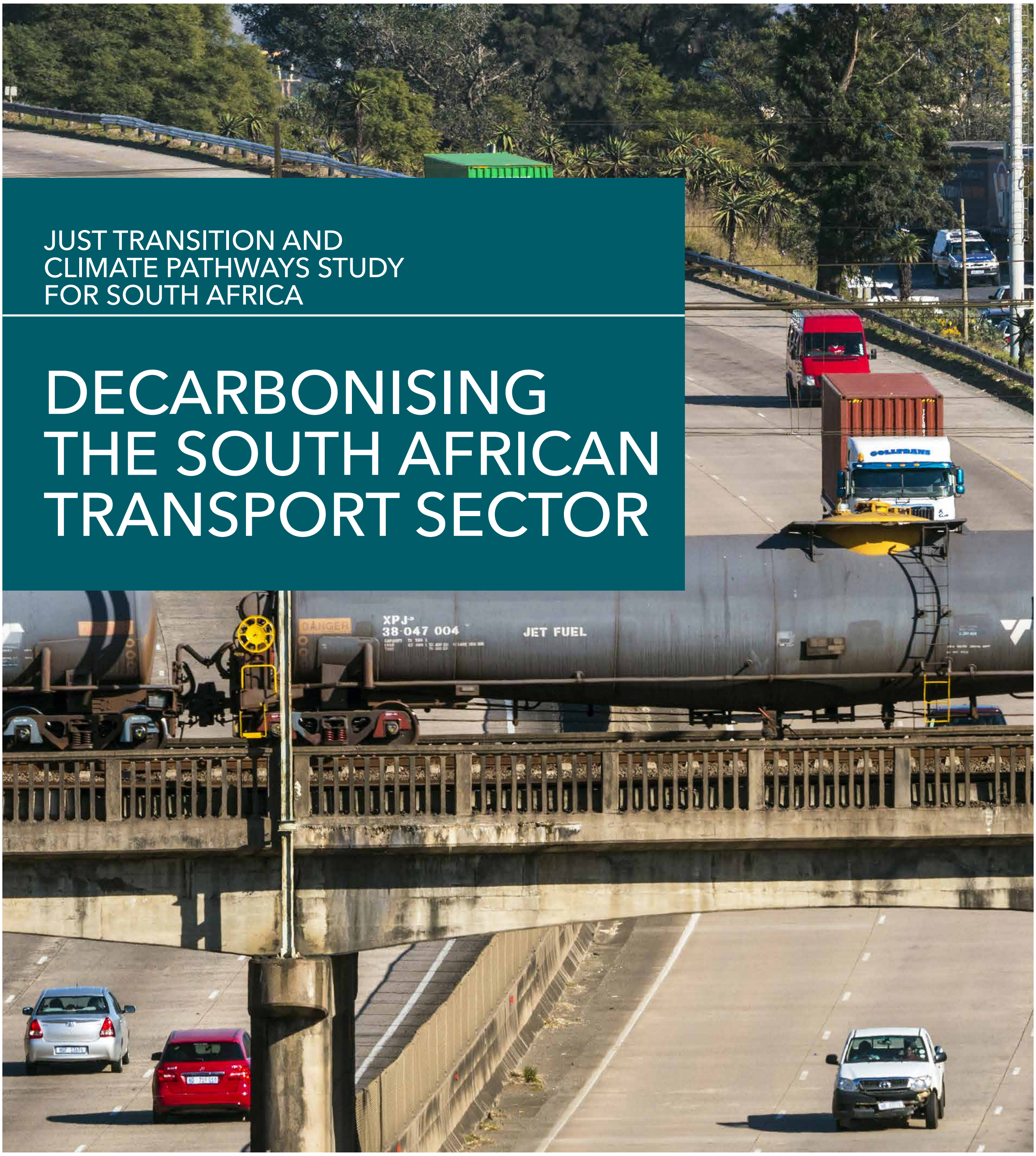
NBI
National Business Initiative

CHAPTER 06

JUST TRANSITION AND CLIMATE PATHWAYS STUDY FOR SOUTH AFRICA

DECARBONISING THE SOUTH AFRICAN TRANSPORT SECTOR



IN PARTNERSHIP WITH

BUSA
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BCG
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ACKNOWLEDGEMENTS

RESEARCH SUPPORTED BY

SOUTH AFRICA UK PACT

UK PACT South Africa: UK PACT has partnered with South Africa to support action on Just Transition pathways and a low-carbon economic recovery. As the third largest economy in Africa, South Africa plays a critical role in economic and policy priority setting at a continental level and across the Southern Africa region. South Africa's long-standing participation in the United Nations Framework Convention on Climate Change (UNFCCC) processes creates a solid platform for an impactful and transformational UK PACT partnership. Moreover, UK PACT seeks to support climate action that will contribute to the realisation of other development imperatives in South Africa, such as job creation and poverty alleviation. Priority areas of focus for UK PACT in South Africa are aligned with key national priorities in the just energy transition, renewable energy, energy efficiency, sustainable transport, and sustainable finance. UK PACT projects can contribute to addressing industry-wide constraints, common metropolitan challenges, and bringing city, provincial and national level public and private partners together to address climate priorities.

WE MEAN BUSINESS COALITION

We Mean Business: This is a global coalition of nonprofit organisations working with the world's most influential businesses to take action on climate change. The coalition brings together seven organisations: BSR, CDP, Ceres, The B Team, The Climate Group, The Prince of Wales's Corporate Leaders Group and the World Business Council for Sustainable Development. Together we catalyze business action to drive policy ambition and accelerate the transition to a zero-carbon economy. NBI has been a regional network partner to WMB since the beginning of 2015.

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Strategic Partnerships for the Implementation of the Paris Agreement (SPIPA): Climate change is a global threat that requires a decisive and confident response from all communities, particularly from major economies that represent roughly 80% of global greenhouse gas emissions. The 2015 Paris Agreement, complemented by the 2018 Katowice climate package, provides the essential framework governing global action to deal with climate change and steering the worldwide transition towards climate-neutrality and climate-resilience. In this context, policy practitioners are keen to use various platforms to learn from one another and accelerate the dissemination of good practices.

To improve a geopolitical landscape that has become more turbulent, the EU set out in 2017 to redouble its climate diplomacy efforts and policy collaborations with major emitters outside Europe in order to promote the implementation of the Paris Agreement. This resulted in the establishment of the SPIPA programme in order to mobilise European know-how to support peer-to-peer learning. The programme builds upon and complements climate policy dialogues and cooperation with major EU economies.

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DI Confederation of Danish Industry

Confederation of Danish Industry: DI is Denmark's largest, most representative and most influential business and employers' organisation, covering manufacturing as well as service industries. DI works with employer and business membership organisations all over the world to reach the UN's Sustainable Development Goals and make their vision of a world with economic opportunities for everyone come alive.

PARTNERS

National Business Initiative

At the National Business Initiative (NBI), we believe in collective action and collaboration to effect change; building a South African society and economy that is inclusive, resilient, sustainable and based on trust. We are an independent business movement of around 80 of South Africa's largest companies and institutions committed to the vision of a thriving country and society. The NBI works with our members to enhance their capacity for change, leverage the power of our collective, build trust in the role of business in society, enable action by business to transform society and create investment opportunities.

Business Unity South Africa

BUSA, formed in October 2003, is the first representative and unified organisation for business in South Africa. Through its extensive membership base, BUSA represents the private sector, being the largest federation of business organisations in terms of GDP and employment contribution. BUSA's work is largely focused around influencing policy and legislative development for an enabling environment for inclusive growth and employment.

Boston Consulting Group

BCG partners with leaders in business and society to tackle their most important challenges and capture their greatest opportunities. BCG, the pioneer in business strategy when it was founded in 1963, today works closely with clients to embrace a transformational approach aimed at benefitting all stakeholders – empowering organisations to grow, build sustainable competitive advantage, and drive positive societal impact. Their diverse global teams are passionate about unlocking potential and making change happen, and delivering integrated solutions.

TERMINOLOGIES

AFOLU	Agriculture, Forestry and Other Land Use
BEV	Battery Electric Vehicle
bbl	Barrel
bn	Billion
BRT	Bus Rapid Transit
BUSA	Business Unity South Africa
c	Cent
CAPEX	Capital Expenditure
CCUS	Carbon Capture Utilisation and Storage
CNG	Compressed Natural Gas
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent
COP27	UN Climate Change Conference of the Parties #27
DACCS	Direct Air Carbon Capture and Storage
e-ammonia	Ammonia (NH3) made with green hydrogen
e-fuels	Fuels made with green hydrogen
e-methanol	Methanol (CH3OH) made with green hydrogen
EIA	United States Energy Information Administration
EJ	Exajoule (10^18 J)
EU	European Union
EV	Electric Vehicle
FCEV	Fuel Cell Electric Vehicle
GDP	Gross Domestic Product
GHGI	Greenhouse Gas National Inventory
GJ	Gigajoule (10^9 J)
Green hydrogen	Hydrogen produced from renewable energy and water
Gt	Gigatonne (10^9 t)
GW	Gigawatt (10^9 W)
GWh	Gigawatt hour
H_2	Hydrogen
HDV	Heavy Duty Vehicle
ICE	Internal Combustion Engine
IEA	International Energy Agency
IPP	Independent Power Producer
IPCC	Intergovernmental Panel on Climate Change
J	Joule
k	Thousand

kW	kilowatt (10^3 W)
kWh	kilowatt hour
LNG	Liquified Natural Gas
MBT	Minibus taxi
mn	Million
Mt	Megatonne (10^6 t)
MW	Megawatt (10^6 W)
NDC	Nationally Determined Contribution
NERSA	National Energy Regulator of South Africa
NPC	National Planning Commission
Parc	All registered vehicles within a defined geographic region
PJ	Petajoule (10^15 J)
PJ/a	Petajoules per annum
pkm	Passenger kilometre
PV	Photovoltaic solar energy
RE	Renewable Energy
REIPPPP	Renewable Energy Independent Power Producer Procurement Programme
RTS	IEA Reference Technology Scenario
SAF	Sustainable Aviation Fuel
Scope 1 emissions	All direct emissions from activities of an organisation
Scope 2 emissions	Indirect emissions from electricity purchased and used by the organisation
Scope 3 emissions	All indirect emissions (not included in Scope 2) that occur in the value chain of the organisation
SDS	IEA Sustainable Development Scenario
Synfuels	Synthetic fuels
TCO	Total cost of ownership
tkm	Tonne kilometre (Freight)
TW	Terrawatt (10^12 W)
TWh	Terawatt hour
UNFCCC	United Nations Framework Convention on Climate Change
WACC	Weighted Average Cost of Capital
xHEV	Hydrid electric vehicle (both electric and ICE)
ZEV	Zero Emissions Vehicle, including BEV and FCEV

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nuGen hydrogen-powered ZEV unveiled at Anglo American's Mogalakwena mine. Image: firstmode.com

OVERVIEW OF CEO CHAMPIONS

Onboarding of additional CEOs ongoing

Joanne Yawitch
NBI CEO

Cas Coovadia
BUSA CEO

Paul Hanratty
Sanlam CEO

Shirley Machaba
PwC CEO

Lungisa Fuzile
Standard Bank South Africa CEO

Leila Fourie
JSE Group CEO

André de Ruyter
Eskom CEO

Arrie Rautenbach
ABSA CEO

Ian Williamson
Old Mutual CEO

Alan Pullinger
First Rand CEO

Portia Derby
Transnet CEO

Stuart Kent
Aurex Constructors CEO

Mark Dytor
AECI CEO

Nolitha Fakude
Anglo American SA Chairperson

Taelo Mojapelo
BP Southern Africa CEO

Deidré Penfold
CAIA Exec Director

Theo Boschoff
AgBiz CEO

Seelan Naidoo
Engen MD and CEO

Mohammed Akoojee
Imperial Logistics CEO

Stuart Mckensie
Ethos CEO

Nombasa Tsengwa
Exxaro CEO

Gavin Hudson
Tongaat Hulett CEO

Nyimpini Mabunda
GE SA CEO

Bertina Engelbrecht
Clicks Group CEO

Tshokolo TP Nchocho
IDC CEO

Hloniphizwe Mtolo
Shell SA CEO

Vivien McMenamin
Mondi SA CEO

Andrew Robinson
Norton Rose Fulbright CEO

Roland van Wijnen
PPC Africa CEO

Njombo Lekula
PPC MD SA Cement and Materials

Alex Thiel
SAPPI CEO

Fleetwood Grobler
Sasol CEO

1.
FOREWORD

JUST TRANSITION AND CLIMATE PATHWAYS STUDY FOR SOUTH AFRICA

South Africa is a signatory to the United Nations Framework Convention on Climate Change (UNFCCC) and to the Paris Agreement. As an energy and emissions intensive middle-income developing country, it recognises the need for it to contribute its fair share to the global effort to move towards net-zero carbon emissions by 2050, taking into account the principle of common but differentiated responsibilities and the need for recognition of its capabilities and national circumstances.

South Africa is highly vulnerable to the impacts of climate change and will need significant international support to transition its economy and to decarbonise. Furthermore, given the country's high rate of inequality, poverty and unemployment and the extent of dependence on a fossil fuel-based energy system and economy, this transition must take place in a way that is just, that leaves no-one behind and that sets the country onto a new, more equitable and sustainable development path; one which builds new local industries and value chains.

In response to the above imperatives, the National Business Initiative, together with Business Unity South Africa and the Boston Consulting Group, has worked with corporate leaders to assess whether the pathways exist for the country's economic sectors to decarbonise by 2050, and whether this can be done in such a way as to build resilience to the impacts of climate change and to put the country onto a new, low emissions development path.

The work done by the business community has interrogated the energy, liquid fuels, mining, chemicals, AFOLU (Agriculture, Forestry and Other Land Use), transport and heavy industrial sectors. The results of the modelling and analytical work have been informed by numerous industry experts, academics and scientists. The results demonstrate that these pathways do exist and that even a country with an economy that is structurally embedded in an energy-intensive production system, can shift.

The results of this work to date have shown that to realise these pathways, efforts must begin now. Timing is of the essence and the business community is of the view that there is no time like the present to create the regulatory and policy environment that would support transitioning the economy.

Accordingly, business can commit unequivocally to supporting South Africa's commitment to find ways to transition to a net-zero emissions economy by 2050.

Furthermore, in November 2022, South Africa tabled its revised Nationally Determined Contribution (NDC) to the UNFCCC. Business recognises the need for greater ambition to position the country as an attractive investment destination and increase the chances of accessing green economic stimulus and funding packages. Specifically, business would support a level of ambition that would see the country committing to a range of 420–350 Mt CO_2e by 2030. This is significantly more ambitious than the NDC put out for public comment, and would require greater levels of support with regard to means of implementation from the international community than is currently the case. It is also consistent with international assessments of South Africa's fair share contribution to the global effort, and it would further ensure that the no-regret decisions, that would put South Africa onto a net-zero 2050 emissions trajectory, would be implemented sooner.

While South Africa has leveraged a degree of climate finance from the international community, the scale and depth of the transition envisaged will require substantial investments over an extended period of time. Critically, social costs and Just Transition costs must be factored in. Significant financial, technological, and capacity support will be required to support the decarbonisation of hard to abate sectors. Early interventions in these sectors will be critical.

Upington, Northern Cape. Photo: scatec.com/locations/south-africa

Business sees the support of the international community as essential for the country to achieve its climate objectives. For this reason, business believes that a more ambitious NDC, and one that would place the country firmly on a net-zero emissions by 2050 trajectory, would have to be conditional on the provision of the requisite means of support by the international community. In this light the business community will play its part to develop a portfolio of fundable adaptation and mitigation projects that would build resilience and achieve deep decarbonisation.

Despite the depth of the challenge, South African business stands ready to play its part in this historical endeavour. Business is committed to working with government and other social partners, with our employees, our stakeholders, and the international community, to embark on a deep decarbonisation path towards net-zero and to build the resilience to the impacts of climate change that will ensure that our country contributes its fair share to the global climate effort.

2.
INTRODUCTION

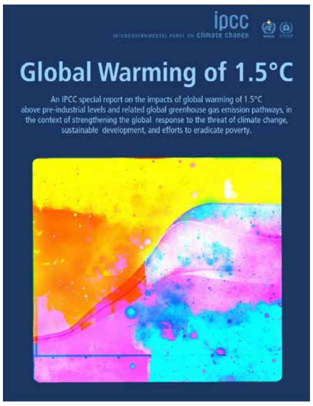
2.1 THE PURPOSE OF THIS REPORT

This report is part of the Just Transition and Climate Pathways study for South Africa. It focuses on the decarbonisation of South Africa's transport sector, and is part of a series of reports that are being released. These reports are intended to leverage further engagement between sector experts and key stakeholders, beyond the extensive stakeholder engagement that has been undertaken since August 2020 within the respective technical working groups of the project. We hope this will foster continued dialogue as we work towards a final report that will collate the individual sector findings and provide collective insight.

2.2 THE CASE FOR CHANGE

2.2.1 CLIMATE CHANGE AND THE RACE TO GLOBAL NET-ZERO EMISSIONS BY 2050

Climate change is the defining challenge of our time. Anthropogenic climate change poses an existential threat to humanity. To avoid catastrophic climate change and irreversible 'tipping points', the Intergovernmental Panel on Climate Change (IPCC) stresses the need to stabilise global warming at 1.5 °C above pre-industrial levels. For a 66% chance of limiting warming by 2100 to 1.5 °C, this would require the world to stay within a total carbon budget estimated by the IPCC to be between 420 to 570 gigatonnes (Gt) of CO_2, to reduce net anthropogenic emission of CO_2 by ~45% of 2010 levels by 2030, and to then reach net-zero around 2050.[1]



Hence, mitigating the worst impacts of climate change requires all countries to decarbonise their economies. In the 2019 World Meteorological Organization report, 'Statement on the State of the Global Climate', the United Nations (UN) Secretary-General urged: "Time is fast running out for us to avert the worst impacts of climate disruption and protect our societies from the inevitable impacts to come."

South Africa, in order to contribute its fair share to the global decarbonisation drive, bearing in mind the principle of 'common but differentiated responsibilities and respective capabilities', should similarly set a target of reaching net-zero emissions by 2050, **and also keep it within a fair share of the global carbon budget allocated, estimated to be between 7 and 9 Gt CO_2e**.[2]

Even if global warming is limited to 1.5 °C, the world will face significantly increased risks to natural and human systems. For example, 2019 was already 1.1 °C warmer than pre-industrial temperatures, and with extreme weather events that have increased in frequency over the past decades, the consequences are already apparent.[3]

1 IPCC. 2018. *Special Report on Global Warming of 1.5°C*.
2 Extrapolation of the medians of various methodologies described by Climate Action Tracker. The full range is 4–11 Gt CO_2e.
3 World Meteorological Organization. 2019. 'Statement on the State of the Global Climate'.

Photo: UN Climate Action Summit

More severe and frequent floods, droughts and tropical storms, dangerous heatwaves, runaway fires, and rising sea levels are already threatening lives and livelihoods across the planet.

South Africa will be among the countries at greatest physical risk from climate change. It is already a semi-arid country and a global average temperature increase of 1.5 °C above pre-industrial levels translates to an average 3 °C increase for Southern Africa, with the central interior and north-eastern periphery regions of South Africa likely to experience some of the highest increases.[4] Research shows that a regional average temperature increase of over 1.5 °C for South Africa translates to a greater variability in rainfall patterns. Models show the central and western interiors of the country trending towards warmer and drier conditions, and the eastern coastal and escarpment regions of the country experiencing greater variability in rainfall as well as an increased risk of extreme weather events.

