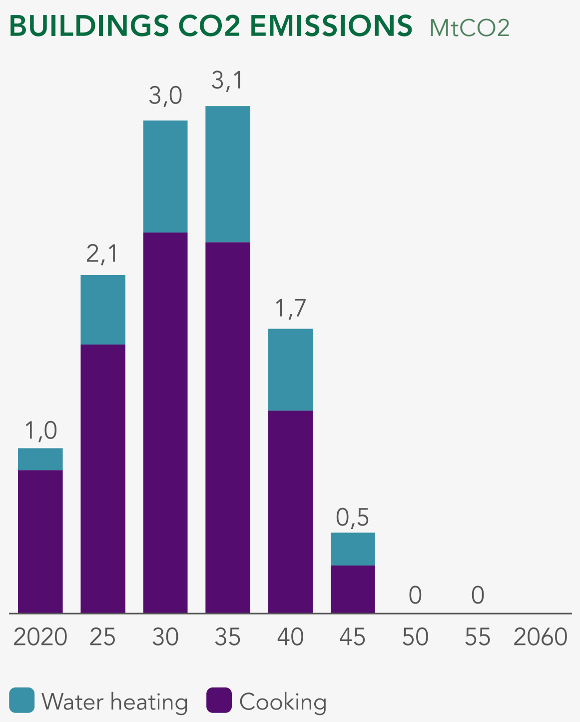
- Electrification of cars, and 2/3 wheelers, buses and light trucks drives the largest share of CO2 reduction
- Hydrogen in heavy trucks and sustainable fuels in aviation and shipping drive the remainder, achieving Net Zero transport by 2060

Source: SEforALL analysis

Cooking and other energy use in buildings

A shift from LPG to clean fuels for cooking and water heating drives buildings decarbonisation





KEY OUTCOMES

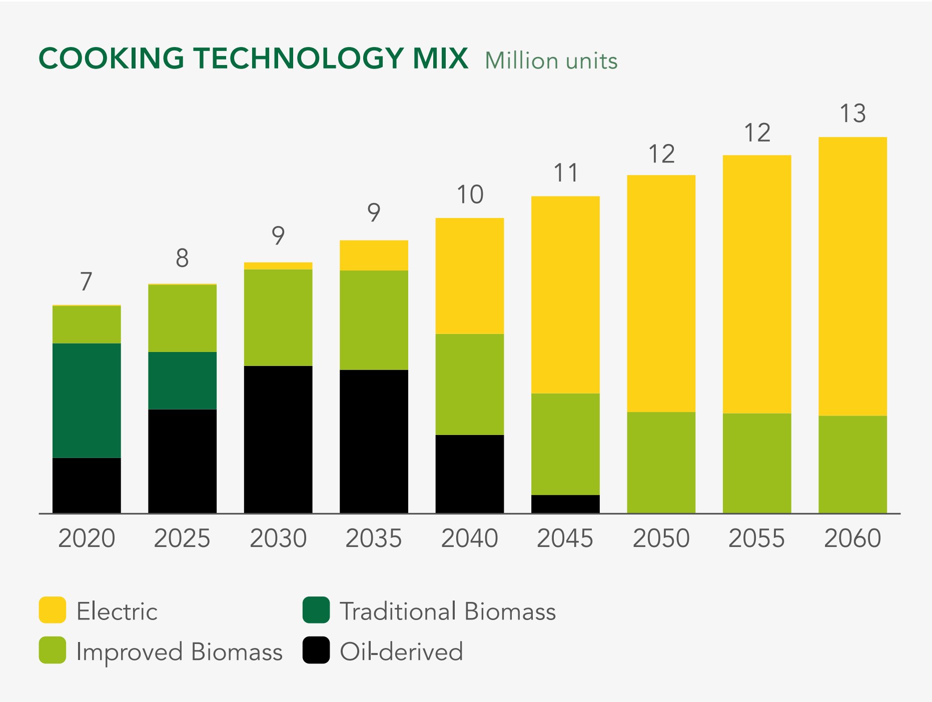
- Rising demand is met with cleaner energy, leading to emissions reduction from 2040
  - Electricity use reaches 90% of the energy mix by 2060, while biomass decreases to 10%
  - CO_2 emissions start to decrease from 2040 as over 60% of the building sector becomes electrified
  - Oil-derived cooking fuel is primarily LPG

UNDERLYING DRIVERS OF THE PATHWAY

- Ghana's building electricity demand growth aligns with countries of similar income levels
- Population with electricity access will grow from 85% in 2020 to 100% in 2030
- Emissions from electricity and biomass are not accounted for in the buildings sector:
  - Biomass emissions are included in the LULUCF sector
  - Electricity emissions are included in the power sector

Source: SEforALL analysis

Cooking is primarily decarbonized through a shift from traditional biomass and LPG to improved biomass and electric cooking



KEY OUTCOMES

- Traditional biomass remains the dominant cooking fuel today, with LPG and improved biomass playing a smaller role
- Traditional biomass is phased out by 2030 in line with SDG7. The phase out is supported by a growing role for both LPG and improved biomass cookstoves
- From the 2030s, electric cooking emerges as a key low-carbon solution in urban households
- By 2060 electric dominates in urban households, and improved biomass in rural households, phasing out LPG

UNDERLYING DRIVERS OF THE PATHWAY

- Policy incentives to reduce the energy cost premium of LPG, sustainable biomass and electric cooking solutions vs traditional biomass