Rising temperatures and increased aridity and rainfall variability will have severe consequences for South Africa's agricultural systems, particularly on the country's ability to irrigate, grow and ensure the quality of fruit and grain crops; and on the health of livestock, such as sheep and cattle. The agricultural system will see decreased productivity and declining health at temperature thresholds. Parasites tend to flourish in warmer conditions, threatening people as well as livestock and crops. Increasing temperatures and rainfall variability threaten South Africa's status as a mega-biodiverse country. Severe climate change and temperature increases will shift biome distribution, resulting in land degradation and erosion. The most notable risk is the impact on the grassland biome, essential for the health of South Africa's water catchments, combined with the risk of prolonged drought.

Finally, rising ambient temperatures, due to climate change and the urban heat effect, threaten the health of people, particularly those living in cramped urban conditions and engaging in hard manual labour, as higher temperatures result in increased risk of heat stress and

4 Department of Environmental Affairs, Republic of South Africa. 2018. *South Africa's Third National Communication Under the United Nations Framework Convention on Climate Change.*

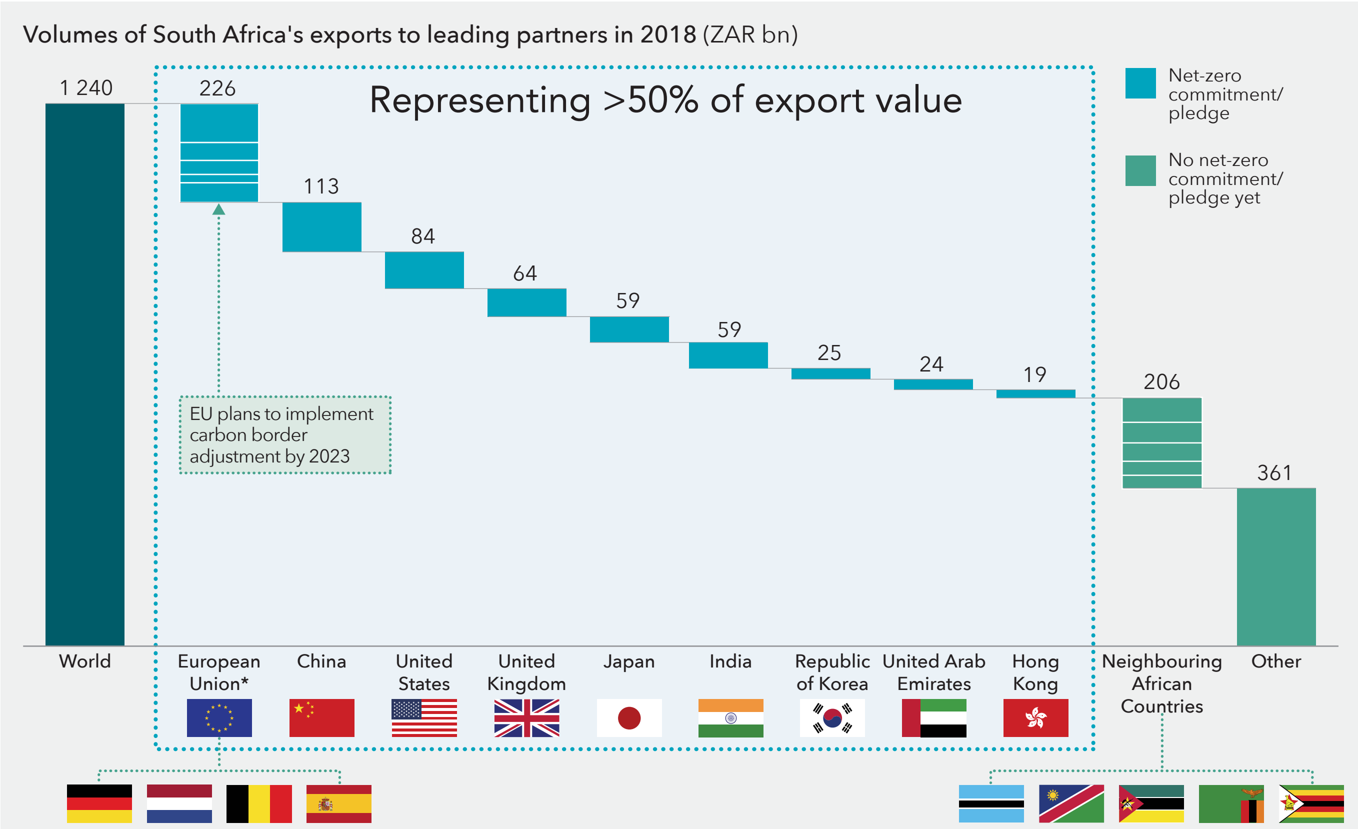
a reduction in productivity. Therefore, limiting global climate change and adapting to inevitable changes in the local climate will be critical to limit the direct, physical risks to South Africa. Like many developing countries, South Africa has the task of balancing the urgent need for a just economic transition and growth, while ensuring environmental resources are sustainably used and consumed, and responding to the local physical impacts of climate change.[5] While South Africa is highly vulnerable to the physical impacts of climate change, its economy is also vulnerable to a range of transition risks posed by the global economic trend toward a low-carbon future, such as those from changing markets and technologies, and from regulations.

South Africa is also facing a significant trade risk. It ranks in the top 20 most carbon-intensive global economies on an emissions per Gross Domestic Product (GDP) basis. The economy will face mounting trade pressure as trade partners implement their low-carbon commitments. South Africa has predominantly coal-based power generation, with the coal-to-liquid (CTL) process in the liquid fuels sector, and a coal-reliant industrial sector. In the mining sector, three of the four most significant minerals in South Africa's commodity footprint are at risk, given the global efforts to curb emissions: thermal coal, Platinum Group Metals (PGMs), iron ore and gold.

The bulk of South Africa's exports comprise carbon-intensive commodities from the mining, manufacturing, and agricultural sectors, which will become less competitive in markets in a future decarbonised world. These sectors also provide the majority of employment of unskilled labour at a regional level.

The carbon-intensity of the South African economy, key sectors, and export commodities must be seen against the backdrop of the country's key trading partners committing to ambitious decarbonisation goals. By October 2022, countries representing 83% of global carbon dioxide emissions and 91% of the world's economy have made ambitious commitments to carbon-neutrality. Many of South Africa's key export markets have set net-zero targets, including the European Union (EU), China, the United States, the United Kingdom, Japan, India, United Arab Emirates (UAE), and South Korea (see Figure 1).[6]

Figure 1: Trade-related risks pose additional threats to South Africa's economy if it does not transition



Note: Exchange rate based on 2018 average = ZAR13:US$24.
* Top three trade partners within EU are Germany, Netherlands and Belgium, and among those with most aggressive targets.

Source: World Integrated Trade Solution 2018; Press research.

5 Department of Environmental Affairs, Republic of South Africa. 2016. *South Africa's Second Annual Climate Change Report*.

6 https://zerotracker.net/


Photo: Shutterstock

As part of the Glasgow Climate Pact at the UN Climate Change Conference of the Parties (COP26) in November 2021, countries were requested to "revisit and strengthen" their 2030 emissions-reduction targets – known as nationally determined contributions or NDCs – by the end of 2022 to better align with the Paris Agreement's goal of limiting global temperature rise to 1.5 °C.

Over and above this, certain regions like the EU are considering carbon border taxes which could impact future trade. Such taxes would be applied on the carbon content of imports to the EU. It is therefore essential to consider how South Africa's competitiveness in global markets, and hence the viability of its industries, will be affected should key trading partners start taking steps to protect their net-zero commitments and enable their net-zero carbon growth trajectories. South Africa will need to address the risks and seize the opportunities presented by climate change.

South Africa will have the chance to tap into new opportunities. Goldman Sachs estimate that around 35% of the decarbonisation of global anthropogenic greenhouse gas emissions is reliant on access to clean power generation, and that lower-carbon hydrogen and clean fuels will be required for hard-to-decarbonise sectors.[7] South Africa has key strategic advantages which can be leveraged to tap into such emerging opportunities. It has a number of significant assets including sun, wind and space. Renewables-dominated energy systems and local manufacturing are key. South Africa's coal assets are aged, and decommissioning coal plants can be done within the carbon budget and with minimal stranded asset risk. Its motor vehicle manufacturing expertise could be transitioned to electric vehicle (EV) production. The country's stable and well-regulated financial services sector, among the most competitive in the world, would make a strong base for green finance for the continent. The combination of wind and solar enables the right kind of conditions for Green hydrogen (Green H_2), setting the stage for South Africa to be a net exporter. The role of PGMs in hydrogen and fuel cell technology and the increased demand for certain mined commodities, like copper for use in green technology, could bolster the minerals sector. South Africa's experience with the Fischer–Tropsch process and installed asset base positions it to be one of the world leaders in carbon-neutral fuels, and other innovations are waiting to be unlocked.

The imperative is clear: South Africa must decarbonise its economy in the next three decades and transform it into a low-carbon, climate-resilient, and innovative economy. This transition also needs to take place in a manner that is just and simultaneously addresses inequality, poverty and unemployment to ensure that no-one is left behind and that the future economy is also socially resilient and inclusive.

7 Goldman Sachs. 2020. *Carbonomics: Innovation, Deflation and Affordable De-carbonisation.*

2.2.2 THE NEED FOR A JUST TRANSITION

With a Gini coefficient of 0.63, South Africa is one of the most unequal societies in the world today.[8] A recent study shows that the top 10% of South Africa's population owns 86% of aggregate wealth and the top 0.1% close to one-third. Since the onset of the COVID-19 pandemic, levels of poverty have further increased and have likely shifted beyond 55% of the population. In July 2020, a record 30.8% of the population was unemployed.[9] Exacerbating this are levels of youth unemployment that are amongst the highest in the world.[10]

As South Africa grapples with the economic recession accompanying the pandemic, and copes with the need to rebuild the capacity of the State and its institutions following a decade of state capture, it must start rebuilding and transforming its economy to make it resilient and relevant in a decarbonised world. However, while a transition towards a net-zero economy will create new economic opportunities for South Africa, it is also a transition away from coal, which without careful planning and new investments will put many jobs and value chains at risk in the short-term, and exacerbate current socio-economic challenges.

Today, the coal mining sector provides almost 0.4 million jobs in the broader economy, with ~80 k direct jobs and ~200 k to 300 k indirect and induced jobs in the broader coal value chain and economy. The impact is even broader when it is taken into account that, on average, each mine worker supports 5 to 10 dependents. This implies a total of ~2 to 4 million livelihoods.[11] The low-carbon transition must do more than simply address what is directly at risk from decarbonisation. The transition must also address the broader economic concern of stalled GDP growth of ~1% for the last five years, rising unemployment with ~3% increase over the last five years,[12] a deteriorating debt to GDP ratio, and the consistently negative balance of trade.[13]

These challenges are more severe given further deterioration during the COVID-19 pandemic. It is therefore critical that South Africa's transition is designed and pursued in a way that is just; meaning that it reduces inequality, maintains and strengthens social cohesion, eradicates poverty, ensures participation in a new economy for all, and creates a socio-economic and environmental context which builds resilience against the physical impacts of climate change.

This transition requires action, coordination, and collaboration at all levels. Within sectors, action will need to be taken on closures or the repurposing of single assets. Job losses must also be addressed with initiatives like early retirement and reskilling programmes, with the latter having the potential for integration with topics like skills inventories and shared infrastructure planning and development. A national, coordinated effort to enable the Just Transition will also be crucial to address the education system and conduct national workforce planning. In order to implement its Just Transition, South Africa will need to leverage global support in the form of preferential green funding, capacity-building, technology-sharing, skills development, and trade cooperation.

To move towards this net-zero vision for the economy by 2050, South Africa must mitigate rather than exacerbate existing socio-economic challenges and seize emerging opportunities to support its socio-economic development agenda. How to ensure a Just Transition towards net-zero and to advance South Africa's socio-economic context is therefore the key guiding principle of this study.

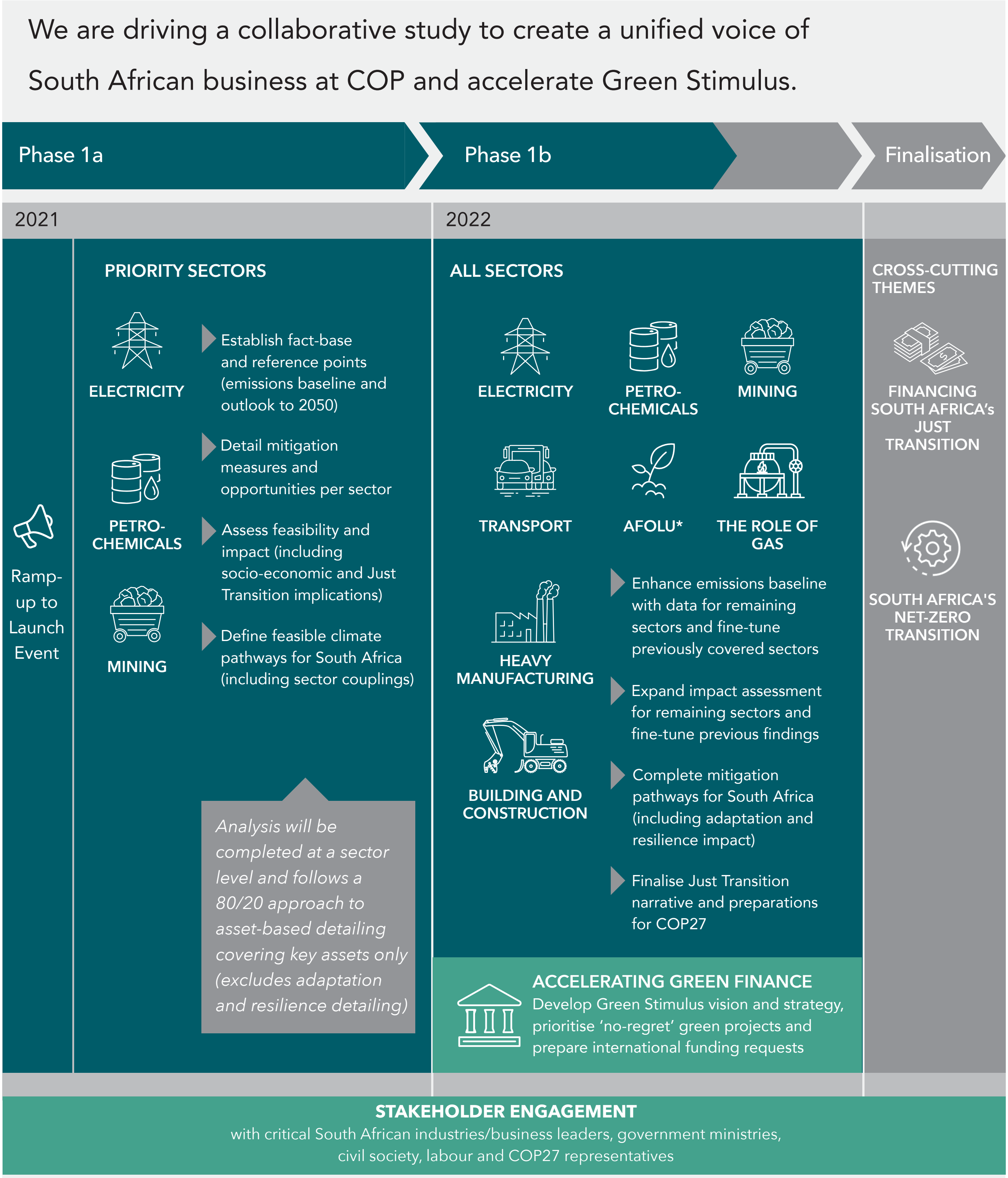
2.3 OBJECTIVES AND APPROACH OF THE OVERALL STUDY

Key objectives. Achieving net-zero emissions in South Africa by 2050, whilst ensuring a Just Transition, is a complex and unique challenge. Extensive studies examining how a Just Transition towards a lower-carbon economy can be achieved in South Africa have already been conducted or are currently underway. There are many different views on what defines a Just Transition in South Africa, which decarbonisation ambitions South Africa is able to pursue and commit to, and how a transition towards a lower-carbon economy can be achieved.

This study is not advocating a particular position. It is not setting ambitions around levels and timelines for South Africa's emission reduction. Nor is it prescribing sector- or company-specific emission reduction targets.

8 The World Bank. 2021. 'South Africa Overview'.
9 StatsSA. 2017. *Poverty Trends in South Africa. An examination of absolute poverty between 2006 and 2015*.
10 Chatterjee, A. et al. 2020. *Estimating the Distribution of Household Wealth in South Africa*.
11 Minerals Council of South Africa. 2020. 'Facts and Figures'.
12 Department of Statistics, Republic of South Africa. 2021.
13 South African Reserve Bank. 2021.

Figure 2: Approach of the overall study



* AFOLU: Agriculture, Forestry and Other Land Use

Source: NBI-BCG project team.

The study does aim to develop the necessary technical and socio-economic pathways research and analysis to support decision-making, and bolster a coordinated and coherent effort among national and international stakeholders. This research is anchored around three key questions:

- What is the cost of inaction for South Africa should it fail to respond to critical global economic drivers stemming from global climate action?
- What would it take, from a technical perspective, to transition each of South Africa's economic sectors to net-zero emissions by 2050?
- What are the social and economic implications for South Africa in reaching net-zero emissions by 2050?

Approach. To understand how a transition of the South African economy towards net-zero emissions can be achieved, the study assessed each sector and intersectoral interdependencies in detail. Our analysis is structured along the understanding of what the decarbonisation pathways could be for key heavy emitting sectors, namely: electricity, petrochemicals and chemicals, mining, metals and minerals, manufacturing, transport, and AFOLU (Agriculture, Forestry and Other Land Use) (see Figure 2). Given this is a multi-year project, a preliminary report is being released as each sector study is completed. Towards the end of the study, each sector analysis will be further refined on the basis of a better understanding of interlinkages. For example, insights gained from the transport sector analysis around the impact of electric vehicles on electricity demand will be leveraged for further refinement of the electricity sector analysis.

The first phase of the study focused on today's key drivers of South Africa's emissions: electricity and the petrochemicals and chemicals sectors which make up more than 60% of the country's total emissions. Given the socio-economic implications of decarbonising South Africa's energy landscape, particularly impacting coal mining regions and the mining workforce, the mining sector was included and assessed as part of the project's first phase.

The second phase of the study focused on the transport and AFOLU sectors.

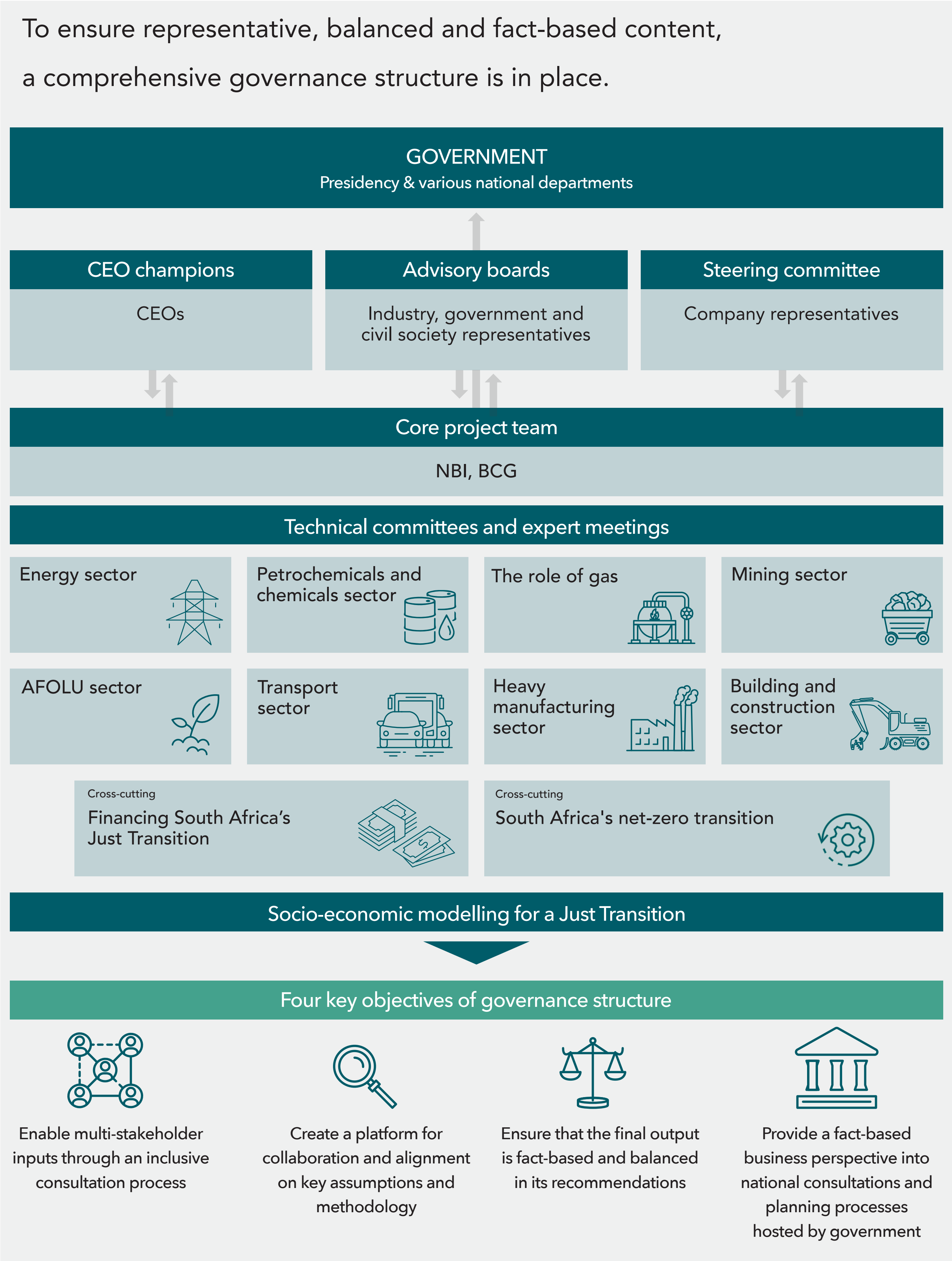
The study also provided a view on the role of natural gas.

Eventually, the study will provide a comprehensive view of the South African economy, its potential future net-zero economy and the pathways that can lead to this future economy as informed by various key stakeholders.

The study is a collaborative effort, aiming to create a unified voice of South African business on the country's needs, opportunities, and challenges in achieving a net-zero economy, involving multiple stakeholders from all sectors. The governance arrangement that has overseen this work is key to enabling this collaborative, multi-stakeholder approach: across multiple levels, key stakeholders are involved in the content development.

The sector assessments were conducted within technical committees which included South African and international experts and stakeholders from private and public sectors, as well as civil society and academia. An advisory board consisting of high-profile representatives from various sectors including industry, government, labour, civil society, and academia and a steering committee consisting of selected private and public sector representatives, provided continuous direction on content development (see Figure 3). In addition, a group of 30 CEOs from across the private sector endorsed and guided the study development (see pages 7–9).

Figure 3: Governance set-up of the study



2.4 APPROACH TO THIS TRANSPORT REPORT

The aim of the transport sector analysis is to identify potential pathways to a just, net-zero transition of South Africa's transport sector by 2050. South Africa's transport sector faces a broad range of challenges, including the carbon intensity of the sector and a complex set of structural inefficiencies, inhibiting the sector's ability to serve as an enabler of economic growth and industrial development. As such, South Africa's future transport sector needs to be decarbonised while managing demand* and improving the efficiency, reliability, and affordability of transport as a service. This analysis answers five key questions:

1. What is the starting point for South Africa's transport sector?
2. How will global decarbonisation trends impact South Africa's transport sector?
3. What net-zero pathways exist for South Africa's transport sector?
   - What local levers are required to fully decarbonise the sector by 2050?
   - What could a net-zero pathway, anchored on these levers, look like for South Africa?
   - What are the key outcomes and signposts to monitor in decarbonising South Africa's transport sector?
4. What are the key enablers to unlock a just net-zero transition for the transport value chain?
5. What are the recommended no-regret actions?

**Note: Managing demand will be critical for the decarbonisation of each mode of transport and also for a Just Transition of the sector. This analysis assesses the high-level impact of spatial planning on the total demand for transport, as per the International Energy Agency (IEA) scenarios, but does not assess quantitatively, and in detail, the impact of improved urban and spatial planning. Addressing South Africa's spatial planning will be essential for a Just Transition.*

South Africa's transport sector encompasses the technologies, systems and infrastructure for passenger and freight transport, across all modes of transport. This assessment of the transport sector focuses only on local intracity, intercity and interprovincial transport within the borders of South Africa in line with the national Greenhouse Gas Inventory (GHGI).[14]

The scope of the analysis across modes is:

- The **road transport** sector: This includes all private passenger vehicles, public buses and minibus taxis (MBTs), and light- to heavy-freight vehicles using the supporting road infrastructure. We do not look at road infrastructure changes that might be needed.
- The **rail transport** sector: This includes passenger and commercial/freight rail. The passenger rail network include the Metrorail and Shosholoza Meyl networks, as well as the Gautrain rail network in Gauteng. The commercial rail sector consists of the Transnet Freight Rail.
- The **local aviation** sector: This encompasses all aeroplanes using airports and airport infrastructure, primarily for inter-provincial passenger transport. We did not look at the need to alter ground infrastructure supporting domestic aviation.
- The **local shipping** sector: This includes the small-scale luxury cruise industry and community fishing industry. The emissions of these industries are negligible, and not reflected in South Africa's emission baseline. As such, this analysis only assesses the strategic implications of decarbonising South Africa's local and international shipping sector rather than quantifying a decarbonisation pathway.

What is not assessed quantitatively in detail in this report is what it would take to decarbonise international shipping and aviation routes. However, the impact on shipping costs as a total percentage of export costs (and therefore global competitiveness) is referenced. A range of stakeholders along the transport value chain have been engaged throughout the assessment, to strengthen the assumptions, test the findings, and enrich the insights. Stakeholders from the upstream energy sectors like the power and petrochemicals sectors, the local public and private transport and logistics sectors, automotive manufacturers, academia, and broader local and international transport experts have also been engaged.

14 Department of Forestry, Fisheries, and the Environment (DFFE), 2021. *National GHG Inventory Report – 2017.*

3.
KEY FINDINGS OF THE TRANSPORT SECTOR ANALYSIS

10 key findings on the transport sector analysis

1. *Transport in South Africa is the third largest emitting sector, with >90% of emissions from road transport. It faces the dual challenge of decarbonising whilst improving transport as a service for consumers and enabling other sectors to decarbonise.*

2. *Global trends in technology and policy can drive a 50% reduction in emissions by 2050, with limited local support – primarily due to electric vehicle (EV) adoption in road transport.*

3. *Without a deliberate and coordinated local effort, South Africa's transport sector will be on a trajectory that is inconsistent with the NDC by 2030 and inconsistent with net-zero by 2050.*

4. *With the right support, the transport sector can be fully decarbonised by 2050 via four key levers:*
   - *Improved spatial planning;*
   - *Mode-shift to rail and public transport;*
   - *Accelerated zero-emission technology adoption, coupled with the decarbonisation of the national grid; and*
   - *Use of green fuels for hard-to-abate aviation and shipping.*

5. *A net-zero pathway requires shifting 15%–20% of road traffic to rail, banning new internal combustion engine (ICE) vehicle sales by 2035 and enabling zero emission vehicle (ZEV) uptake for remaining road transport, as well as blending to 100% sustainable aviation fuels by 2050.*

6. *Of all levers that must be pulled to get the transport sector to net-zero, the one that is likely to have the largest financial impact on the end-user of transport as a service is the greening of fuels. The use of green fuels is highly OPEX-intensive with a fuel premium of up to 2.1x for e-ammonia, 2.5x for e-methanol and 1.7–2.1x for e-kerosene, even in 2050.*

7. *South Africa should strategically prioritise high value/value-added exports by developing local beneficiation and industrialisation capacity to mitigate the impact of costly green synfuels (e-ammonia and e-methanol) on shipping costs considering the high trade-weighted distance to key trade partners (such as China, EU and US).*

8. *Key uncertainties and signposts lie in the choice of battery electric vehicles (BEVs) vs fuel cell electric vehicles (FCEVs) in heavy duty transport, autonomous vehicle adoption, the impact of spatial planning, and the interaction between formal and informal public transport.*

9. *To achieve this ambitious pathway, South Africa must build and operate an efficient public transport system, invest in rail and port infrastructure as well as improve their reliability and efficiency, and incentivise EV adoption and public transport use.*

10. *Immediate next steps and no-regret actions include incorporating EVs in the EU trade agreement to reduce import tariffs, investing in revitalising the rail infrastructure, and improving governance within rail and port management.*

3.1 TOWARDS A NET-ZERO TRANSPORT SECTOR IN SOUTH AFRICA

3.1.1 WHAT IS THE STARTING POINT FOR SOUTH AFRICA'S TRANSPORT SECTOR?

The global transport sector

Globally, the transport sector enables economic growth and industrial development by facilitating the movement of people and goods, but the sector is a major emitter. In 2019 the transport sector was responsible for almost 25% of global emissions. Even with decreases in transport demand linked to the COVID-19 pandemic, the transport sector still contributed approximately 20% to global emissions in 2020, and is expected to return to similar levels beyond 2023. The global transport sector's emission footprint is driven by the sector's reliance on fossil fuels, with 90% of transport energy needs in 2020 met with oil.[15]

Beyond managing the demand for transport, decarbonising transport will require the shifting to more efficient transport modes and the scale-up of decarbonised, net-zero compatible modes of transport. According to the IEA *Net Zero by 2050 report:*[16]

- **Road transport** accounts for the majority, around 80%, of the sector's total emissions globally due to the combustion of petrol and diesel in light passenger vehicles, buses and light- to heavy-freight vehicles. The decarbonisation of the road transport sector will require a shifting of road demand to rail, with rail capturing 20% of the total passenger demand by 2050, and uptake of up to almost 2 bn light battery electric vehicles (BEVs), hybrid electric vehicles (xHEVs) and fuel cell electric vehicles (FCEVs) by 2050, from 11 mn in 2020.
- **Rail transport** is a low-emitting and efficient mode of transport. The emissions from rail transport are negligible, contributing only ~1% to the sector's global direct emissions in 2020 – with this contribution maintained pre- and post-pandemic. The rail sector will, however, be a key enabler to decarbonise and improve the efficiency of both road and aviation transport, with a mode-shift to rail. The share of electricity and hydrogen in the rail energy mix in 2050 reaches 96%, with 90+% electricity and 5% hydrogen.
- **Aviation and shipping** also contribute to the sector's greenhouse gas emissions with ~0.6 Gt and ~0.8 Gt emitted in 2020, respectively, due to the combustion of jet fuel and marine gas oil. There is a role for shifting aviation demand to rail, but the decarbonisation of these sectors will also require the uptake of lower and zero-emission fuels, with the consumption of fossil jet fuel ramping down from 9 EJ in 2020 to 3 EJ in 2050, and with the use of sustainable zero-emission fuels ramping up from 2030, to reach 80% of the energy supply in 2050.[17]

Definitions of lower emission alternatives to conventional oil products

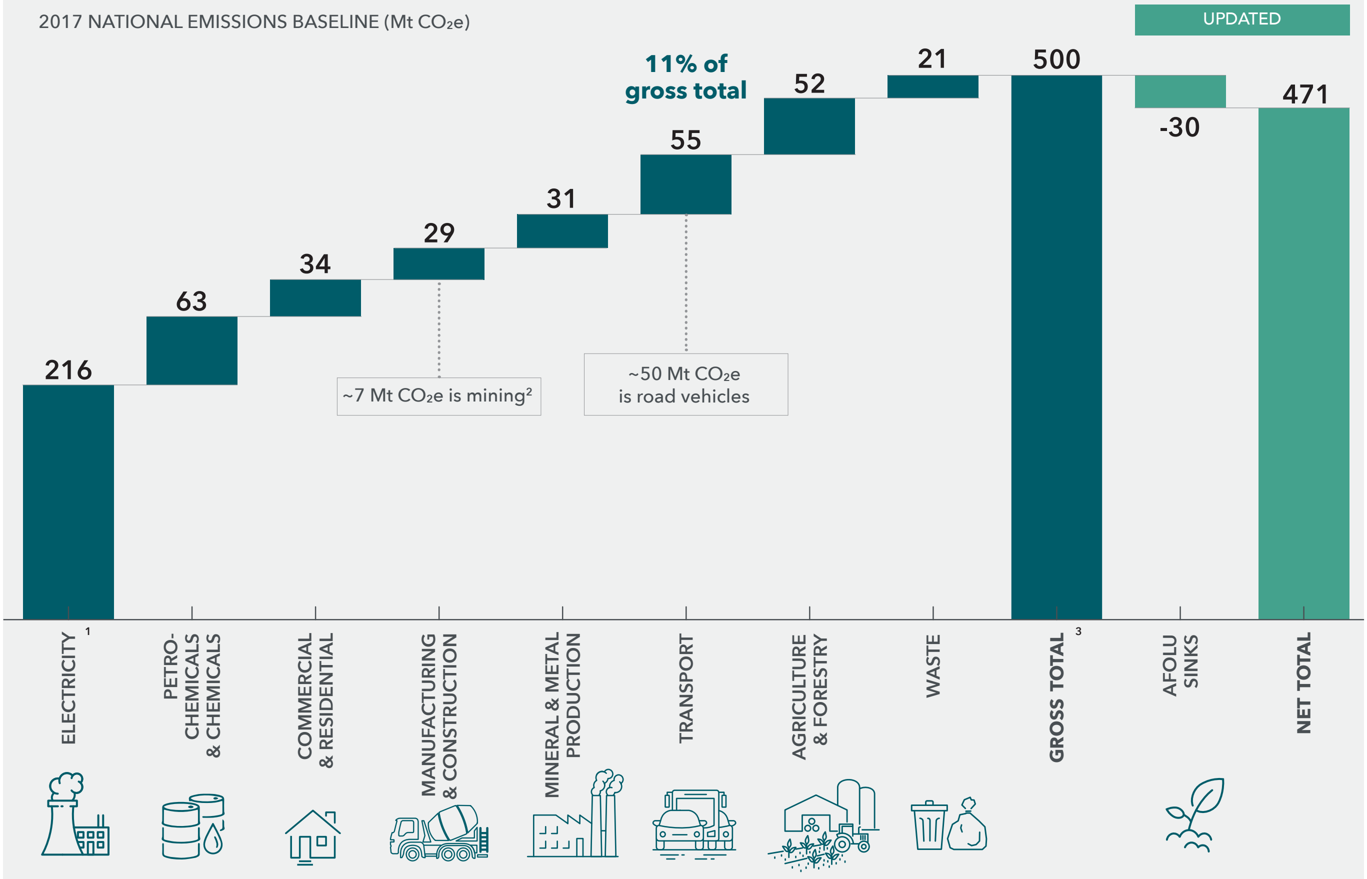
- **Biofuels**: Substitute fuels derived from biogenic carbon sources, such as bioethanol from sugarcane, biodiesel from used cooking oil or biogas, and biomethane from anaerobic digestion of organic wastes. These have the potential to drastically lower lifecycle emissions versus fossil-based equivalents, depending on supply chain and process emissions.
- **E-fuels**: Substitute fuels, either Green hydrogen itself or derivatives using Renewable Energy (RE) and sustainable carbon dioxide or nitrogen, such as Sustainable Aviation Fuel (SAF) or e-methanol synthesised from direct air capture (atmospheric), CO_2 or e-ammonia using nitrogen captured with RE. These have the potential to be true net-zero fuels, with all carbon emitted having been captured from the atmosphere.
- **Low-emissions fuels**: General term for substitute fuels (biofuels and e-fuels). Since the carbon emitted in combustion is equivalent to the carbon captured in organic feedstock growth or removal from the atmosphere, they can approach net-zero (depending on production and supply chain emissions). Typically used as drop-in replacements, their sustainability status depends on their reduction in lifecycle carbon emissions versus the fuel they are replacing.

15 IEA, 2021. *Net Zero by 2050 – A Roadmap for the Global Energy Sector.*

16 IEA, 2021.

17 South Africa's export shipping market, with the supporting port infrastructure, is classified as international, non-local, shipping and as such is excluded from the baseline. The strategic implications of decarbonising international shipping are assessed, similar to local shipping.

Figure 4: The transport sector's contribution to South Africa's national gross emissions



Notes: 1. Emission figures based on view of electricity & heat production, of which electricity production contributes >97% of emission.
2. GHGI does not explicitly state estimate for mining emissions so this has been estimated. Assumed scope 1 emissions share of top 12 companies is same as their market share (80%) and use this to gross up to 100% . To be validated with CDP data.
3. Gross total excludes categories 1A5 as it is not linked to any sectors and 1B1 to avoid the double counting of fugitive emissions from coal mining which are included In the mining sector emissions approximation. Agriculture emissions: Agriculture (~47Mt, labelled as 'AFOLU excl. FOLU' in GHGI) + energy emissions in agriculture/forestry/fishing (~4Mt). AFOLU sinks: FOLU (labelled as 'land' in GHGI) + Other ('harvested wood products').

Source: GHGI (2017), IEA (2015), WEO (2019), CDP (2015), GHGI (2015), CAT.

South Africa's transport sector

Transport in South Africa is the third largest emitting sector, with >90% of emissions from road transport. It faces the dual challenge of decarbonising whilst improving transport as a service for consumers and enabling other sectors to decarbonise.