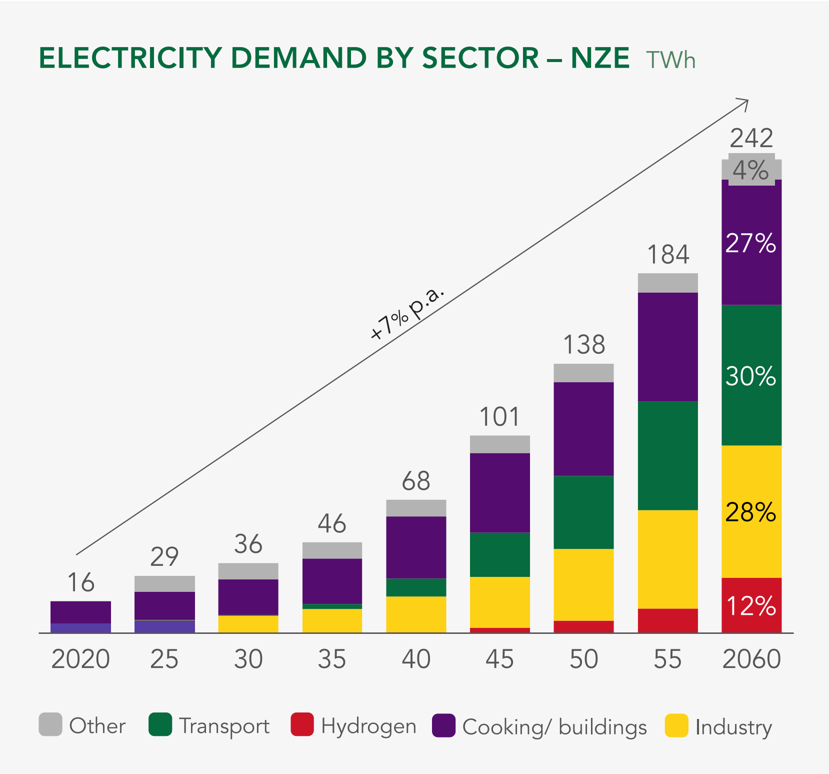
ALTERNATIVE SOLUTIONS

- Overall it is highly likely that improved biomass and electric cook stoves will play a key role in decarbonising the sector
- Consumer preferences may drive a different balance of these two technologies

Source: SEforALL analysis

Power

Power demand grows around 15x to 2060, driven by increasing population and GDP/capita



KEY OUTCOMES

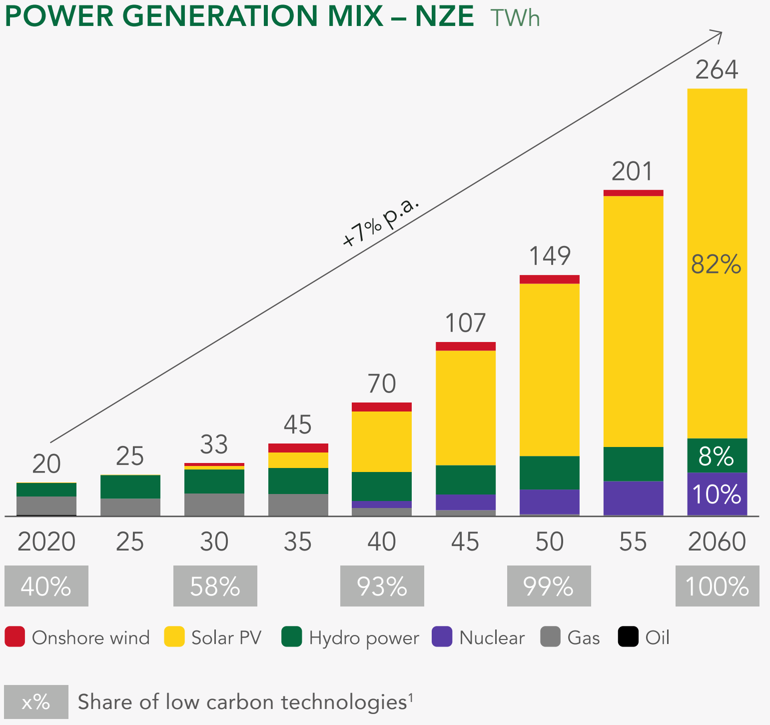
- Demand for power in Ghana grows at 7% p.a. to 2060
- The buildings and industry sectors, which today account for almost all electricity demand, grow strongly to 2060
- Transport emerges as a significant source of demand from around 2040, and by 2060 accounts for almost 30% of total demand
- Production of green hydrogen production also emerges, accounting for 12% of demand by 2060

UNDERLYING DRIVERS OF THE PATHWAY

- Income growth drives substantial power demand growth, primarily in the buildings and industry sectors
- Growth in transport and hydrogen sectors is driven by the Net Zero target, and the associated electrification of transport and the shift to hydrogen in the transport and industry sectors

Source: SEforALL analysis

Solar PV meets the majority of growth in power demand and drive decarbonization of the sector



KEY OUTCOMES

- Power demand grows 15x to 2060 due to robust underlying growth, and electrification of end-use demands
- New solar PV meets the majority of this increase
- Rest of growth is met with nuclear and hydro, as far as available resource allows
- By 2060, unabated fossil is phased out, with storage playing the key balancing role

UNDERLYING DRIVERS OF THE PATHWAY

- By the mid-2020s solar PV emerges as is the most cost-competitive power generation technology. However, deep decarbonisation through solar PV will require storage, increasing costs and requiring public support
- Nuclear can provide cost-effective baseload low-carbon power, but will require significant lead times due to consenting, planning and construction timelines
- Hydro can also provide cost-effective flexible power, but its maximum resource is estimated at 2.5 GW

[1] Includes solar, wind, geothermal, hydro, biomass, nuclear and CCS technologies