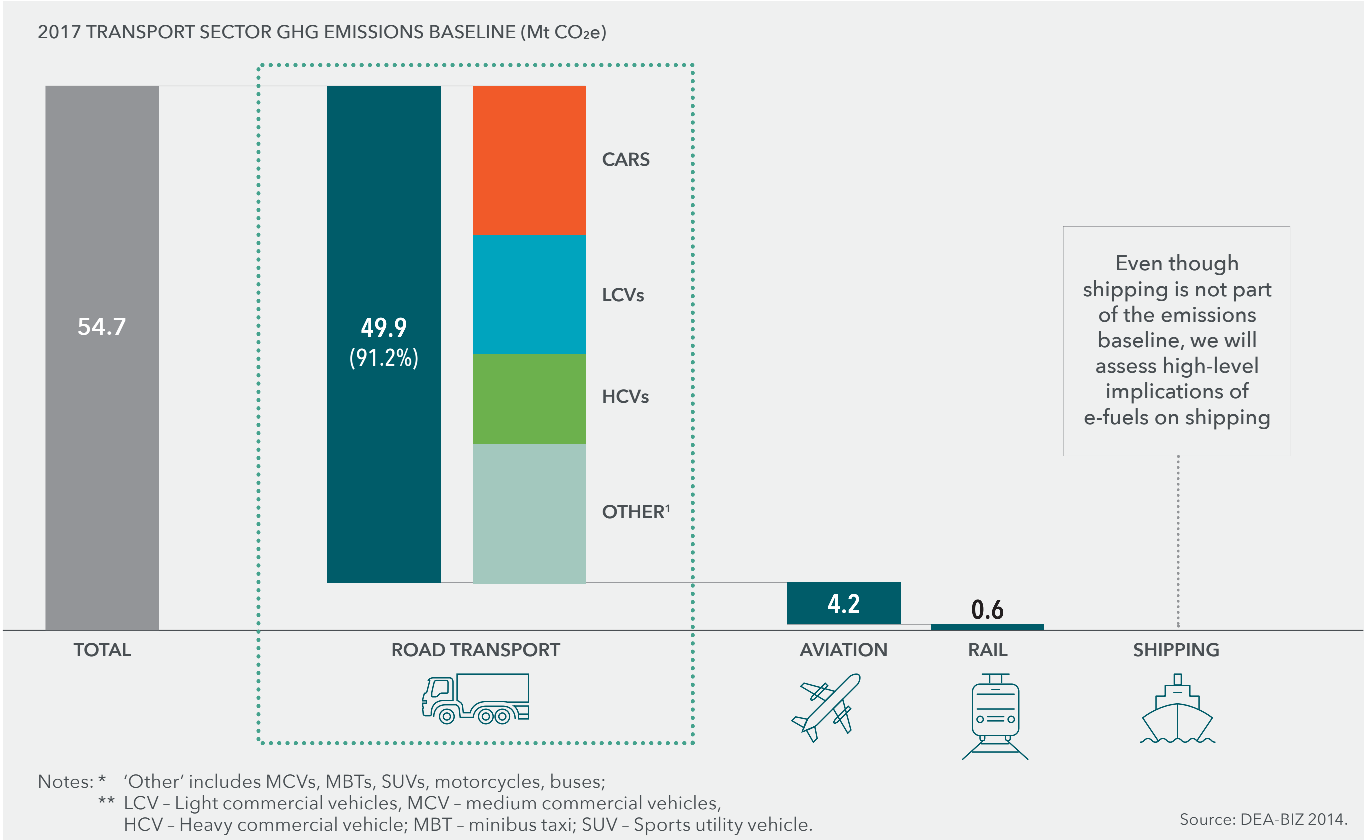
South Africa's transport sector faces a complex set of challenges across the modes of transport. It faces the dual challenge of needing to be decarbonised, whilst improving transport as a service that enables:

1. **Social development** by promoting safe, reliable, accessible, and affordable mobility for people
2. **Economic and industrial development** by facilitating the efficient and reliable movement of goods and provision of services to consumers and for infrastructure development
3. **Environmental and climate-resilience** by eliminating the significant emissions footprint, addressing broader environmental impacts like air pollution, and prioritising climate-resilient infrastructure.

The sector is the third largest emitter in South Africa, with almost 55 Mt CO_2 emissions contributing more than 10% to South Africa's national gross emissions (Figure 4).[18] Across modes, the transport sector faces a broader set of challenges, including for example, the high cost, unsafe, unreliable current public transport system and the deteriorating road and rail infrastructure it uses. These challenges, exacerbated by the spatial planning legacy of Apartheid in South Africa, limit the sector's ability to enable social development, economic growth, and industrial development in South Africa.

18 Department of Forestry, Fisheries, and the Environment (DFFE), 2021. *National GHG Inventory Report – 2017.*

Figure 5: 2017 Transport sector emissions sectoral breakdown



South Africa's transport emissions are primarily driven by the **road transport** sub-sector which contributes 90+% to the sector's emission baseline, with almost 50 Mt CO_2 directly emitted in 2017.[19] The road sector's emissions stem from the combustion of ~850 PJ [25bn L] of petrol and diesel in ~8 mn passenger vehicles, more than ~300 k MBTs, ~60 k buses and almost ~3 mn light- to heavy-freight vehicles.[20]

The roads, especially in major cities, are critically congested and the infrastructure is deteriorating, with around three-quarters of the South African National Roads Agency SOC Ltd (SANRAL) roads older than the original 20-year planned lifespan. The public bus system, which includes the Bus Rapid Transit (BRT) in Durban, Johannesburg and Cape Town, and the taxi industry, 90% of which is the informal MBT industry, are the main public road transport systems, all of which face safety and reliability challenges.[21] While the public bus and train systems are more affordable, largely due to government subsidies, ~70% of households' needs are captured by the more costly MBTs due to their higher accessibility and flexible routes.[22]

The high cost of public transport is reflected in the South Africa transport survey, which indicated that most households in the lowest income quintile spend more than 20% of their monthly income on public transport.[23]

South Africa's road transport sector creates at least 900 k direct jobs, almost 430 k of which are linked to the taxi industry. The freight sector creates ~260 k jobs, with ~170 k linked to freight handling and the remaining ~90 k linked to freight road transport. The passenger sector creates an additional 50 k direct jobs, with significantly more indirect jobs linked to the production and sale of liquid fossil fuels, for example.[24]

The local **aviation sector** is the second largest contributor to South Africa's transport emissions, with ~4 Mt in 2017.[25]

19 Department of Forestry, Fisheries, and the Environment (DFFE), 2021.
20 Electronic National Traffic Information System (eNaTIS), 2021.
21 Saferspaces.org, 2022. *The state of public transport in South Africa*.
22 Statistics South Africa, 2021. *National Household Travel Survey 2020*.
23 Statistics South Africa, 2021. *National Household Travel Survey 2020*.
24 Transport Education Training Authority, 2018. *TETA Sector Profile – Integrated Report 2018*.
25 Department of Forestry, Fisheries, and the Environment (DFFE), 2021.

The sector's emissions are due to the combustion of almost 60 PJ (~2 bn L) of jet fuel. The average ticket cost for domestic air travel ranges from ZAR1 000–ZAR2 000. These high and variable prices make air travel inaccessible to many South Africans.[26] The aviation sector is the second smallest employer in the transport sector with ~50 k direct jobs, followed only by the 5 k direct jobs in the shipping sector.[27]

South Africa's **rail sector** only contributes 1% to the sector's direct emissions, with less than 1 Mt direct CO_2 emissions in 2017. Approximately 40% of South Africa's rail is conventional rail that runs off the combustion of diesel – the only contributor to the sector's direct emissions. The remaining ~60% is electric rail, which is more emissions-intensive than diesel rail due to South Africa's emissions-intensive power supply. The indirect emissions from electricity of rail transport are higher than the direct emissions from diesel, both in relative and absolute terms, with 85% of the sector's emissions stemming from electricity consumption.[28] The rail sector's infrastructure is deteriorating with aged assets and inadequate maintenance. The infrastructure faces challenges with safety and reliability, which is perpetuated by theft and crime. In 2020, these factors contributed to more than 20 freight trains, on average, being cancelled per day.[29] The rail sector is also a significant employer, with almost 110 k direct jobs, excluding those in the freight sector.[30]

The maritime or shipping sector in South Africa is predominantly international commercial/freight shipping. Domestic shipping is limited to passenger cruises and small-scale boats for fishing and leisure. Therefore, there are limited domestic emissions from the maritime sector, as shown in Figure 5. However, the decarbonisation of the global shipping industry will have significant impact on South Africa, where 98% of international trade is seaborne.[31]

To estimate what a future decarbonisation pathway for the transport sector could look like, it is critical to understand what South Africa's transport sector demand trajectory looks like in a reference case. With an annual growth of ~2% per annum, linked to economic and population growth, the demand for transport could almost double by 2050, reaching ~700 bn passenger kilometres (pkm)[32] and more than 960 bn tonne-kilometres (tkm)[33] in 2050.

This doubling of the demand for transport strengthens the decarbonisation imperative – without local efforts to decarbonise, and if the emission factors across modes remain flat, the transport sector's annual emissions could double from ~55 Mt in 2020 to more than 100 Mt in 2050, one quarter of South Africa's national emissions today.

Photo: Shutterstock

26 Airports Company South Africa, 2021. *Statistics*.

27 Transport Education Training Authority, 2018.

28 Department of Forestry, Fisheries, and the Environment (DFFE). *South Africa's Greenhouse Gas Mitigation Potential Analysis 2010 – Technical Appendix E Transport Sector.*

29 Department of Transport & Passenger Rail Agency of South Africa, 2015. *Challenges related to rail & road network system*.

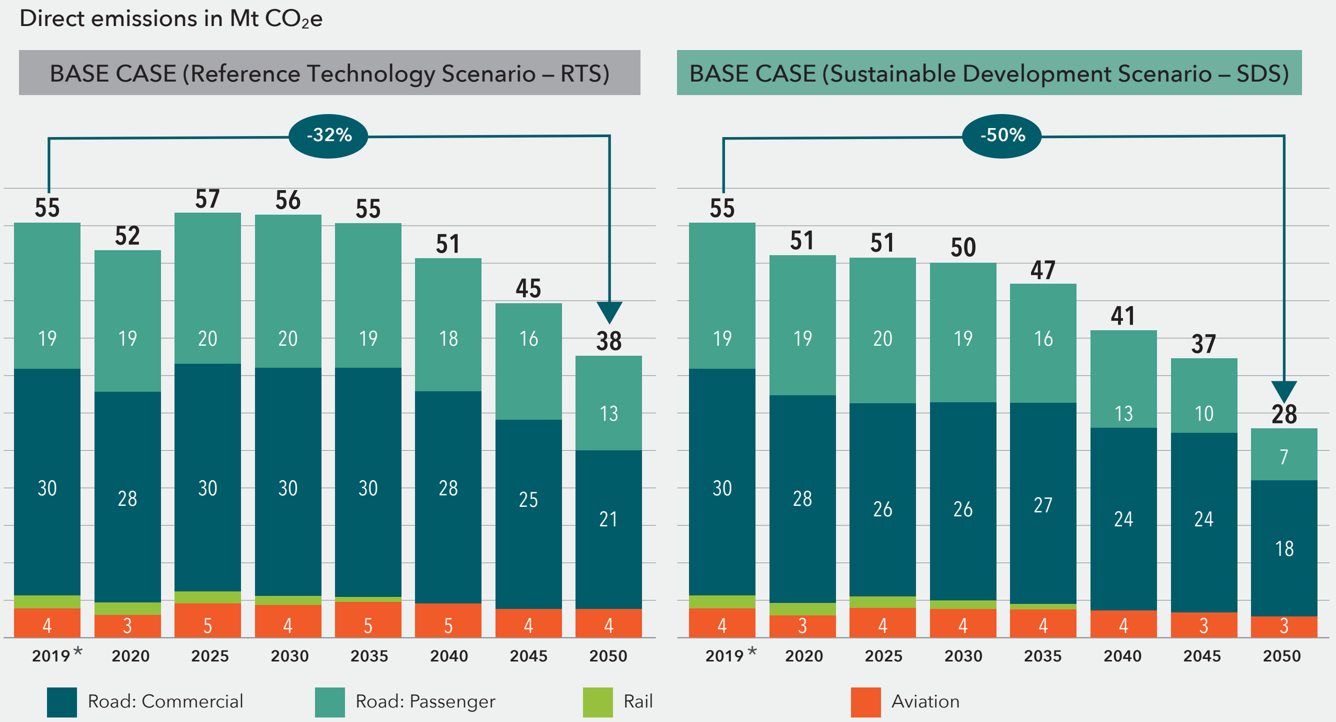
30 Transport Education Training Authority, 2018.

31 Transnet National Ports Authority, 2021. *Port Statistics.*

32 Passenger kilometre is the unit of measurement for the transport of 1 passenger over 1 kilometre.

33 Tonne kilometres is the unit of measurement for freight transport which represents the transport of 1 tonne of goods over 1 kilometre.

Figure 6: South African transport sector emissions as evolution driven by global trends



- Uptake of zero-emissions tech across modes drives decline in emissions.
- **Road transport the main driver of emissions (almost 90%)** despite being most affected by global decarbonisation trends.
- Emissions in aviation remain, given relatively low adoption (< 50%) of sustainable fuels and growing demand.

- **Lower overall transport demand** and increased uptake of road commercial ZEVs** leads to greater emissions reduction.
- Residual emissions mainly **driven by >4 mn remaining ICEs and hybrids** in road transport with an almost 90% share of emissions.
- Adoption of sustainable aviation fuel occurs at the same rate as the RTS.

Note: * The 2019 national vehicle parc is sourced from National Traffic Information System (Natis) and triangulated with NAAMSA and IHS Markit data.
** ZEVs refers to zero-emission vehicles; excluding international aviation energy demand.

Source: eNatis; ICCT; IEA; IHS Markit; Marklines; NAAMSA; BCG battery model; NBI-BCG project team.

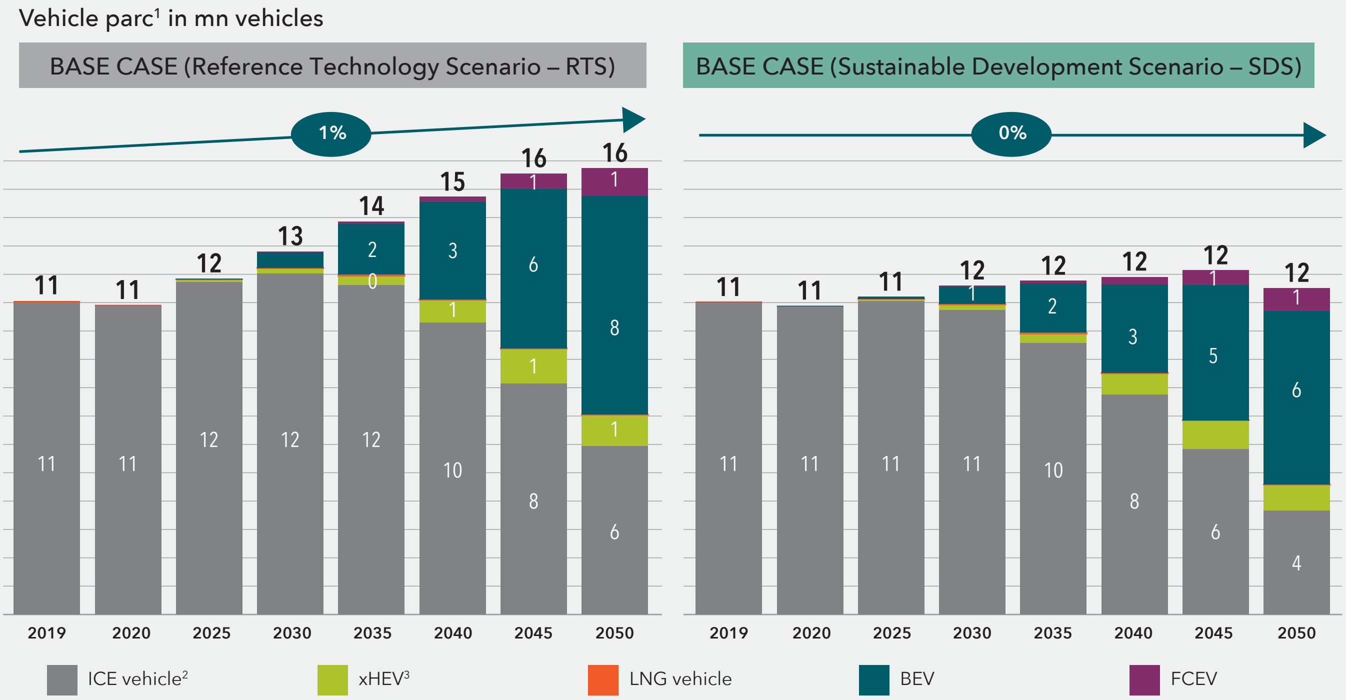
3.1.2 HOW WILL GLOBAL DECARBONISATION TRENDS IMPACT SOUTH AFRICA'S TRANSPORT SECTOR?

Overview of the sector's evolution as impacted by global trends

Global trends in technology and policy can drive a 50% reduction in emissions by 2050, with limited local support – primarily due to electric vehicle (EV) adoption in road transport.

This report uses scenarios as described by the IEA. A global base case (the IEA Reference Technology Scenario) was used to project the uptake of green transport solutions in SA as driven only by global technological change, transport and logistics standards, and international bans and regulations. More rigorous change was based on the IEA Sustainable Development Scenario, which still does not reach net-zero CO_2 emissions by 2050. This is only achieved in the IEA Net Zero Scenario, https://www.iea.org/reports/world-energy-outlook-2021/scenario-trajectories-and-temperature-outcomes.

Figure 7: Evolution of the vehicle parc as driven by global trends



- Vehicle parc growth driven by demand growth but passenger cars growth restricted by rise of on-demand mobility.
- Passenger: ZEVs reach competitiveness in the late 2020s/early-2030s (given high BEV import tariffs) with **~60% adoption by 2050**.
- Commercial: ZEVs reach competitiveness in mid-2030s with **~56% adoption by 2050**.

- Shift to public transport and **rising dominance of on-demand mobility** restricts the growth of the passenger vehicle parc.
- Passenger: ~60% adoption in ZEVs as in RTS.
- Commercial: Overall, 56% adoption of ZEVs as in the RTS. ZEVs reach competitiveness in **heavy road commercial in early 2030s with adoption increasing to 54% (v 46% in RTS)**.

Notes: 1. Vehicle parc does not include non-self-propelled vehicles and cycles, BEV – battery electric vehicle, FCEV – fuel cell electric vehicle, LNG – liquefied natural gas vehicle, ZEV – zero-emission vehicles (i.e. BEV & FCEV)
2. ICE vehicles include petrol and diesel vehicles.
3. xHEV includes: Hybrid electric vehicles (HEVs); mild-hybrid electric vehicle (MHEV); and plug-in hybrid electric vehicle (PHEV).