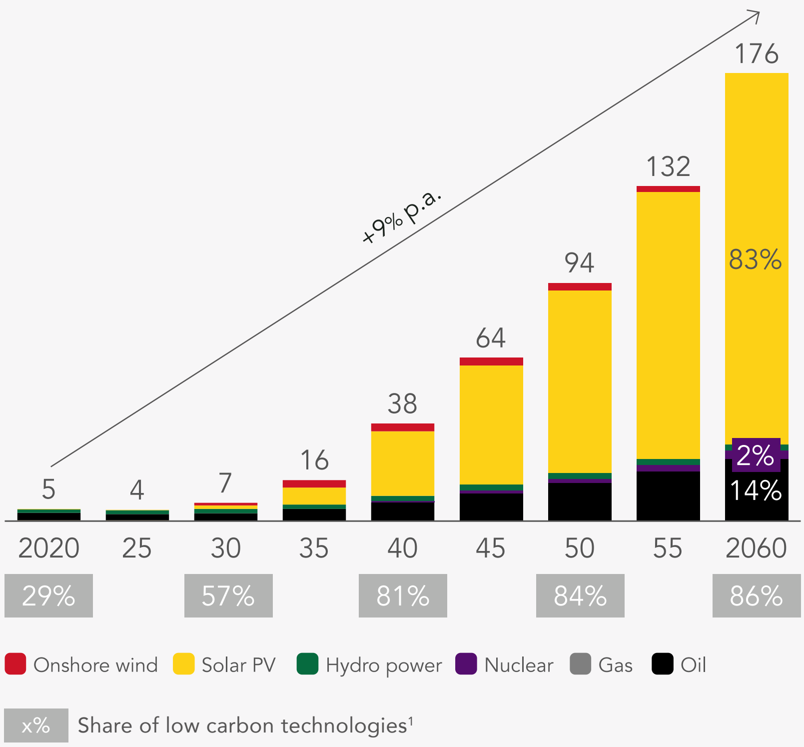
Source: SEforALL analysis

ALTERNATIVE SOLUTIONS

- Solar PV is highly likely to play a key role in the generation mix, while wind may play a complementary role. The precise mix of wind and solar will depend on their cost reduction pathway
- Significant storage is needed to firm the output from wind and solar. Alternative sources of firm power could include a greater role for nuclear, gas CCS, or hydrogen generators

The growth in generation requires a substantial growth in new capacity, dominated by solar and wind

POWER GENERATION MIX – NZE GW



[1] Includes solar, wind, geothermal, hydro, biomass, nuclear and CCS technologies

Source: SEforALL analysis

KEY OUTCOMES

- Total capacity grows in line with demand
- Solar PV accounts for the majority of capacity with over 150 GW in 2060
- Gas capacity also rises to around 25 GW by 2060. By 2060 gas is primarily used for security of supply
- Other technologies (gas CCS, nuclear, hydropower, and hydrogen) contribute only a small share of total capacity
- This pathway requires new capacity additions of <1 GW in the 2020s, rising to around 3 GW per year in the 2035s and 6-12 GW per year in the 2040s and 50s
- The fast build out of solar capacities would require significant technical, financial and policy support, to simplify and accelerate projects development

UNDERLYING DRIVERS OF THE PATHWAY

- Unabated gas is the cheapest form of reserve capacity and operates at only 2% capacity factor by 2060

Source: SEforALL analysis

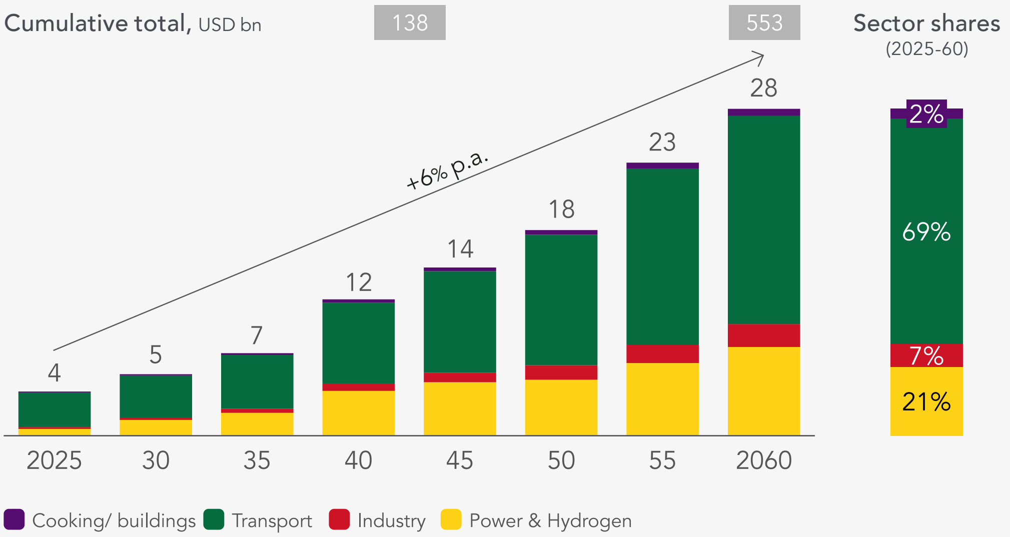
CHAPTER THREE

Socioeconomic impacts and financing needs

Around USD 550 bn cumulative capital investment is needed, with power and transport accounting for around 90% of this total

TOTAL ANNUAL CAPITAL INVESTMENT REQUIRED BY SECTOR[1], NZE

USD bn



KEY OUTCOMES

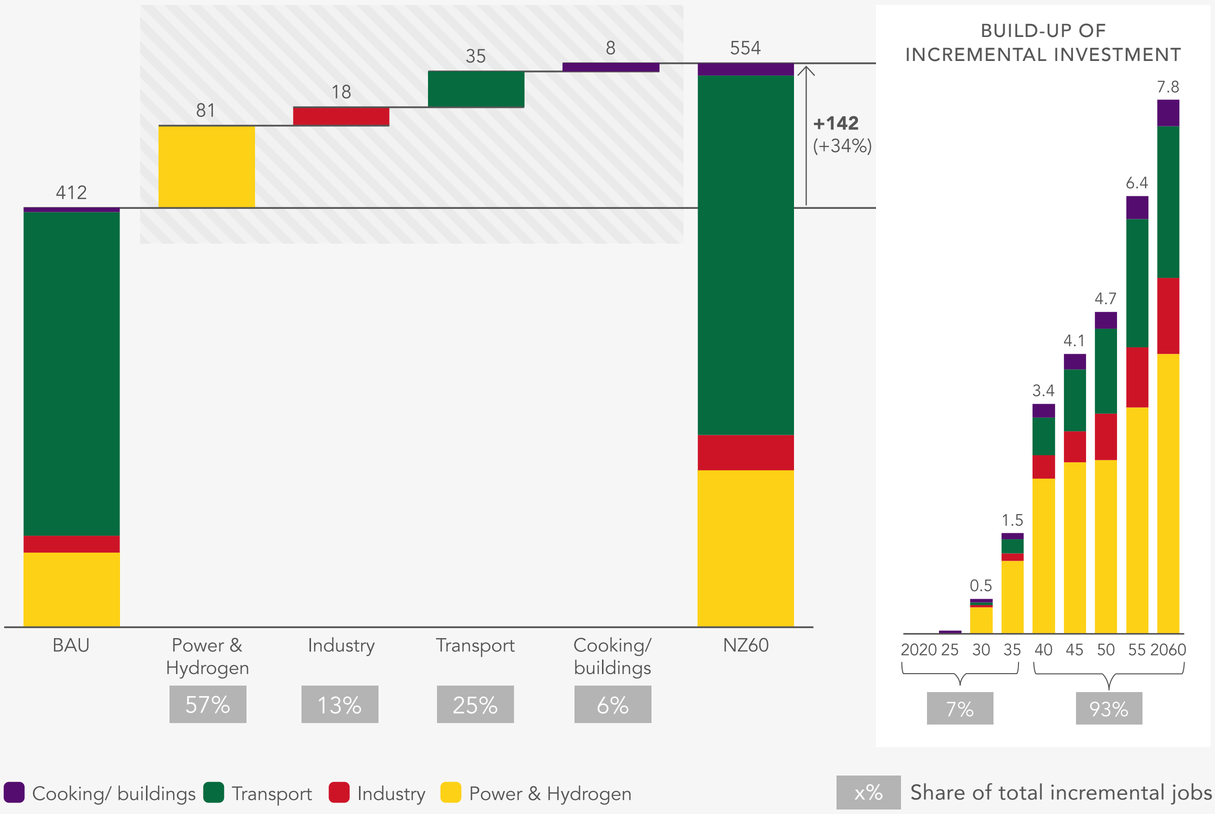
- Overall investment in energy technologies grows around 5x between 2025 and 2060, driven by income and population growth as well as a shift to more capital-intensive low-carbon technologies
- Throughout the period, transport accounts for the largest share of investment, at around 70%. The very high share of capital investment in transport is driven by the costs of private cars and other vehicles, with ownership growing significantly as incomes grow
- Power and hydrogen accounts for a significant share at around 20% of investment
- Industry and buildings account for a smaller share of investment, at under 10% of total

[1] This chart shows investment at 5-year intervals ; values do not sum to cumulative investment.

Source: SEforALL analysis

Around USD 140 bn capital investment is additional to investment needs in a BAU scenario

CHANGE IN CUMULATIVE INVESTMENT NZE VS BAU BY SECTOR, 2020-60 USD bn



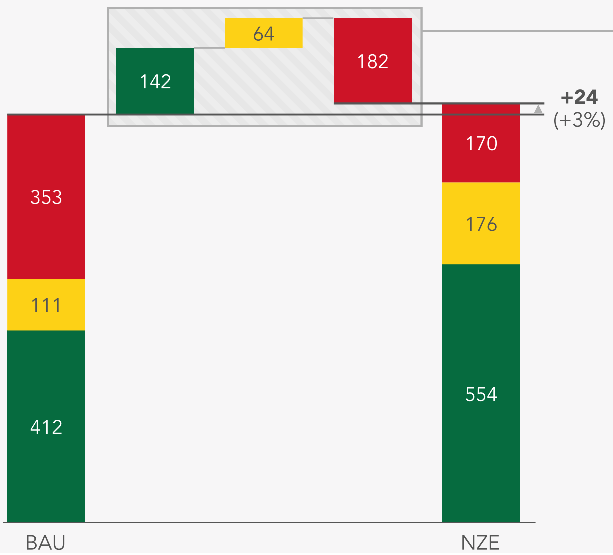
KEY OUTCOMES

- Total energy technology capex is around USD 410 bn in the BAU scenario; total capex rises by a further USD 140 bn in the NZE scenario, to around USD 550 bn.
- The majority of this capex growth is driven by additional investment in the power sector (USD 80 bn additional capex) and transport sector (USD 35 bn). Additional investment in the industry and buildings sectors makes a smaller contribution to the additional capex needs.
- The majority of the additional capex needs arises from 2040 as growth in energy demand and the shift to lower-carbon energy technologies are highest in this later period

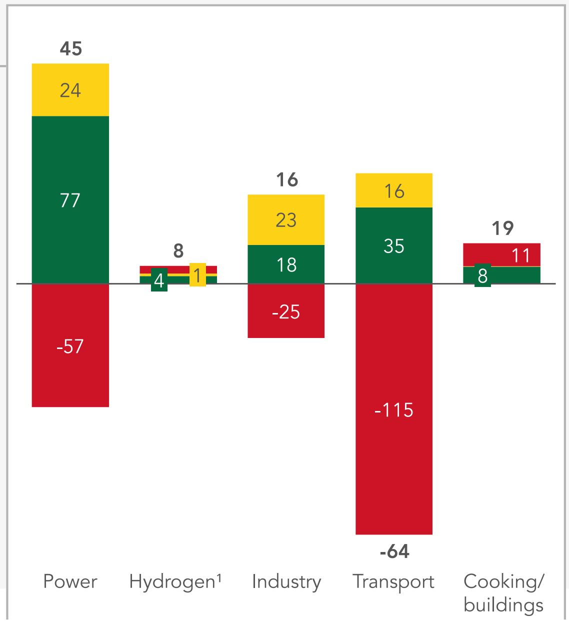
Source: SEforALL analysis

Net zero requires around USD 24bn in cumulative additional spending over BAU between 2020 and 2060