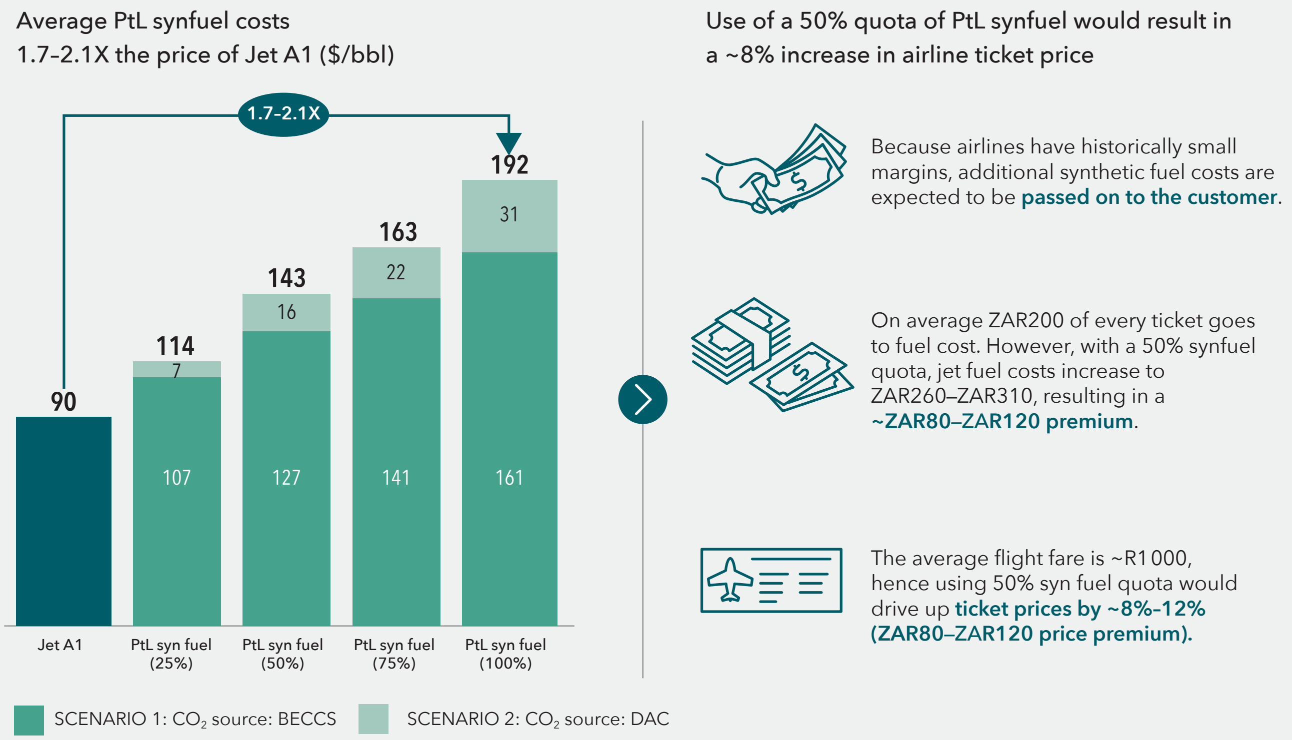
Source: eNatis; ICCT; IEA; IHS Markit; Marklines; NAAMSA; BCG battery model; NBI-BCG project team.

With minimal local intervention, global trends will drive unavoidable change across the transport sector leading to 40%–50% reduction in direct transport emissions by 2050 (see Figure 6). This is driven primarily by government bans on ICE vehicles but also low-carbon alternatives, like BEV's for example, reaching parity on a total cost of ownership basis vs. fossil fuel alternatives. In the short- to mid-term however, emissions reduction is negligible due to the 'inertia' (for example 99% + ICE-based vehicles with ~10+ year replacement rates, consumer behaviour, availability of supporting infrastructure, etc.) that exists in the car parc. In fact, by 2030, emissions could rise by 5% and only a 10%–20% reduction is seen by 2040. If left unmanaged, the scale of change required between 2040 and 2050 to reach net-zero, will therefore be unmanageable, leading to stranded assets both on bank loan books and in manufacturing. A deliberate and coordinated local effort is therefore foundational to enable a net-zero trajectory in transport by 2050.

In the two base cases projected for South Africa from the IEA RTS and SDS scenarios, and without enabling local policy, the number of ICE vehicles more than halves from ~11 mn vehicles in the vehicle parc in 2019 to only 4–6 mn in 2050 (see Figure 7). The number of ICE vehicles does, however, increase in the short- to mid-term, peaking at ~12 mn vehicles in the 2030s. After 2035, the number of ICE vehicles in the vehicle parc declines due to the substitution of ICE vehicles with ZEVs annually. By 2050, passenger and freight adoption of 50%–60% for ZEVs results in ~7–9 mn BEVs and ~1 mn FCEVs for heavier freight in the parc. A more granular view of this car parc change is as follows (numbers including xHEVs):

- **Passenger parc (private):** The number of ICE vehicles more than halves, from 8 mn in 2020 to 1–3 mn in 2050. The ICE vehicles are replaced with 5–7 mn BEVs by 2050.

Figure 8: Comparison of e-fuel costs in the South African aviation sector in 2050

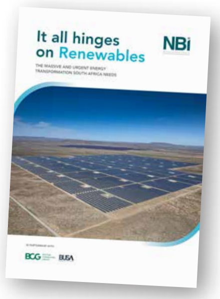


Note: Dollars per barrel, based on theoretical average cost to produce (as no commercially active facilities exist); BECCS= Bioenergy carbon capture. The analysis accounts for neither carbon tax nor green subsidies. This is a comparison at 2050, and therefore takes into consideration learning rates of green technologies.

Source: S&P Platts Jet Fuel Price Index; CAAFI; ICCT 2019; NBI-BCG project team.

- **MBT and bus parc (public):** Across both the IEA's Reference Technology Scenario (RTS) and Sustainable Development Scenarios (SDS), the number of ICE MBTs and buses increases from ~390 k in 2020 to 430 k–620 k in 2050, due to the growth in transport demand and the shifts to public transport. In the base case, a maximum of 30 k–50 k BEVs are in the public vehicle parc by 2050.
- **Light- to medium-freight parc:** The number of light- to medium vehicles increases from ~2.8 mn to 4.2 mn–4.8 mn by 2050 driven by economic growth. BEVs are the main decarbonisation lever, accounting for almost 50% of the light to medium vehicle freight parc by 2050. C/LNG vehicles and FCEVs make up only ~1% together due to prohibitive cost structure.
- **Heavy-freight parc:** The number of ICE vehicles declines by 30%–50% from 2020–2050, with 20 k–25 k FCEVs and 30 k–50 k BEVs by 2050. There is a short-term role for C/LNG vehicles peaking with 11 k-13 k by 2035 in the base case (~5% of the heavy-freight parc). CNG vehicles will be relevant for short travel distances while LNG for long-haul transport.

In the **rail transport** sector, mode-shifts to rail and the switch from diesel to electric rail was assumed to follow the IEA Net Zero scenario (localised for South African transport sector inputs). Based on this scenario, electric rail reaches 100% of passenger and freight rail from around 2040, due to the electrification of rail in the base case. The demand for diesel for rail ramps down, as a result, from 23 PJ in 2019 to 0 PJ in 2050 with a corresponding increase in electricity consumption from ~10 PJ in 2019 up to 40 PJ in 2050. The ramp-down of diesel decreases the direct emissions of rail from ~1 Mt to 0 Mt in 2050 (with no indirect emissions by 2050, assuming a grid supply of electricity in line with a net-zero trajectory as per the NBI/BCG report, *It all hinges on Renewables*.

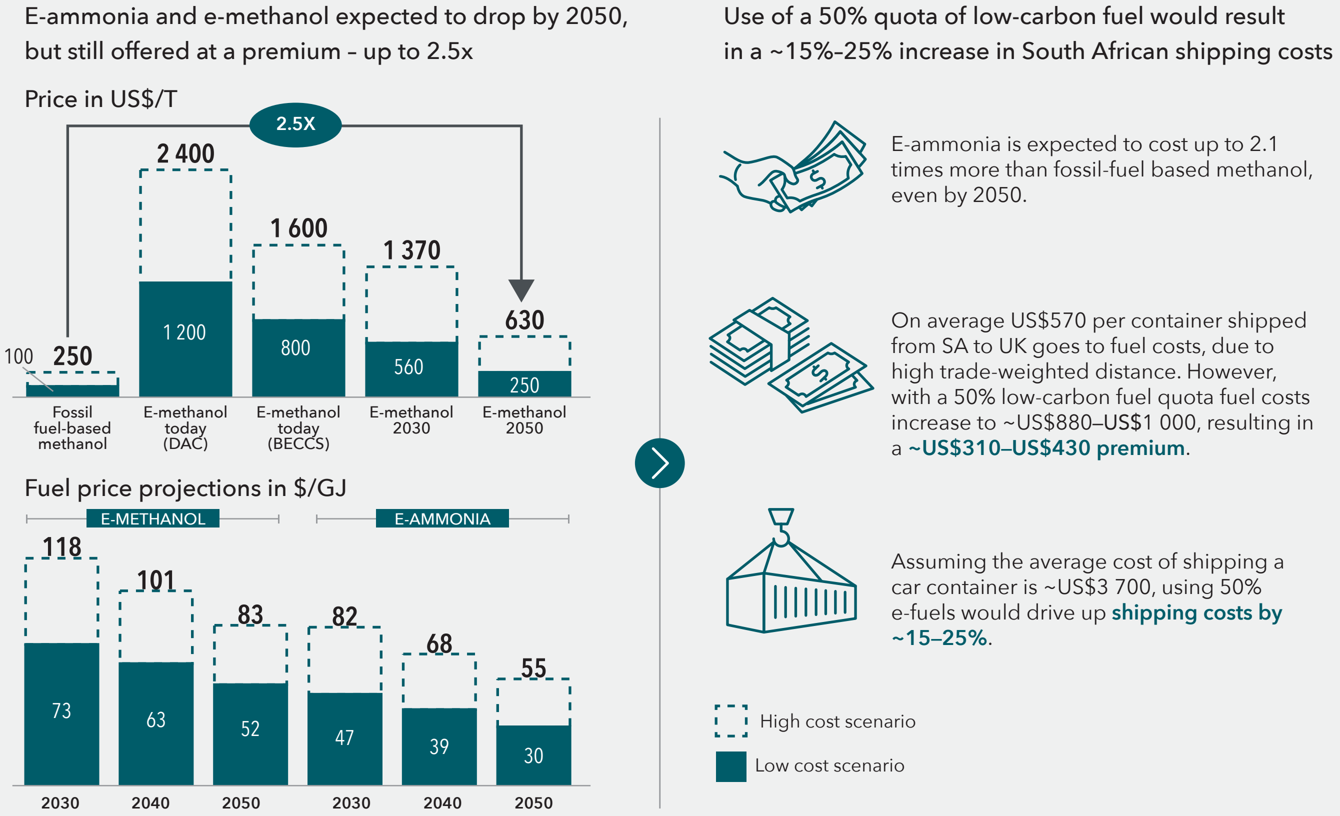


For the aviation and shipping sectors, the decarbonisation of fossil-derived liquid fuels will be critical, because alternative green technologies like fuel cell or electric ships and aeroplanes are still very nascent and yet to be proven at scale. The **aviation sector**'s primary energy input today is jet fuel, contributing to the sector's emissions of ~4 Mt. Increasing the blending of SAF with jet fuel will be key to decarbonising the sector, but blends of 25%–100% could come at cost premiums of 1.7–2.1 times the current price of jet fuel (see Figure 8).

Similarly, the decarbonisation of local **shipping** in South Africa will require the greening of marine gas oil with a role for e-methanol and/or e-ammonia. These green fuels cost 2.1–2.5 times the cost of marine gas oil today (see Figure 9).

Figure 9: Evolution of e-fuel cost in the South African shipping sector through to 2050

In shipping, e-ammonia and e-methanol are used, costing by 2050 up to 2.1X and 2.5X the cost of marine gas oil today



Notes: The analysis accounts for neither carbon tax nor green subsidies. This is a comparison at 2050, and therefore takes into consideration learning rates of green technologies.
1. Direct air capture.
2. Bioenergy with carbon capture and storage.
3. Cost difference between scenarios largely driven by uncertainties (and geographical differences) on costs for renewable energy, electrolysis and CO_2 capture.

Source: DNV GL, IRENA, Lloyd's Register Methanol institute, TNO report, UMAS, NBI-BCG project team.

Across all transport modes, as a result of the change in demand and shift towards ZEVs and greener fuels, the demand for conventional liquid fuels reduces from ~960 PJ in 2019 to less than 530 PJ in 2050 (Figure 10). The fossil fuels are substituted mainly with electricity for passenger and light-freight road transport and rail transport, hydrogen for heavy-freight and e-kerosene/sustainable aviation fuel for aviation.

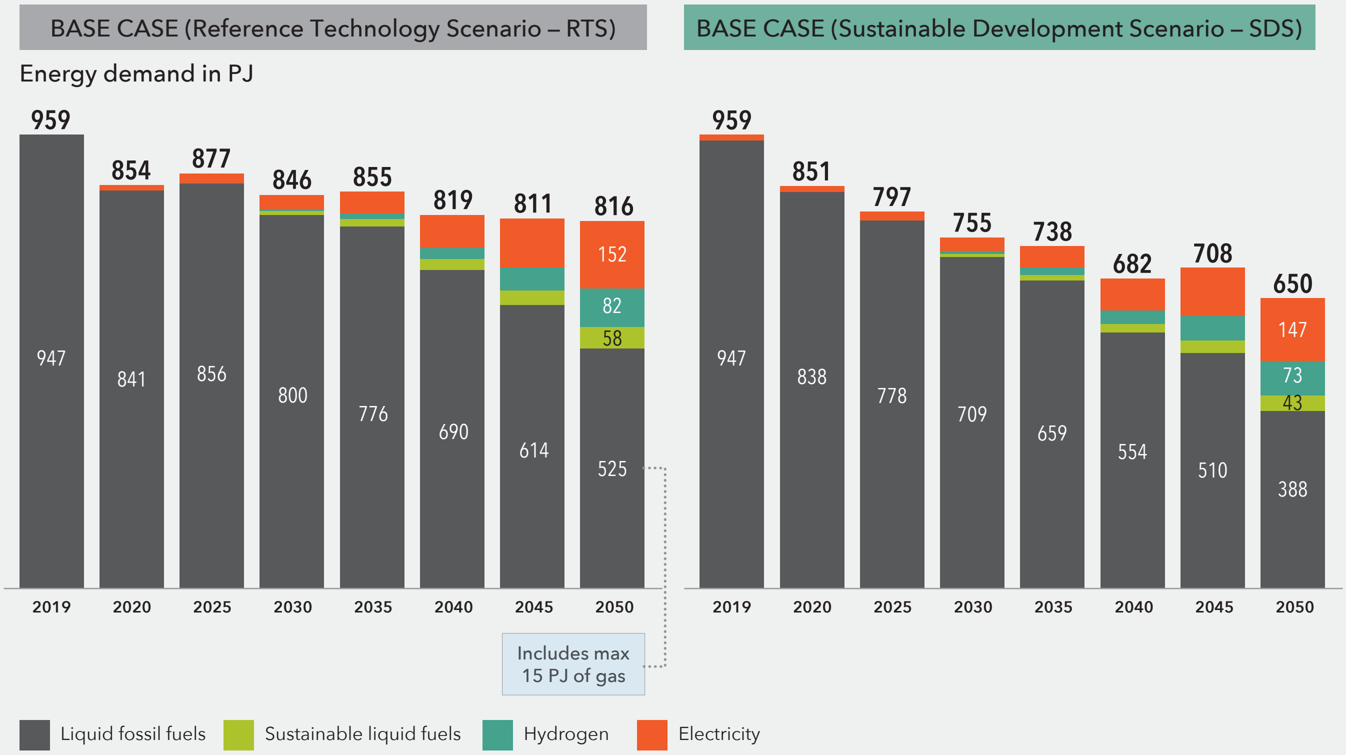
Although this is not nearly enough to achieve a net-zero trajectory, it does imply significant change for the fossil fuels production and distribution sector in South Africa, where, even in a base case scenario, a 50% reduction in conventional fuel demand can be a reality.

The decarbonisation of the power supply will be critical to mitigating the indirect road and rail emissions, especially as electricity accounts for a growing share of the energy demand. Based on the carbon intensity of South Africa's power grid today, the indirect emission factor for BEVs vs. fossil fuel alternatives are significantly higher as shown in Table 1.

Table 1: Emissions factors

Emissions intensity	BEV equivalent (g CO_2/km)	Petrol/Diesel equivalent (g CO_2/km)
Passenger Vehicles	154	136
Heavy-freight	814	230
Rail	–	60

Figure 10: Evolution of South African energy demand in the transport sector driven by global trends



Note: Liquid fossil fuels refers to conventional diesel, petrol, LNG and jet-kerosene; Sustainable liquid fuels or sustainable aviation fuel (SAF) refers to synthetic jet-kerosene; Excluding international aviation energy demand.

Source: eNatis; ICCT; IEA; IHS Markit; Marklines; NAAMSA; BCG battery model; NBI-BCG project team.

As such, if the power sector is not decarbonised, the road and rail sector's indirect emissions could reach ~32 Mt and ~8 Mt per annum respectively in 2050, equivalent to~40%–50% of the direct emissions in 2050 and ~80% of transport sector direct emissions today.

> ***Without a deliberate and coordinated local effort, South Africa's transport sector will be on a trajectory that is inconsistent with the country's NDC by 2030 and inconsistent with net-zero by 2050.***

While the global trends outlined above yield significant emissions reductions of 40%–50% by 2050, the emissions reductions in the next 10–15 years are relatively negligible, at only around 10%. For reference, hitting the lower end of South Africa's NDC commitment will require a ~30% reduction in emissions across the economy. Therefore, without deliberate and coordinated local policy, South Africa's transport sector could be on a trajectory that is inconsistent with the NDC by 2030 and with net-zero by 2050.

Furthermore, there is a risk that the local automotive manufacturing sector for passenger and commercial vehicles will collapse as it gets out of sync with key export markets. Approximately 60% of local vehicle production is exported, of which 60% is European markets.

Many European nations have already committed to significant EV targets by as early as 2030, as shown in Figure 11.

As the export markets accelerate the shift to ZEVs, if South Africa lags, Original Equipment Manufacturers (OEMs) will not be able to export locally manufactured goods and therefore will be unable to continue operations based on local demand alone. To ensure a continuation of automotive manufacturing operations in South Africa, OEMs will need to convert/ invest in production lines for ZEVs. However, the business case for local manufacturing of ZEVs hinges on a significant local demand market which today does not exist and will be nowhere near the scale required by 2030 in a 'base case' scenario.

The decarbonisation of South Africa's transport sector will be influenced and driven by four key factors – the first two are largely impacted by global factors and the third and fourth by local choices.

1. **Technology maturity and consumer preferences:** The cost competitiveness of green technologies globally and the emerging consumer preferences.
2. **Exogenous variables:** Global transport and logistics standards as well as international bans and regulations.
3. **Power sector evolution**: Loadshedding (rolling power cuts) experienced since the late 2000s have a significant

Figure 11: Overview of ZEV commitments abroad

Regulatory develpment move at a different pace across regions: EU and UK are leading, USA and China are following in most dimensions

	EU	UK	US	CHINA
Auto standards/ air quality	■ Euro 6c ■ No ICE registrations for cars and vans after 2035	■ Euro 6c ■ No new sales of gasoline, diesel, or MHEV after 2030; no sales of HEV and PHEV after 2035	■ EPA 2010 ■ No nationwide bans on ICE registration; California to ban non-ZEVs registrations after 2035	■ China 6a ■ No new sales of gasoline, diesel or MHEV after 2030; no sales of HEV and PHEV after 2035
Carbon pricing	■ Domestic carbon pricing (ETS)	■ Domestic carbon pricing (ETS) like EU	■ No carbon pricing, providing tax incentives instead	■ Limited domestic carbon pricing
Supply chain transparency	■ Supply chain Due Diligence regulation	■ Ban imports produced by forced labour	■ Ban imports produced by forced labour	■ N/A
Trade barrier	■ Cross-border carbon pricing (CBAM) (expected) ■ Deteriorating UK-EU trade relationships	■ Deteriorating UK-EU trade relationships	■ US-China trade war ■ US-export bans on critical next-generation technologies	■ 'China for China' policies ■ Export restrictions ■ US-china trade war
Fuel cells	■ Target to reach 3.7 mn FCEV by 2030 ■ Subsidies for purchase of FCEV and installation of HRS 16 trucks	■ Lower VAT (17.5% to 5%) for micro-CHP purchase	■ Regional FCEV target in California: 1 mn by 2030 ■ Subsidies for purchase and installation of HRS	■ Target to reach 1 mn FCEV before 2030 ■ Subsidies for purchase of FCEV

impact on consumer willingness to shift to EVs. Additionally, at the current grid emissions factors, the electric vehicles will have greater emissions than current combustion vehicles.