CHANGE IN CUMULATIVE SPENDING NZE VS BAU
2020-2060, USD bn



CHANGE IN CUMULATIVE SPENDING NZE VS BAU
2020-2060, sectorial view, USD bn

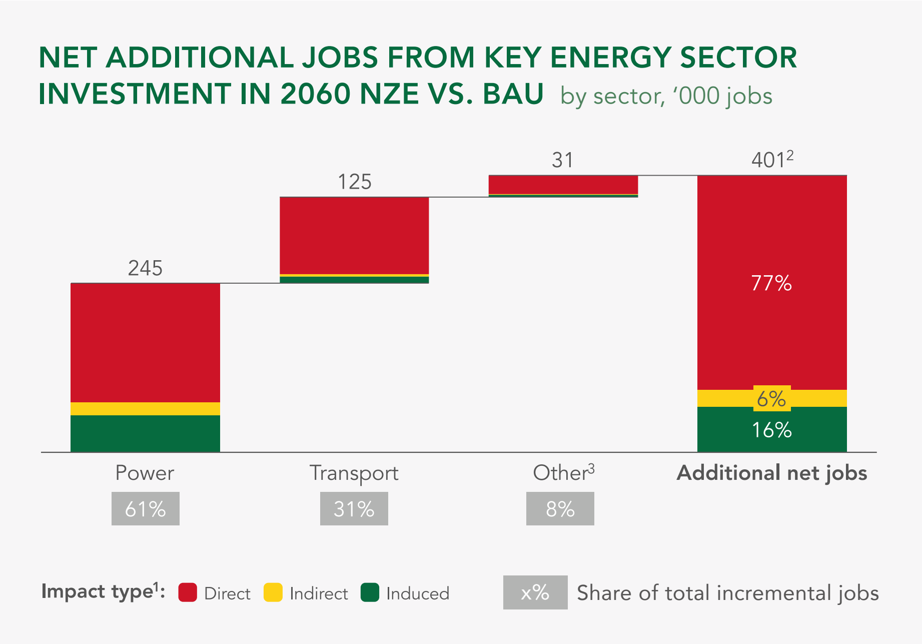


KEY OUTCOMES

- Total capex and O&M are around USD 140 bn and USD 65 bn higher than under BAU, respectively; while fuel costs are around USD 180 bn lower
- The majority of the additional capex spending occurs in the power and transport sectors, with some additional capex spending in the industry and buildings sectors
- The majority of the fall in fuel costs occurs in the transport and power sectors. In the power sector spending is around USD 45 bn higher than under BAU; while in the transport sector the fuel cost savings outweigh the increased capex, with spending in this sector around USD 65 bn less than under BAU

[1] Electricity and hydrogen are not allocated to end-uses
Source: SEforALL analysis

The additional investment could also support around 400 thousand additional jobs in 2060 across the economy



KEY OUTCOMES

- As with economic activity, transport sector investment supports the majority of the additional jobs. The investment directly supports around 112,000 jobs in the construction (25%) and maintenance (75%) of electric vehicle charging and hydrogen fueling infrastructure, as well as 3,500 indirect and 10,000 induced jobs in the supply chain and wider economy.
- Power sector investment also supports a significant number of additional jobs. The investment directly supports 172,000 jobs in the construction of renewable generation assets as well as 20,000 indirect and 50,000 induced jobs.

[1] Direct impact refers to contribution of the first level of (immediate) suppliers of the specific sector, has not been included as investments in target subsector do not significantly increase the output. Indirect effect refers to contribution of suppliers of suppliers of the specific sector; while induced refers to contribution of spending by employees employed directly and indirectly by sector and its suppliers

[2] Equivalent to 2% of Ghana's active population in 2060 (45% active out of 58 million people)

[3] Includes Hydrogen, buildings and industry sectors

Note: Positive value refers to job creation, while negative value refers to job loss

Srouce: SEforALL analysis

Capital raising

A combination of private sector capital and de-risking instruments could help finance Ghana's energy transition

NON-EXHAUSTIVE

	CORE FINANCE PROVIDERS				PROVIDERS OF DE-RISKING INSTRUMENTS e.g., guarantees/insurance, first-loss-capital, etc.				
	Private sector			Domestic public sector	International institutions				
Actors	Commercial financial institutions	Corporations	Households and individuals	Public institutions	Multilateral DFIs[1]	Bilateral DFIs[1]	National DFIs[1]	Green finance funds	Private foundations
Examples	Ghana Commercial Bank FirstRand Bank BNP Paribas Blackrock Pimco Major pension funds	BHP Billiton Royal Dutch Shell	N/A	Ghana Ministry of Finance	World Bank African Development Bank	French Agency for Development UK FCDO USAID GIZ	Development Bank of Ghana	Green Climate Fund Global Environment Facility Adaptation Fund Clean Technology Fund	Rockefeller Foundation ClimateWorks Foundations Bloomberg IKEA Foundation Bezos Earth Fund

RETURN FOCUS: ← ECONOMIC RETURNS → (all providers); ← ENVIRONMENTAL IMPACT → (providers of de-risking instruments)

[1] Development finance institutions

Source: Climate Policy Initiative, expert interviews

Capital markets could provide the largest funding pool, but some project archetypes might require de-risking to become bankable

Agent responsible for deployment: Private Public

Potential level of support by financing source/estimated level of de-risking required: High Medium Low