4. **Policy choices:** Local incentive schemes, bans and regulations and national budget allocations.

The road transport sector will be heavily impacted by the global factors in (1) and (2) above, global technology maturity, international transport, and logistic standards, and bans and regulations, with the other modes, like rail, influenced almost entirely by local policy and action. A range of low-carbon transport technologies with varying degrees of maturity will impact each of these modes of transport globally and in South Africa (see Figure 12). This analysis focuses on the more mature, proven technologies across modes:

- The assessment of the passenger and freight **road transport** sector focuses on the technology shift from ICE vehicles to BEVs, xHEVs and FCEVs. The analysis also considers the role of sustainable, zero-emissions fuels like e-diesel.
- The **rail transport** sector assessment focuses on the shift from diesel and electric trains to electric, high speed, and autonomous trains.
- The assessment of the **local aviation and shipping** sectors assesses the impact of green fuel, like SAF, also known as e-kerosene, and e-methanol and e-ammonia.

Deep dive on the decarbonisation of transport in South Africa

Case study 1: Unlocking South Africa's electric vehicle market

What is required to scale-up demand for EVs in South Africa?

As South Africa has a coal-intensive electricity grid, together with load-shedding, the key requirement is for supporting energy infrastructure that is energy resilient and low-carbon. The uYilo smart grid ecosystem project initiated in 2015 directly addresses these through the following:

- Solar arrays for energy generation
- Energy storage through re-purposed electric vehicle batteries in second life, embracing the circular economy
- Autonomous local energy management systems for solar-storage-grid optimisation and load levelling
- Network of AC and DC fast chargers
- Grid ancillary services from electric vehicles through vehicle-to-grid

As Africa's largest dedicated and most technologically advanced electric vehicle charging hub, the project serves as the test bed for technology innovation, sustainable business models and market benchmark for the energy and mobility sectors.

A broader challenge in market development is bridging the gap on capacity development on the electric vehicle ecosystem. The national Green Transport Strategy highlights the specific sustainable development need of educating and stimulating awareness to accelerate behavioural change. The *Shifting the Transport Paradigm of South Africa* project under the South Africa-UK PACT country programme being delivered by uYilo has been providing technical assistance to key organisations and decision-makers for sustainable climate actions on electric road transport, charging infrastructure, and international best practices.

As all vehicle manufacturers transition their products into electric vehicles, South Africa will become a market for electric vehicle model introductions to achieve alignment to the National Development Plan milestones for transport.

What is being done today to move the needle towards scaling-up EVs in the country?

South Africa's current aspirations for electric vehicles are guided by:

- Signatory to **Paris Agreement** adopted in 2015.
- **National Development Plan**: Transition to low-carbon economy.
- **Green Transport Strategy**: Strategic Pillar 8: promotion of hybrid and electric vehicles.

Policy instruments:

- **Environmental CO_2 levy**: Penalise the buyers of vehicles with high CO_2 emissions.
- **Fuel levy**: The levy raises the cost of petrol and diesel at the pump and thereby effectively promotes greener alternatives.
- **Fuel economy and CO_2-labelling**: The measure allows consumers to make model-to-model comparisons with regards to fuel economy and CO_2 emissions of different cars and should promote greener transport.
- **Carbon tax**: Gives effect to the polluter-pays-principle which helps to ensure that consumers take on negative adverse costs of driving CO_2e-emitting vehicles. This is typically based on a cost per km structure for each class of vehicles.

National standards:

- Requirements for electric power train.
- Conducive rates for domestic, industrial, commercial, and public access charging stations (AC and DC).
- National Road Traffic Act.
- National Road Traffic Regulations.


Photo: Shutterstock

Figure 12: Maturity of global transport trends today

	Status quo		MATURITY OF GLOBAL TRANSPORT TRENDS			
ROAD	ICE vehicles & diesel/petrol		Hybrid EVs + diesel/petrol/ electrical (e.g. MHEV, HEV, PHEV)	Battery EVs + electricity	Micro-mobility (e.g. light modes, E-bikes, e-scooters)	Shared vehicles (e.g. car sharing, ride hailing/ pooling)
RAIL	Conventional rail + diesel	Electric rail (intra-city and inter-city/ province) + electricity	Electric rail (intra-city and inter-city/province) + electricity		High speed electric rail + electricity	
AIR	Conventional air + jet fuel		N/A			
SEA	ICE engine + Marine gas-oil		N/A			

Scaled-up/stand-alone | Industrial scale needing support | Proven but not yet scaled | Passenger transport | Freight transport

The impact of technology maturity and consumer preferences

The technologies available to decarbonise each class of road vehicles vary in maturity, and therefore, cost competitiveness. The pace of decarbonisation will, as a result, vary across these vehicle classes and modes. The five-year Total Cost of Ownership (TCO) is used to compare the total costs of conventional ICE vehicles to lower-carbon LNG vehicles and more disruptive ZEVs like BEVs and FCEVs over five-year periods (see Deep dive: Total Cost of Ownership (TCO) assessment of different vehicle classes for road transport, on page 36).

Note that typical freight ownership contracts are 2–3 years, which is less than the 5-year TCO period accounted for in the analysis. Therefore, innovative financial solutions will be required to address this gap, i.e. absorb the premium in a shorter time-frame using development finance for example.

Most green technologies to decarbonise road transport are projected to become economically viable in South Africa in the next 2–10 years, but there are nuances across the classes of vehicles.

However, it is important to note that cost parity on a TCO basis alone will not see widespread adoption of ZEVs. This will need to be supported by the rollout of charging and refueling infrastructure, a reliable electricity supply, and a selection of ZEVs for consumers to choose from, as well as lowering the upfront cost of ZEVs.

ICE vehicles + CNG

ICE vehicles + biodiesel

Fuel cell EVs + H2

ICE vehicles + e-diesel

Autonomous vehicles (e.g. delivery robots, robo taxis)

Autonomous trains

Hyperloop

Maglev

Conventional air + bio-based SAF (e.g. HEFA, AtJ)

Conventional air + PtL synthetic fuel (e.g.e-kerosene)

Fuel cell air + Green H_2

Hybrid & full electric air (e.g. battery/ H_2/solar-powered)

Urban aerial mobility (e.g. delivery drones, eVTOLs, flying cars)

ICE engine + biodiesel/ synthetic diesel

Adapted ICE engine + biomethane

Adapted ICE engine + synthetic gas

Adapted ICE engine + e-methanol

Adapted ICE engine + e-ammonia

Fuel cell engine + Green H_2

Electric shipping (e.g. battery electric, nuclear powered)

Note: Plug-in hybrid electric vehicles (PHEV), hybrid electric vehicles (HEV) and mild hybrid electric vehicles (MHEV).

Source: IGUA Annual Report 2020, NBI-BCG project team.

Deep dive: Total Cost of Ownership (TCO) assessment of different vehicle classes for road transport

The evolution of TCO, reflecting predominantly global technology trends and global regulation and standards, is assessed for each vehicle class. For passenger vehicle classes, light private vehicles and MBTs, the TCO is assessed on a total cost basis (i.e. in ZAR) and for light- to heavy-freight vehicles, the TCO is measured on a cost per kilometre basis. The TCO includes the costs of green fuels (fossil, electricity, green H_2, etc.) in addition to capital expenditure.

Findings

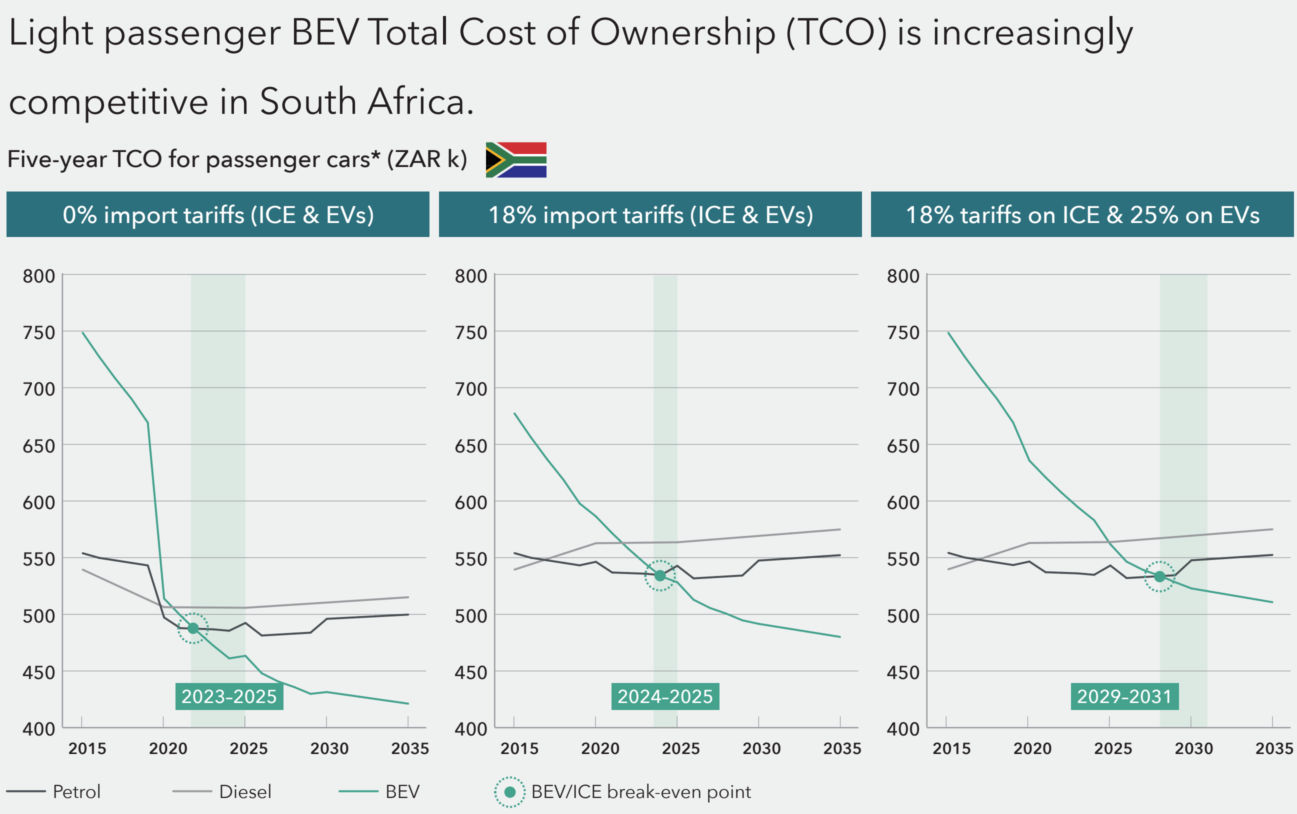
Light passenger vehicles (see Figure 13)

- In the absence of any import tariffs and local manufacturing, BEVs could reach cost parity with light ICE passenger vehicles as early as 2023–2025 in South Africa with a five-year TCO of ~ZAR500 k. Equal import tariffs on ICE vehicles and BEVs (18%) could push this out to 2024–2025, or in a worst-case scenario, where import tariffs remain at current levels (18% ICE vehicles, 25% BEVs), this could push out to as late as 2029–2031.
- This finding crystalises the need for enabling policy, such as enabling import tariffs, that do not inhibit the the cost competitiveness of ZEVs, to decarbonise the road transport sector.

MBTs (see Figure 14)

- Similarly, in the absence of any import tariffs, BEVs could reach cost parity with ICE MBTs as early as 2025–2027 in South Africa with five-year TCO of ~ZAR800 k. Equal import tariffs on ICE vehicles and BEVs (12%) could push this out to 2027–2029, or in a worst-case scenario where import tariffs remain at current levels (12% ICE vehicles, 20% BEVs), this could push out to as late as 2030–2032.

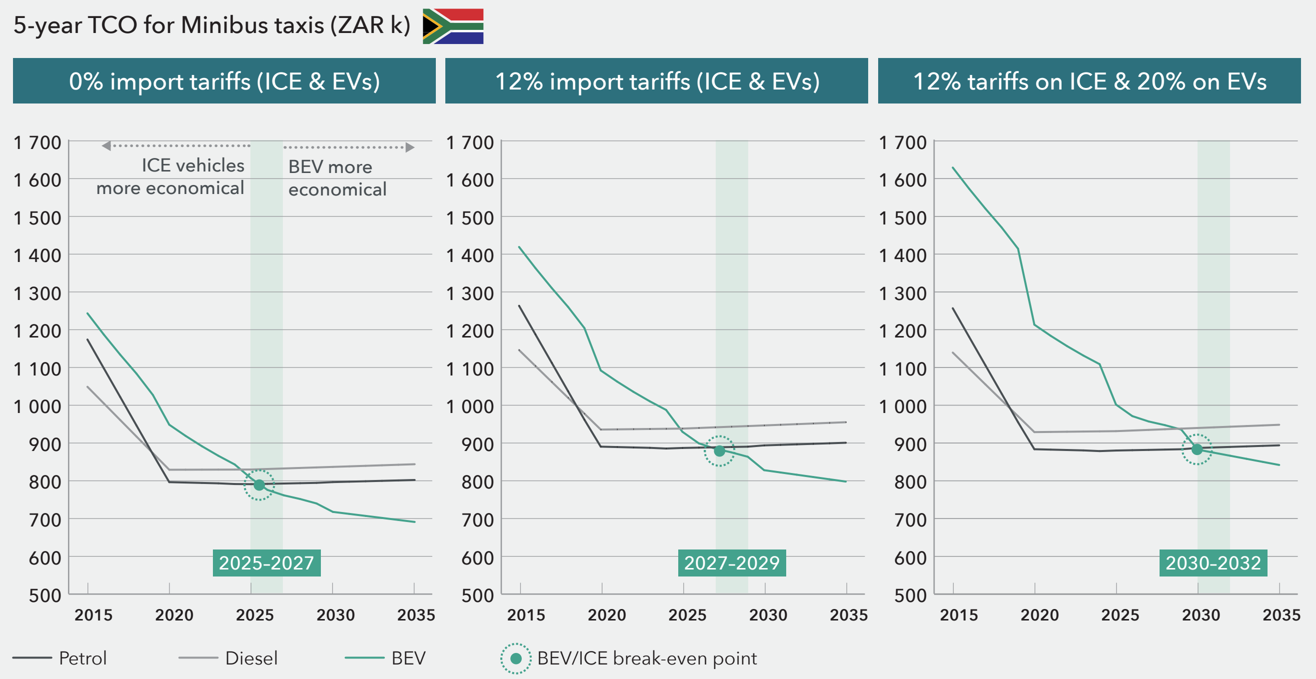
Figure 13: TCO evolution for light passenger vehicles



Notes: Assumes BEV pouch/prismatic cells.
1. Includes B, C, D, and SUV segments.
2. 18% = 25%–7% discount for EU.
3. 40% for BEVs = 25% + 15% luxury tariff in line with tariffs today.

Source: NBI-BCG project team.

Figure 14: TCO evolution for minibus taxis



Note: Assumes BEV pouch/prismatic cells.

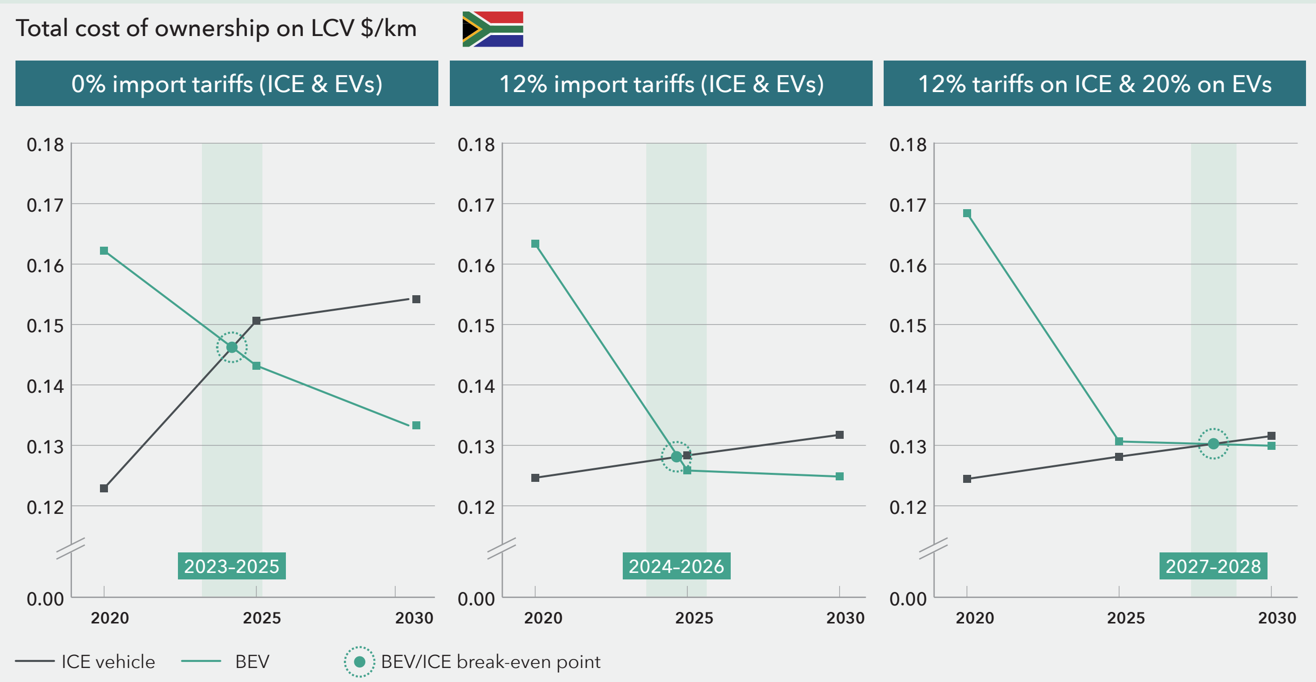
Source: NBI-BCG project team.

Light-freight vehicles (see Figure 15)

- In the absence of any import tariffs and local manufacturing, BEVs could reach cost parity with light-freight ICE vehicles as early as 2023–2025 in South Africa, similar to passenger transport.

Equal import tariffs on ICE vehicles and BEVs (12%) could push this out to 2024–2026, or in a worst-case scenario where import tariffs remain at current levels (12% ICE vehicles, 20% BEVs), this could push out to as late as 2027–2028.

Figure 15: TCO evolution for light-freight vehicles



Note: LCV – light commercial vehicles; FCEVs not considered for LCV due to lack of competitiveness in the shown period.

Source: Desktop search, Eskom, BCG Battery forecast, NBI-BCG project team.

- Across American, European and Chinese benchmarks BEVs are expected to account for the largest share of sales of light-freight vehicles by 2030 for inner-city and inter-city delivery.