NON-EXHAUSTIVE

SECTOR	PROJECT ARCHETYPE	TOTAL FINANCING NEED USD BN		AGENTS RESP. FOR DEPLOYING INVESTMENT	TYPICAL FINANCING SOURCES OVER THE NEXT 10 YEARS				Need for derisking	COMMENT / RATIONALE
		UP TO 2035	2035-60		Comm. FL	Corp.	House-holds	Dom.Pub. Sector		
Industry	1. Industrial CC(U)S	0.9	25	Private/Public: SOE and/ or private companies	High	High	Low	Medium	High	Could be attractive to int'l capital as technologies mature
	2. Green steel facilities, incl. scrap steel (electric arc furnaces, gas/H2 DRI)	0.1	2	Private: Private companies	High	High	Low	Low	High	Could be attractive to int'l capital as technologies mature
Transport	3. Electric cars and 2/3 wheelers	3.0	110	Public: Consumers	High	Medium	High	Low	High	Domestic debt market, complemented with government subsidies
	4. BEV or FCEV bus fleet	1.9	30	Private/Public: SOE and private companies	High	High	Low	Medium	Medium	Existing infrastructure is partially government owned (50%)
	5. Electric trucks	0.5	105	Private: Private companies	High	High	Low	Low	High	Scalable fleets (USD 20+ mn) pot. suitable for capital markets
	6. Electric and H2 vehicle fueling infrastructure	0.2	25	Private/Public: SOE and/ or private companies	High	High	Low	Medium	High	Public-private partnerships for deployment in key locations
Cooking	7. Clean cookstoves[1]	0.5	1	Private: Private companies and consumers	Low	Medium	High	Low	High	Currently difficult to scale
Power	8. Grid infrastructure and distribution connections	2.7	45	Private/Public: SOE and/ or private companies	High	High	Low	High	High	Existing infrastructure is government owned
	9. Mini-grid solutions / off-grid solutions	1.9	1	Private: Private companies	High	High	Low	Low	High	Scalable projects (USD 20+ mn) pot. suitable for capital markets

[1] Includes electric, LPG, and improved biomass technologies

[2] Includes solar, wind, hydro, geothermal, and hydrogen

[3] Includes gas, gas with CCS, biomass with CCS, and nuclear;

[4] Assumption: the same electrolyzers are used for balancing and industry end-uses;

Sources: SEforALL analysis; Better Guarantees, Better Finance, Blended finance Taskforce (2023); Financing Clean Energy Transitions in Emerging and Developing Economies, IEA (2021); expert interviews

SECTOR	PROJECT ARCHETYPE	TOTAL FINANCING NEED USD BN		AGENTS RESP. FOR DEPLOYING INVESTMENT	TYPICAL FINANCING SOURCES OVER THE NEXT 10 YEARS				Need for derisking	COMMENT / RATIONALE
		UP TO 2035	2035-60		Comm. FL	Corp.	House-holds	Dom.Pub. Sector		
Power Continued	**10.** Utility scale renewables[2] power plants	9.8	55	SOE and/ or private companies	●	●	○	◐	●	Medium (USD 20-50+ mn) to large scale (USD 50+ mn) projects attractive for int'l investors
	11. Utility scale fossil and other conventional[3] power plants	2.3	25	SOE and/ or private companies	◐	◐	○	◐	◐	Limited appetite from int'l investors & providers of de-risking instruments
	12. Batteries for balancing	0.0	60	Private companies	●	●	○	○	●	Scalable projects (USD 20+ mn) pot. suitable for capital markets
Hydrogen	**13.** H2 production and storage (green and blue)[4]	0.0	4	Private companies	●	●	○	○	●	Scalable projects (USD 20+ mn) pot. suitable for capital markets

Blended finance and other de-risking instruments can help reduce perceived investment risk and attract private capital