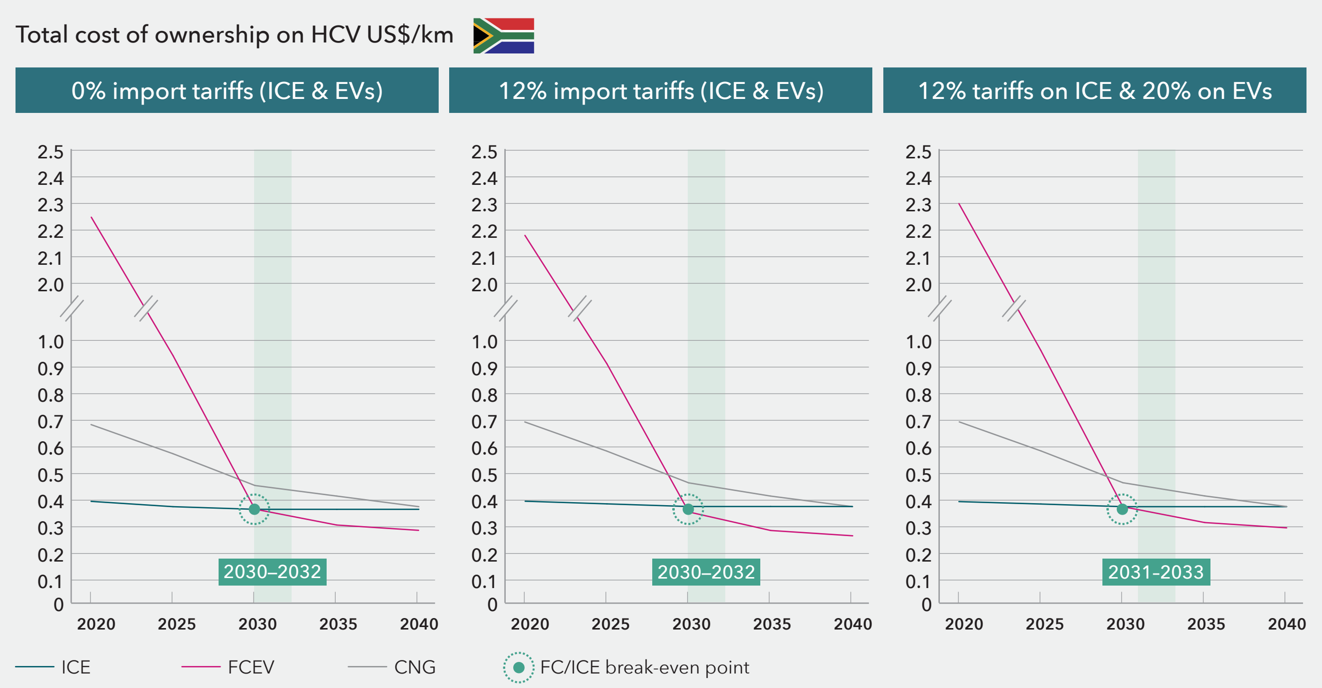
Heavy freight vehicles (see Figure 16)

- In the absence of any import tariffs and local manufacturing, FCEVs could reach cost parity with heavy-freight ICE vehicles by 2030 at the earliest. Equal import tariffs on ICE vehicles and BEVs (12%) would have little extra impact, or in a worst-case scenario where import tariffs remain at current levels (12% ICE vehicles, 20% BEVs), this could push out to as late as 2031–2033.
- There is variability on the share of FCEVs relative to LNG trucks in the share of new heavy-freight vehicle sales by 2030 across America, Europe and China. In America, LNG trucks have the largest share in sales across medium- to heavy- freight vehicles for intercity deliveries and long-haul transport. In Europe, there is a more even split between LNG vehicles and FCEVs for heavy-freight, while in China FCEVs clearly dominate the sales. These benchmarks reiterate the need for enabling policy, beyond the technology evolution, to promote decarbonisation and support local value chains.
- For heavy-freight vehicles, the evolution of BEVs relative to FCEVs is a key signpost to monitor, given the uncertainty on whether BEVs can for example overcome charging and range limitations.

Key assumptions

- The effect of inflation is not accounted for. The analysis only reflects functional changes in prices of commodities, vehicle purchases, etc.
- The cost and size of batteries will continue to decrease – with a 50% reduction in prices from a 2020 base level reached by the end of the decade.
- The adoption of powertrains follows the technology adoption curve, based on global benchmarks across developed and developing markets.
- Consumers will start to adopt EVs when the ICE-EV TCO parity point is reached, where the TCO of a BEV is equal to that of an ICE vehicle.
- Steady-state adoption of EVs in South Africa will favour ZEVs (BEVs and FCEVs) instead of hybrid vehicles, with global bans on HEVs projected to influence OEM decisions.
- The adoption of diesel vehicles after the parity point is reached will follow an exponential reduction, due to diesel ICE vehicles being more expensive than petrol ICE vehicles.

Figure 16: TCO evolution for heavy-freight vehicles



Notes: HCV – heavy commercial vehicles; BEVs not considered for HCVs as they are considered not competitive due to range issues within the shown period.
1. Assuming 20%–8% discount for EU imports.
2. 20% assuming no discounts on BEVs in line with tariffs today.

Source: Desktop search, Toyota, NBI-BCG project team.

The cost competitiveness of technologies will not be the only driver of the decarbonisation of the road vehicle parc. In fact, the majority of consumers in the passenger vehicle market today do not make a purchase decision based on TCO at all, but consider other factors, like upfront capital costs, charge time and availability of charging infrastructure, as well as the variety/range of vehicles available. The uptake of BEVs for passenger modes will therefore be heavily influenced by the availability of financing options for ZEVs that lower the upfront capital costs to the consumer (e.g. via leases), the large-scale roll-out of charging infrastructure, an uptake of a broad range of ZEV options in vehicle showrooms and of course a stable, and affordable power supply. Therefore, there is likely to be a lag between cost competitiveness and adoption of ZEVs (which is accounted for in the penetration rates used to model the change in car parc over time).

These factors also reinforce the critical role that local policy can play in addressing the slow uptake of ZEVs due to consumer preferences.

Photo: Shutterstock

3.1.3 WHAT NET-ZERO PATHWAYS EXIST FOR SOUTH AFRICA'S TRANSPORT SECTOR?

This section is structured along two sub-chapters:

1. The net-zero **levers required** to fully decarbonise South Africa's transport sector.
2. A net-zero **pathway** for South Africa's transport sector: the key outcomes and milestones of selected combinations of the levers.

Net-zero levers to fully decarbonise the sector by 2050

> ***With the right support, the transport sector can be fully decarbonised by 2050 via four key levers:***
> - ***Improved spatial planning;***
> - ***Mode-shift to rail and public transport;***
> - ***Accelerated zero-emission technology adoption, coupled with the decarbonisation of the national grid; and***
> - ***Use of green fuels for hard-to-abate aviation and shipping***

One of the most effective ways of charting a course to net-zero for the transport sector is improved spatial planning. This refers to intelligent design of cities and transport infrastructure such that the total number of passenger-kilometres and cargo-kilometres travelled are minimised. This includes densification of urban areas to enable efficient public transport and building walkable or '20-minute cities'.

For example, population density in Johannesburg today is highly dispersed (see Figure 17) primarily due to the legacy of spatial apartheid, and can be characterised as an 'urban sprawl'. Shifting to higher population density cities with smartly design transport corridors will minimise the number of 'people-movements' and 'cargo-movements' required. This will be the most impactful lever to sustainably meet demand and effectively decarbonise transport. However, a significant piece of analysis is required to determine what South Africa's optimal spatial planning design looks like taking into consideration (to name but a few major factors – these are non-exhaustive): 1) the impact of the physical risk of climate change and adaptation required; 2) the evolution of trade flows and

Figure 17: Urban sprawl of South Africa

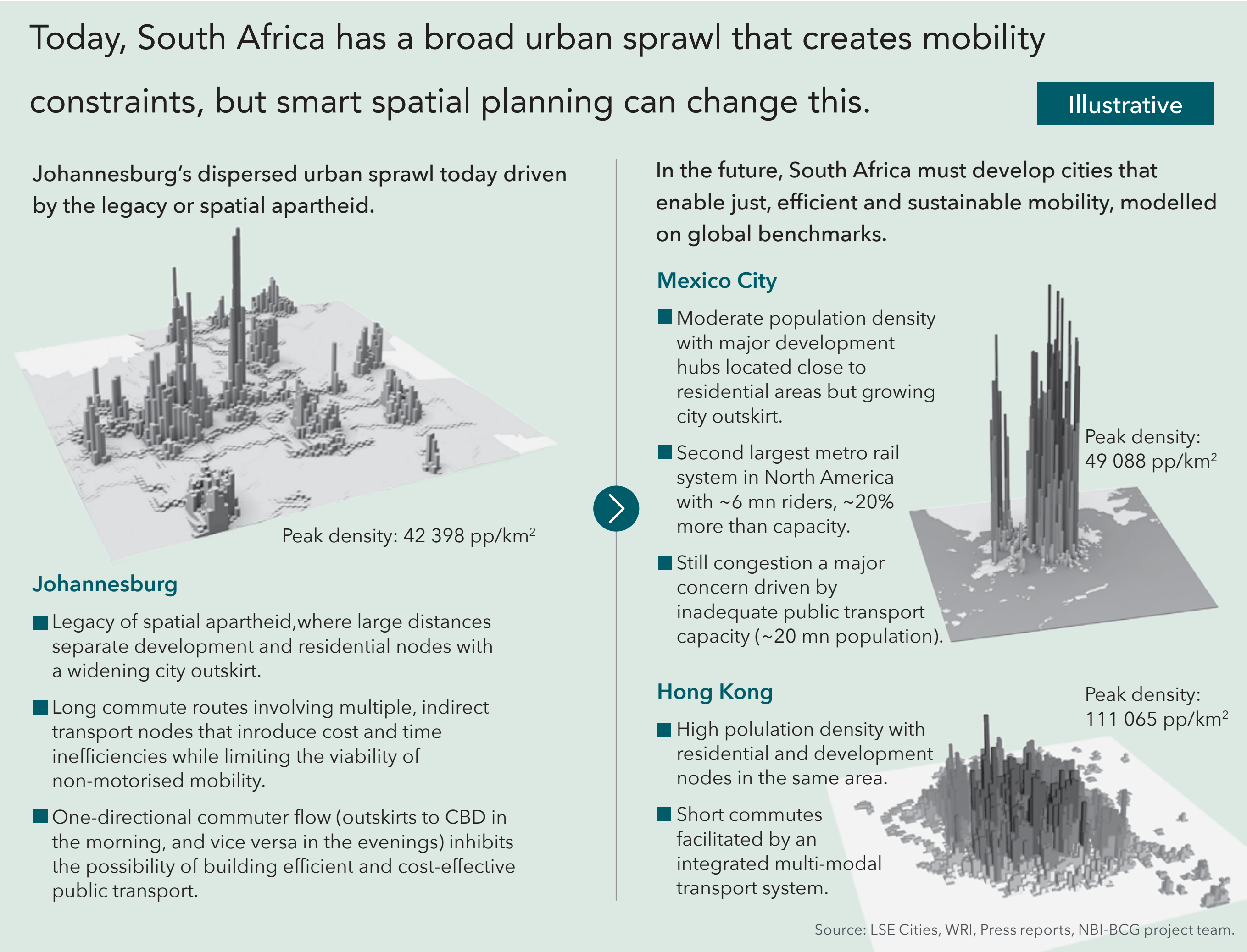


Figure 18: Key trade-offs across the three core decarbonisation levers

		Modal shift	Technology shift	Fuel greening
ECONOMIC AND INDUSTRIAL DEVELOPMENT	Infrastructure investment	**at least ZAR300 bn** **to expand rail along major corridors**	**at least ZAR100 bn** **for 1.4 mn EV public charging units**	**ZAR60 bn** **for 0.8 mn public charging units**
	Impact on transport cost	■ **30%–50% ZAR/ passenger decrease for public transport (MBT versus BRT)**	■ **~70%* decline in annual vehicle OPEX (100 k/ annum for minibus taxis)**	■ **1.6X–2.1X increase in fuel cost****
	Impact on adjacent industries	■ **3 bn L/a** residual liquid fossil fuel demand ■ Cement/steel demand	■ **1 bn L/a** residual liquid fossil fuel demand ■ 1.2 Mt/a Green H_2 demand	■ **1 bn L/a** residual liquid fossil fuel demand*** ■ Up to **15 bn L/a** Green fuel demand
SOCIAL DEVELOPMENT	Tax revenue losses	■ **ZAR700 bn** in cumulative fuel tax losses ■ **74%** of annual revenue to drop by 2050	■ **ZAR1 000 bn** in cumulative fuel tax losses ■ **95%** of annual revenue to drop by 2050	■ **ZAR600 bn** in cumulative fuel tax losses ■ **55%** of annual revenue to drop by 2050
	Ability to address current challenges	■ Broader transport access ■ Improved efficiency mitigates road congestion ■ Reduced road wear and tear	■ No major changes in structure ■ Cheaper costs improve access to mobility	■ No improvement

Notes: * Based on ICE MBT OPEX of 130 k ZAR/annum to BEV MBT OPEX of 30 k ZAR/annum.
** The cost of e-kerosene produced in the MENA region using the Fischer-Tropsch process used to find a premium compared to the average kerosene price between 2010 and 2019. The range is associated with use of PEM or SOEC electrolysis and DAC versus point-source capture for CO_2 supply.
*** This will improve balance of payments due to lower crude oil imports

Source: IGUA Annual Report 2020, NBI-BCG project team.

economic activity across the major hubs; 3) the future of work, how long-the 'work-from-anywhere' culture will persist, and to what extent.

Apart from improved spatial planning and minimising transport demand , fully decarbonising South Africa's transport sector will require local action along three key net-zero levers, each with techno- and socio-economic trade-offs (see Figure 18).

1. **Modal shift (shifting road to rail):** Addresses the broader structural inefficiencies in the sector. Shifting inefficient road transport, with high levels of road congestion, to more efficient rail transport, could increase the accessibility of public transport, by improving affordability, as rail transport is 30%–50% cheaper per passenger than MBTs. However, South Africa's current rail infrastructure is insufficient to meet this additional demand for rail (many trains are cancelled daily due to infrastructure and operational bottlenecks). Developing new rail infrastructure is highly capital intensive, requiring investments of at least ZAR300 bn, and given the country's constrained balance of payments, will need to be carefully managed and strategically prioritised. Public-private partnerships could help in addressing the significant investment needed to address South Africa's rail network challenges. In addition, the corresponding impact to the 430 k jobs linked to the MBT industry and 260 k jobs linked to the freight sector would need to be carefully managed.
2. **Technology shift (shifting to zero-emissions vehicles – ZEVs):** Is critical to address the lag between technology maturity and adoption to decarbonise road transport. BEVs are up to 70% cheaper to operate than ICE vehicles, due to higher efficiency, lower electricity costs relative to petrol and diesel, and lower maintenance costs. To reach 100% ZEV adoption by 2050, up to ZAR100 bn in EV charging infrastructure could be required. A comprehensive suite of private action and

policies, ranging from emissions standards to sales restrictions and credit programmes, will be required to fully implement this lever.

3. **Fuel greening (replacement of fossil fuels):** This is necessary to mitigate the emissions from the remaining combustion of fossil fuels, by replacing these fossil fuels with lower- and zero-emission alternatives. This refers only to heavy trucking, aviation, and shipping – the other transport categories are electrified. Zero-emission fuels are operationally expensive, unlike the other two levers, with a fuel premium of up to 2.1X for e-ammonia, 2.5X for e-methanol, and 1.7X–2.1X for SAF. These green fuels will be critical for the hard-to-abate aviation and shipping modes, where limited alternatives exist, and will require clear phase-in targets to accompany fossil fuel phase-out targets.

> ***A net-zero pathway requires shifting 15%–20% of road traffic to rail, banning new ICE vehicle sales by 2035 and enabling ZEV uptake for remaining road transport, as well as blending to 100% sustainable aviation fuels by 2050.***

A net-zero pathway for South Africa's transport sector, the key outcomes and milestones

In addition to improved spatial planning, South Africa's path to a net-zero transport sector by 2050 will require action along all three levers. By order of priority, South Africa should first shift aviation and road demand to more efficient, low-carbon rail modes, leveraging existing and new infrastructure. The uptake of ZEVs for the remaining road transport should then be accelerated with ICE vehicle sale bans from 2035. Finally, the remaining fossil fuels in the aviation sector should be phased out with sustainable zero-emission fuels by 2050, although there could be a transitionary role for blends of jet fuel with lower-carbon and zero-emission fuels prior to 2050.

The net-zero pathway assumes the following:

- **Shifting aviation and road transport to rail** modes increases the share of rail in passenger transport to increase from almost 5% in 2020 to 15%–20% in 2050, and in freight from just over 20% to 30%–40%, in line with the global benchmarks outlined in the IEA Net Zero report
- **Accelerating the adoption of ZEVs** to reach 100% by 2050 requires a ban on ICE vehicle sales from 2035 and at least comparable import tariffs on ICE vehicles and ZEVs, with 18% tariffs on all new passenger vehicles (ICE and BEV) and 12% on all commercial vehicles (ICE, BEV, FCEV). This direct sales ban would need to be supported by a ban on imports into the secondary market and clearly mandated and implemented emissions standards for the vehicle parc.
- **Greening the remaining fossil fuels in the aviation** sector requires the phase-out of jet fuel, with 100% SAF. The boundary condition of 100% SAF is used to reach net-zero emisisons for the aviation sector by 2050 and assumes that neither Direct Air Carbon Capture and Storage (DACCS) nor Carbon Capture Utilisation and Storage (CCUS) are feasible, given the lack of proven, suitable storage sites and the low concentration and spread of the emissions. Sustainable carbon sources that can be used include second generation biomass.

The role of rail in South Africa's net-zero transport system

Rail is one of the most efficient and least-emitting transport modes for moving passengers and freight. Globally, urban and high-speed rail infrastructure has expanded significantly in the past decades – making the movement of goods and people more convenient, faster, cheaper and less carbon-intensive.

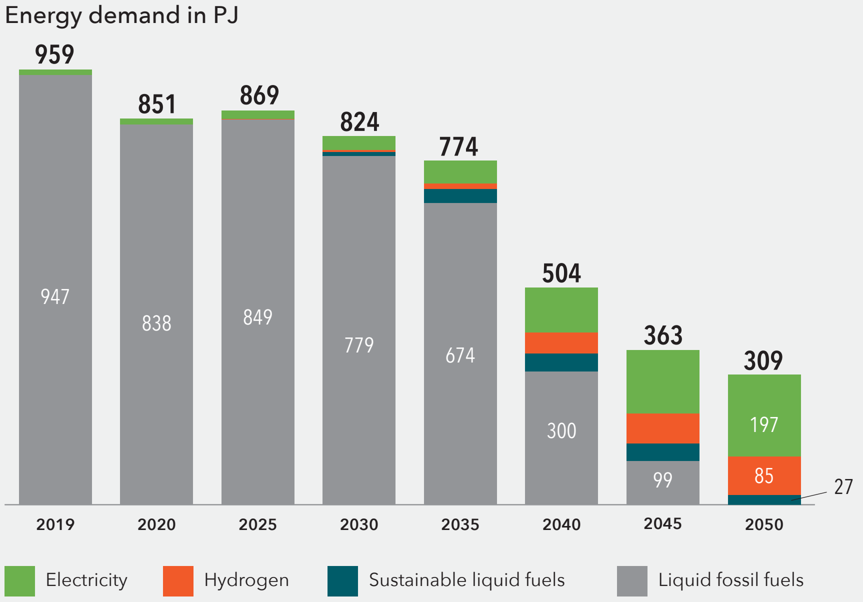
However, converse to global trends, South Africa has experienced a reduction in passenger and freight transport via rail. This is due to the inadequate state of South Africa's rail network today – which is suffering from "a massive capital investment backlog and inadequate funding, obsolete and ageing infrastructure, deteriorating rolling stock and outdated technologies, and limitations of narrow gauge", as well as vandalism and theft.* This resulted in at least 20 freight train journeys cancelled per day in 2020.** Overall, the continuous deterioration of South Africa's rail network has led to an increasing reliance on more expensive, inefficient, and carbon- intense road transport for private and commercial transport.