KEY DERISKING INSTRUMENTS

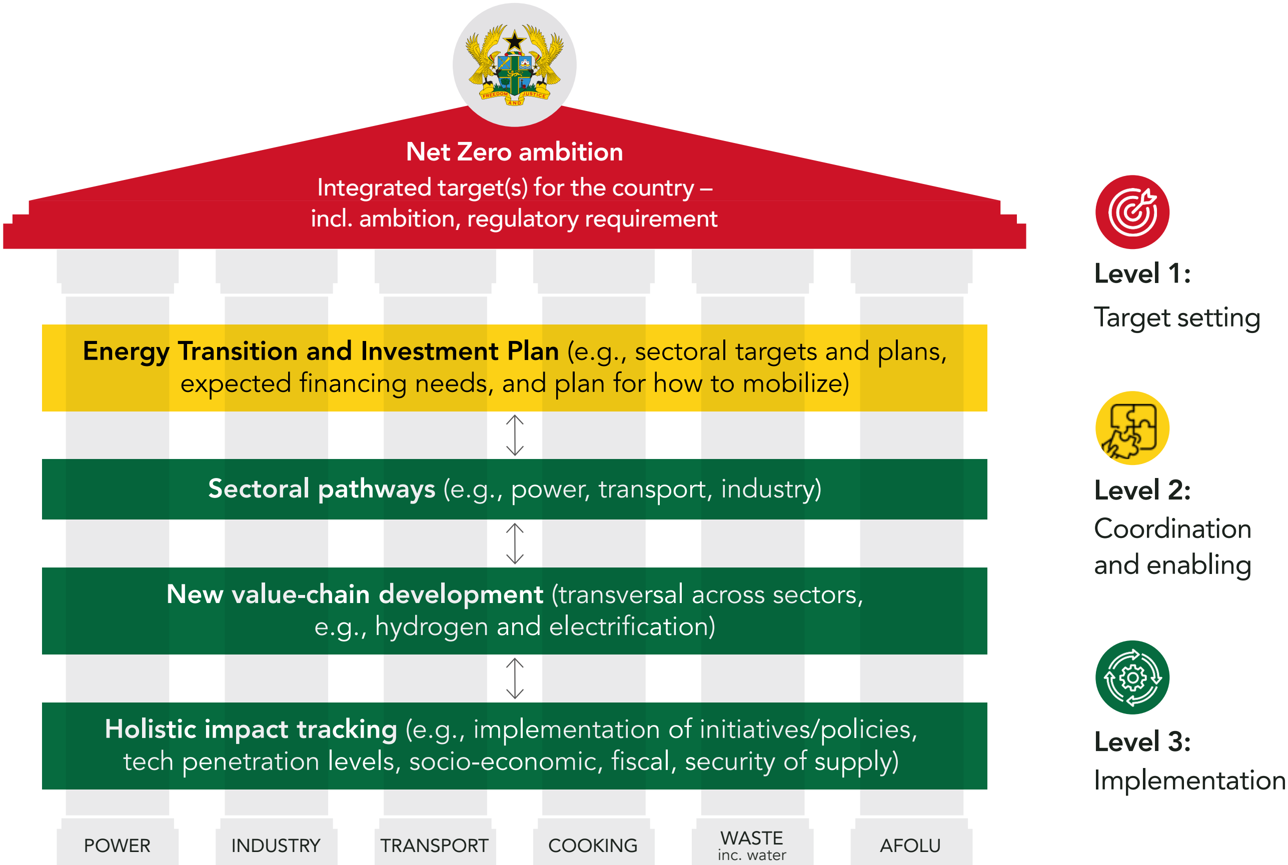
NON-EXHAUSTIVE

INSTRUMENT	RISK								
	MACRO		CREDIT			TECHNICAL		MARKET	
	POLITICAL/ COUNTRY RISK	CURRENCY RISK	CREDIT RISK	LIQUIDITY RISK	DEMAND RISK	CONSTRUCT-ION RISK	OPERATIONAL RISK	LACK OF PIPELINE	OFF-TAKE TISK
1. Guarantees	■		■	■		■	■		■
2. Insurance	■			■		■	■		
3. Hedging		■			■				
4. Junior/ subordinated cap			■	■		■	■	■	
5. Securitization			■	■					
6. Contractual mechanisms					■				■
7. Results-based incentivies							■		
8. Grants								■	

Source: Better Guarantees, Better Finance, Blended finance Taskforce (2023)

Implementation plan

To successfully implement the net-zero ambition, a best-practice governance structure, process, and action plan is needed



Level 1: Target setting. A national Net Zero ambition provides an overall target and vision for the country. The more concrete the end goals are, and the more clear the country is on the required pre-requisites to achieve them, the better private and public actors can act in accordance to them.

Level 2: Coordination and Enabling. An integrated Energy Transition and Investment Plan (ETIP) ensures transparency and coordination across the ministries, and sectoral policies are consistent with national objectives. This also includes organizing for success, e.g. through the establishment of an Energy Transition Office that coordinates and drives progress.

Level 3: Implementation. Private and public actors responsible for the implementation at the sector level (mandates, price incentives, controls, enablers). This includes sectoral pathways with clear mechanisms to ensure policies are owned by the relevant ministries (but roll up to the overall target). It also includes the development of new technology and fuel platforms for themes that transcend sectors – such as like Carbon Capture and Storage. And it includes holistic impact tracking, from tracking emission impact and clean technology uptake, to optimizing socio-economic ("just transition") and fiscal impact.

There are barriers to be addressed across sectors to enable an orderly energy transition

NON-EXHAUSTIVE

SECTOR	IMPLEMENTATION BARRIERS	ACTIONS REQUIRED
O&G	• High cost of reducing oil and gas sector emissions, particularly in refining	• Regulation and standards: – Institute penalties per mcf of gas flared to ratchet up pressure for operators to decarbonize – Set mandatory gas flare reduction required for operating licenses renewal • Price incentives or regulations: – Create tax holidays for operators to invest in gas monetization infrastructure and emissions reduction technology (e.g. LDAR, VRUs), or investment in CCS (e.g. pioneer status) – Co-invest or help finance required natural gas infrastructure (e.g. gas trunk-line, treatment/processing infra) which in turn helps make it attractive for companies to monetize the gas vs. flaring or re-injecting • Enabling programs: – Play orchestration role to launch collaborative decarbonization projects (e.g. CCS hub pilot project) which would reduce the cost of decarbonization to individual O&G operators
Industry	• Cost premium of hydrogen DRI process due to shift from coal or gas to hydrogen as a reducing agent • High cost of CCS applications in cement production and high temperature heat processes • Immature market and high capital cost of heat pumps for low-temperature heat processes	• Regulation and standards: – Implement mandatory leak detection and repair requirements on gas-fired boilers to reduce methane emissions – Set strict energy efficiency standards, especially for new construction and/or major renovations, requiring the use of heat pumps where possible • Price incentives or regulations: – Develop framework to enable green premium capture (e.g. mandating transparency and certification in production processes) – Develop incentive schemes that mitigates unprofitable share of investments in new clean technologies (such as CCS applications) • Enabling programs: – Where possible, create critical mass for decarbonized products and act as launching customer (incl. collaborating with manufacturers and distributors to reduce costs and improve supply chain) – Develop midterm infrastructure plans (especially around new-value chains) to enable private-sector players to anticipate decarbonization options available

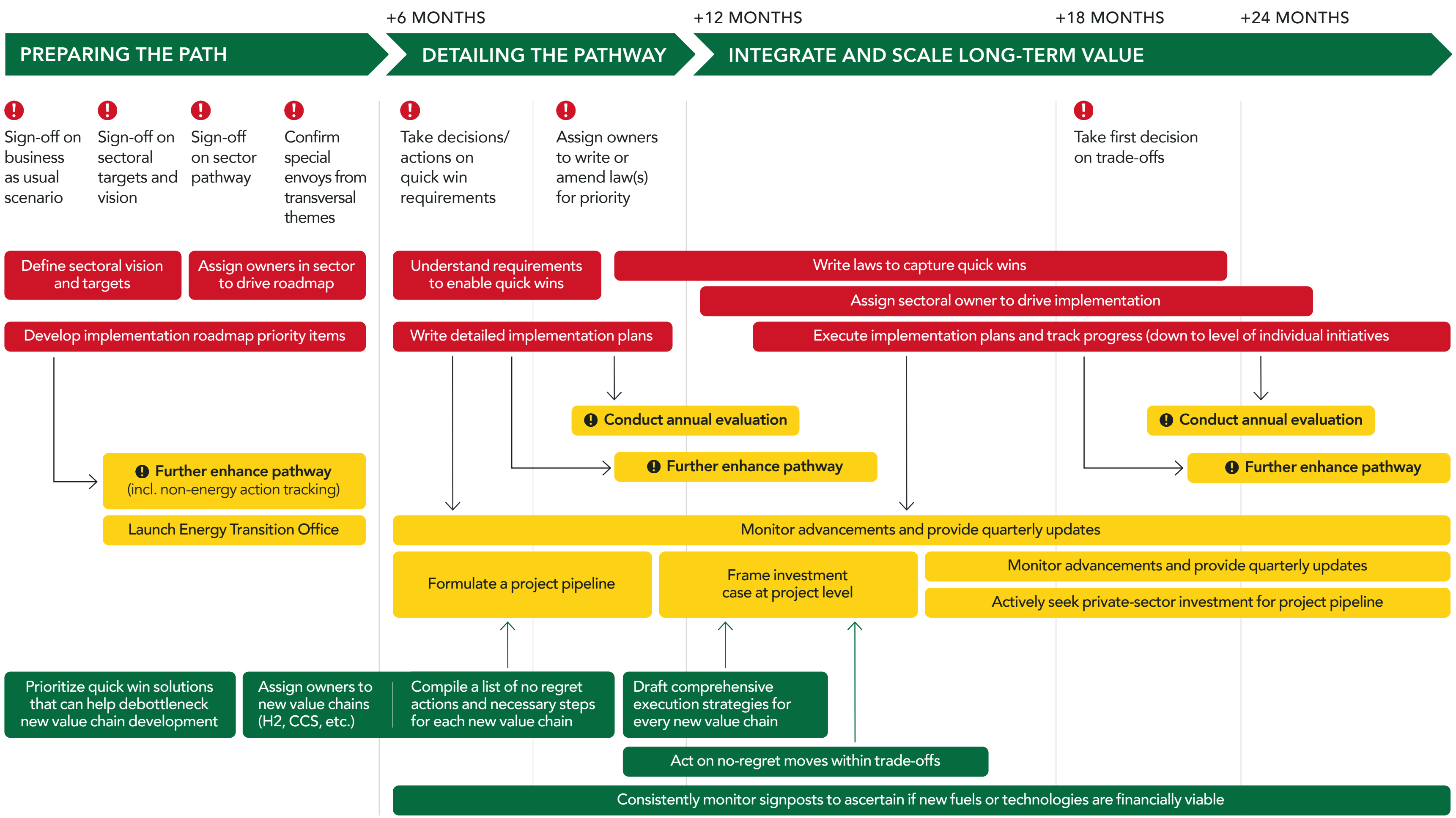
(CONTINUED)

<table>
<tr><th>SECTOR</th><th>IMPLEMENTATION BARRIERS</th><th>ACTIONS REQUIRED</th></tr>
<tr><td>Transport</td><td>• High cost of sustainable aviation fuels and low-carbon shipping fuels
• Deployment of electric vehicles will depend on consumer preferences
• High capital costs of electric and hydrogen vehicles
• Limited charging and fuelling infrastructure may slow growth of passenger and freight low emission vehicle markets</td><td>• Price incentives or regulations:
– Implement incentive mechanisms to drive uptake of low-carbon fuels in aviation and shipping. Ensure infrastructure is in place to enable low-carbon fuels usage near ports and airports
– Building on ambition of National Electric Mobility Roadmap, implement incentive mechanisms to ensure consumers shift to electric and fuel-cell vehicles when cost-competitive (e.g. purchasing tax credits, low-emission zones, vehicle trade-in programs, free parking, lower vehicle registration costs)
• Enabling programs:
– Develop and implement delivery plan for electric vehicle charging infrastructure (incl. grid assessment, regulatory framework, home charging incentives, and partnerships with the private sector)
– Where possible promote further efficiency and drive behavioral shift (e.g., to buses and trains)</td></tr>
<tr><td>Cooking/ Buildings</td><td>• High energy costs of modern and low-carbon cooking solutions (LPG, sustainable biomass, electricity)</td><td>• Price incentives or regulations:
– Provide grants, loans and subsidies to ease the requirements of capital-intensive investments (like electric stoves)
• Regulation and standards:
– Set policies to reinforce adoption of modern cooking solutions (e.g., mandating electric stoves in urban new builds)
– Building on ambition of ECOWAS Refrigerators and Air Conditioners Initiative, implement standards to improve energy efficiency of electrical appliances</td></tr>
<tr><td>Power and hydrogen</td><td>• At high volumes solar PV and wind require battery storage, which carries a cost premium; and depress electricity prices, potentially deterring investors
• Gas CCS carries capital cost premium</td><td>• Price incentives or regulations:
– Building on ambition of Renewable Energy Master Plan, create interventions to speed up deployment of especially solar PV and wind (e.g., net metering framework, renewable energy projects incentives, etc.)
• Enabling programs:
– Implement incentive mechanism for flexibility (for CCS in industry/ power, or batteries in micro-grids)</td></tr>
</table>

An Energy Transition Office could ease coordination and implement a detailed roadmap that brings together actions

ILLUSTRATIVE EXAMPLE OF AN IMPLEMENTATION ROADMAP

Owner: Sectoral Coordinating body New value chains / Decision point



JOURNEY TO COP 28 & 29

SEP '23	Present ETIP at UNGA
NOV '23	Further showcase details at COP 28
DEC '23	Establish and resource ETO
'24	Develop sectoral level implementation plans + new value chains
JUNE '24	Develop project funnel and investor engagement at SEforALL Global Forum and beyond
NOV '24	Present concrete projects for investors at COP 29

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