Going forward, South Africa needs to fix and expand its rail network, given the critical role rail plays in enabling decarbonisation and supporting and driving economic growth by unlocking more efficient and affordable movement of goods and people across the country – rail is the backbone of the transport system across urban spatial development. To stimulate this road-to-rail modal shift, the following potential solutions should be explored:

1. Refurbish and expand existing rail infrastructure. In particular, establishing dedicated rail transport corridors, e.g., Johannesburg-Durban, Johannesburg-Cape Town. This will ensure that rail transport dominates in these areas, and becomes the preferred transport option.
2. Develop suitable road to rail exchange hubs to allow for increased heavy freight transport.

Notes: * Department of transport: *National rail policy draft white paper,* 2017. Available at: https://www.gov.za/sites/default/files/gcis_document/201708/draftwhitepapernationalrailpolicy.pdf
** *Engineering News*: Transnet bemoans cable theft at Pretoria Complex, rolls out diesel locos

Figure 19: Evolution of transport energy demand in a potential net-zero pathway (PJ)



Notes: 1. Based on ICE MBT OPEX of 130 k ZAR/annum to BEV MBT OPEX of 30 k ZAR/annum.
2. The cost of e-kerosene produced in the MENA region using the Fischer-Tropsch process used to find a premium compared to the average kerosene price between 2010 and 2019. The range is associated with use of PEM or SOEC electrolysis and DAC versus point-source capture for CO_2 supply.

Source: IGUA Annual Report 2020, NBI-BCG project team.

3. Impact of the net-zero pathway

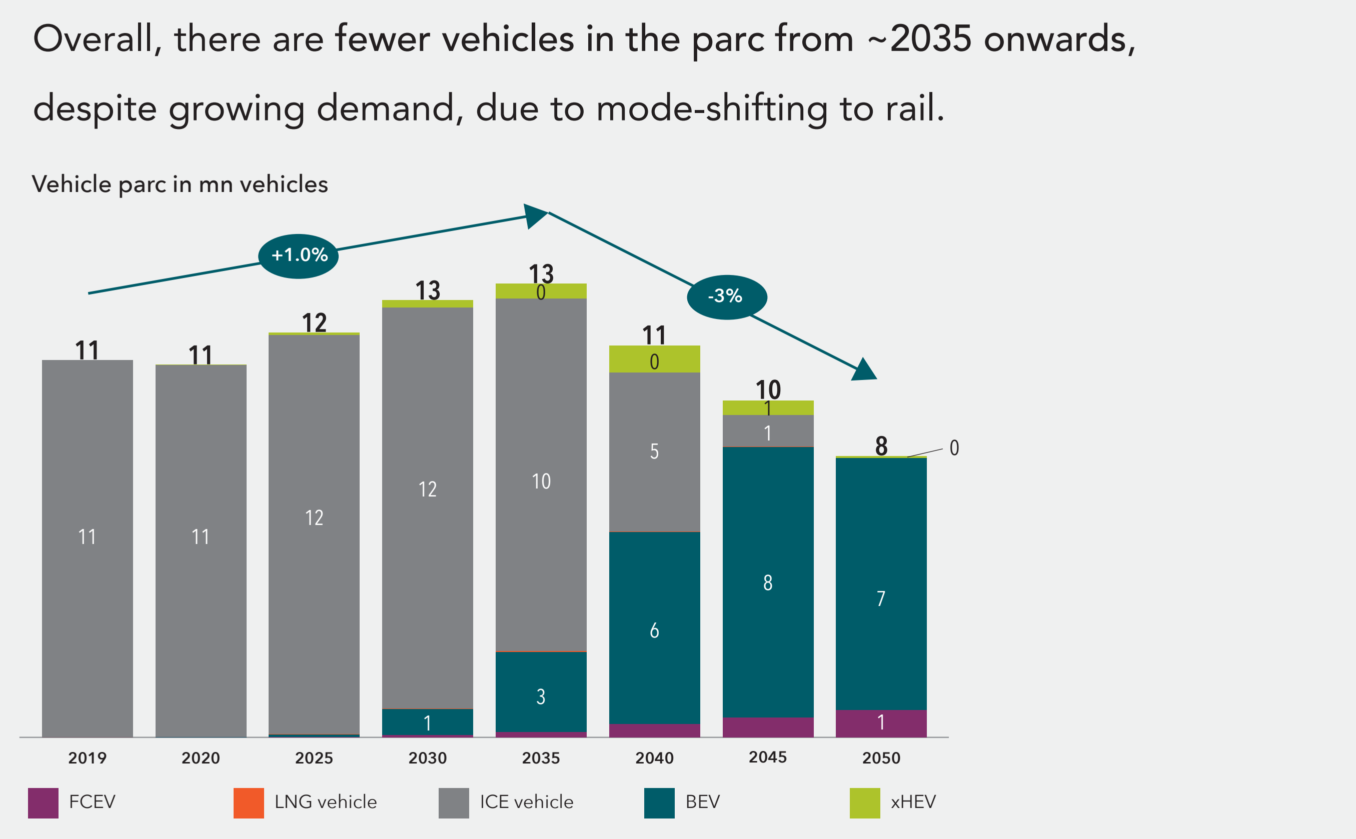
Shifting aviation and road transport to rail. The scaling of rail demand will require the electrification and optimisation of the existing rail network to mitigate the direct and indirect emissions and meet demand, given that the current utilisation of the passenger and freight network is less than 50%. There will, in addition, be a role for the development of a new High-Speed Rail (HSR) network from Johannesburg to eThekwini (Durban) and possibly from eThekwini (Durban) to Cape Town, where HSR is cost-competitive with aviation and where critical ridership can be reached. This scaling of rail demand will rely on the decarbonisation of the power supply, with up to 45–50 PJ of electricity needed per annum by 2040 and 60–85 PJ of electricity needed by 2050 (included in Figure 19). The key outcomes to monitor beyond the decarbonisation of the power sector include the impact of SAF on aviation ticket prices because higher aviation prices could make other inter-city and inter-province passenger and freight routes viable for HSR.

Accelerating the adoption of ZEVs. Up to 7 mn BEVs for light passenger and freight road transport and 1 mn FCEVs for freight are required by 2050 to achieve 100% ZEV adoption for the remaining road demand, which has not been shifted to rail (see Figure 20). This uptake of BEVs will require a national roll-out of EV charging infrastructure, with up to 30–45 thousand new public charging units required per annum, and the roll-out of hydrogen refuelling infrastructure for key, long-distance freight routes. The uptake of BEVs in the net-zero pathway could require around 130 PJ (~35 TWh) of electricity equivalent to 20% of the total electricity demand in 2019 (200 TWh), and the uptake of FCEVs for heavy freight could require up to 85 PJ (almost 1 Mt) of Green H_2 per annum (see Figure 19). In the net-zero pathway, an average of 600 thousand ICE vehicles will need to be scrapped per annum from 2035 to 2050. These vehicles are no longer used in the vehicle parc due to prohibitive operational costs but still have residual terminal value. The transport sector will need to partner with players in the circular economy to recycle and reuse the parts from these scrapped vehicles.

Greening the remaining fossil fuels in the aviation sector. To replace all remaining conventional aviation jet fuel with SAF, a maximum of 50 PJ (almost 1.5 bn litres) of SAF could be required by 2040. However, as demand is shifted from aviation to rail, this demand for SAF scales down to ~30 PJ (almost 1 bn litres) by 2050 in the net-zero pathway. As mentioned previously, SAF comes at a cost premium in 2050 of 1.7X–2.1X the cost of jet fuel today, even with South Africa's potentially low-cost Green H_2.

To reach 100% SAF blends by 2050, local airlines will need to implement blending targets in line with sectoral and national commitments and international standards. In the path to a net-zero aviation sector, the challenged balance sheets of many local airlines will need to be managed to enable the uptake of the more costly sustainable fuels.

Figure 20: Evolution of the vehicle parc in a potential net-zero pathway (mn vehicles)



Source: NBI-BCG project team.

By decarbonising road, rail and aviation transport in South Africa, 100% of the direct emissions are addressed (see Figure 21). Even though small-scale and not reflected in the baseline, a net-zero future transport sector for South Africa also requires the phase-out of marine gas oil with 100% e-ammonia and/or e-methanol. Replacement with lower-carbon and zero-emission shipping fuels will be required for all local shipping, to fuel all outbound and to refuel the inbound ships. E-methanol and e-ammonia cost up to 2.5 times more than marine gas oil.

Adopting the optimal net-zero pathway will enable the transport sector to decarbonise while addressing the broader socio-economic objectives by improving transport as a service and enabling a Just Transition.

The optimal net-zero pathway will enable the continued operation and growth of the local automotive sector by stimulating early and accelerated EV adoption, enabling the South African vehicle market to remain largely in sync with key export markets such as Germany, UK and the US (the top three export destinations) that supplement local sales to enable economies of scale production. For example, this can include aligning the ban of ICE and hybrid vehicle sales with EU targets of 2035. Increased adoption of public passenger transport through more and improved rail and bus infrastructure will play a role in improving transport as a service, providing affordable and accessible transport.

Additionally, enhancing the competitiveness of freight rail will have positive knock-on impacts on inland prices and export competitiveness while increasing demand for cement and steel, with positive short-term impacts on the construction sector. Concurrently, the increased use of electrified rail freight will be a key lever for decarbonising scope 3 emissions (indirect value chain) of the manufacturing and mining sectors.

Of all levers that must be pulled to get the transport sector to net-zero, the one that is likely to have the largest financial impact on the end-user of transport as a service is the greening of fuels. The use of green fuels is highly OPEX-intensive with a fuel premium of up to 2.1X for e-ammonia, 2.5X for e-methanol and 1.7X–2.1X for e-kerosene, even in 2050.

South Africa should strategically prioritise high value/value-added exports by developing local beneficiation and industrialisation capacity to mitigate the impact of costly green synfuels (e-ammonia and e-methanol) on shipping costs considering the high trade-weighted distance to key trade partners (such as China, EU and US).

South Africa's primary trade routes cover relatively long distances and so fuel costs, as a percentage of total value of goods exported, are likely to be disproportionately high relative to other emerging markets. For example, it costs roughly US$3 700 to ship a container from South Africa to the UK today. The cost of fuel alone is ~US$600/container (~15%). A 50% synfuel quota could yield a 15%–25% increase in shipping costs for South Africa, further worsening this statistic. To manage the impact of costly synfuels on shipping transport costs, South Africa should strategically prioritise local beneficiation, industrialisation and, as a result, high value/value-added exports. In a world with higher fuel costs that materially impact shipping and aviation costs, low-value bulk commodity exports will be significantly affected (in terms of end costs to the consumer).

Key uncertainties and signposts

Key uncertainties and signposts lie in the penetration of BEVs vs FCEVs in heavy duty transport, autonomous vehicle adoption and the interaction between formal and informal public transport.

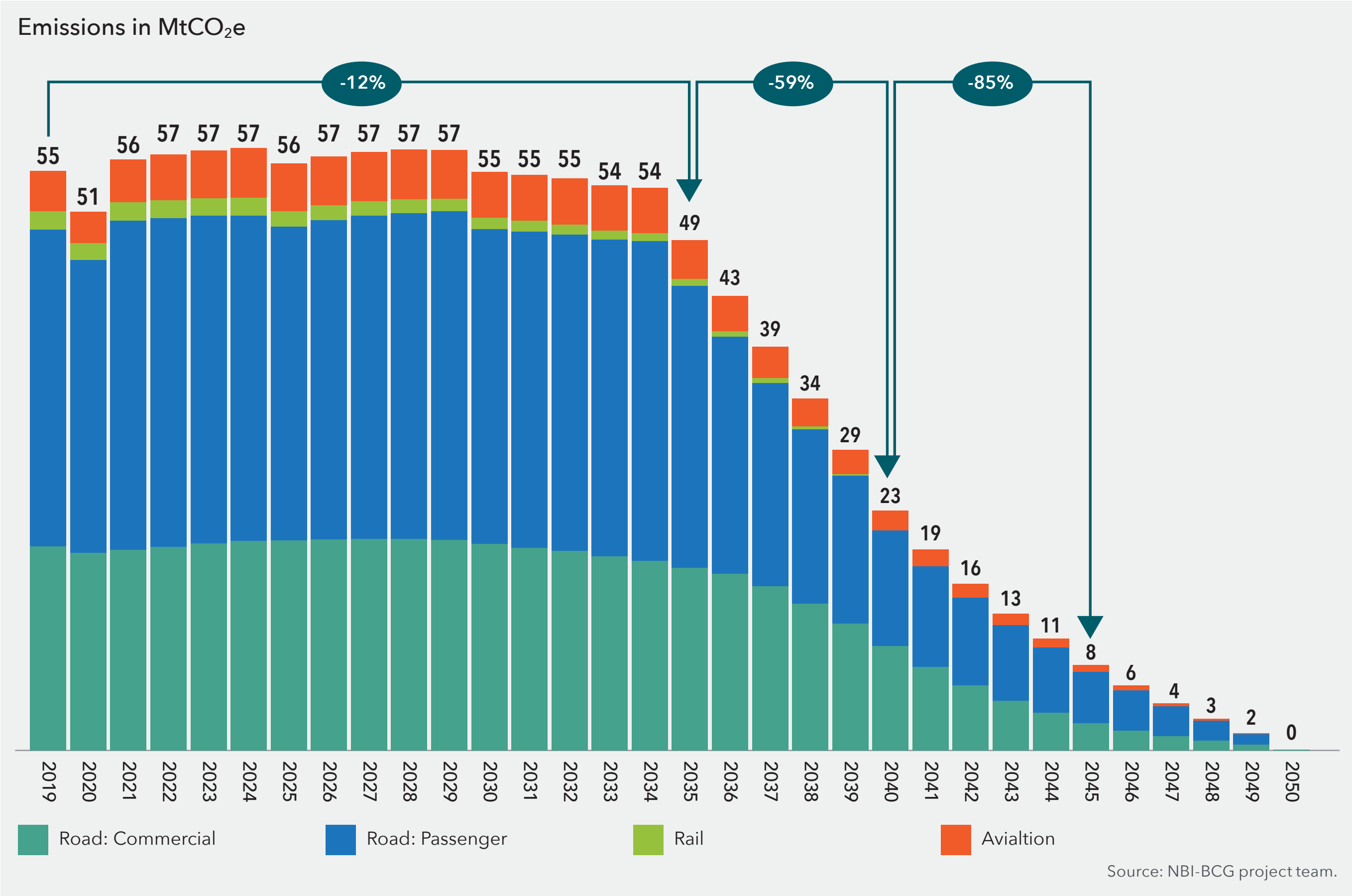
In the mid- to long-term uncertainties exist on how techno-economic factors, policy environment, and the behaviour of consumers will develop. Highlighted below are the key uncertainties identified by this study.

Consumer preferences cannot be easily influenced, thus significant incentives/disincentives are required to ensure an uptake of new energy vehicles in the short-term. Overall, adopting the optimal net-zero pathway will require wholesale behavioural changes, such as the move away from vehicle ownership to the use of public transport and non-motorised travel. And when considering vehicle ownership, total cost of ownership models will need to take preference over up-front capital expenditure considerations.

Although spatial planning benefits the transport sector by reducing demand, implementation needs coordination across sectors and society to enable large-scale change. The development of spatial planning, particularly in the major cities, will play a pivotal role in enabling a wholesale behavioural change across sectors.

Centre in Cape Town.

Figure 21: Evolution of transport sector emissions in a net-zero pathway ($MtCO_2e$)



Source: NBI-BCG project team.

In heavy duty transport, FCEVs are a strategic play for South Africa to stimulate demand for Green H_2. The likely development of research in solid-state batteries indicates that they are expected to be feasible and possibly cheaper by 2050.

The availability of innovative finance solutions is a key lever to accelerate the adoption of EVs in the short-term and will require disruption from financers – this study does not take a stand on how this will play out.

The role of minibus taxis and the broader informal transport industry is uncertain in a net-zero transport system. Options include formalising the industry or integrating the MBTs as-is into the future public transport infrastructure. MBTs currently play a critical role in transport, driven by the widely dispersed nature of South Africa's populations in cities and towns. Additionally, the informal transport sector employs more than 350 k people across the country. Further, without policy and regulatory incentives this shift may take longer than anticipated and emission reductions may not materialise within the targeted timeframe. Therefore, it is critical to make decisions early to ensure certainty and a smooth Just Transition to net-zero especially, in the context of increased rail transport.

3.2 HOW TO ENABLE THE DECARBONISATION OF SOUTH AFRICA'S TRANSPORT SECTOR

3.2.1 WHAT ARE THE KEY ENABLERS TO UNLOCK NET-ZERO TRANSITION FOR THE TRANSPORT VALUE CHAIN?

To achieve this ambitious pathway, South Africa must build and operate an efficient public transport system, invest in rail and port infrastructure as well as improve their reliability and efficiency, and incentivise EV adoption and public transport use.

The transport ecosystem will need to make coordinated strategic choices to set the country on a net-zero trajectory, to address the value already at risk in key sectors like automotive manufacturing, petrochemicals and chemicals, and mining, and to unlock critical reindustrialisation opportunities.

From within the transport sector

From within the transport sector itself, there are three critical enablers to decarbonise:

1. Invest in reliable, efficient physical infrastructure, with a focus on rail infrastructure expansion and management.
2. Develop green, efficient, and reliable public transport systems, with a focus on BRTs and potentially MBTs for intra-city transport in major cities.
3. Implement enabling policy and regulation, in transport and across the broader value chain.

Infrastructure: A preliminary high-level assessment of the techno- and socio-economic impacts revealed that three main transport physical infrastructure developments are required in South Africa:

- **Develop High Speed Rail** along the Johannesburg–Durban–Cape Town corridor to decarbonise inter-provincial travel and improve the quality of public transport.
- **Expand rail freight along the Johannesburg–Durban–Cape Town** corridor to improve the efficiency of freight transport, reduce the associated cost of transport and reduce road congestion.
- **Invest in EV public charging infrastructure** to enable short- and long-range EV travel and signal to consumers that EV use is possible in South Africa.

Public transport: an **accessible, efficient and safe public transport system** is required:

- South Africa must invest in a green BRT system for major cities for short intra-city passenger transport to decarbonise and improve the quality of public transport.
- South Africa will need to integrate the BRT system with MBTs for last-mile transport, with urbanisation in parallel with densifying cities to enable critical ridership. The electrification of the taxi fleet will need to be a clear policy programme along the lines of the Taxi Recapitalisation Programme.

Enabling policy and regulation is addressed in Section 3.2.2 of this report.

The broader value chain

The broader value chain presents a range of enablers of the decarbonisation of the transport sector. Those with potentially the most significant socio-economic impact in the transport value chain include:

- The local production of Green H_2 and green fuels in the petrochemicals and chemicals sector.
- The local production of BEVs and fuel cells in the automotive and manufacturing sectors.
- The exploration and mining of clean technology minerals in the mining sector.

Focusing on the **local petrochemicals and automotive sectors**, South Africa should:

1. Establish l**ocal BEV (light vehicles) manufacturing capacity** to maintain the local market and sustain and grow the export market, both of which are critical for the operations of automotive manufacturers in South Africa. Even in a base case, local automotive manufacturers could leverage their existing operational experience and access to local and regional deposits of key raw materials to supply the almost 800 000 new BEVs required in the vehicle parc by 2030
2. Scale **local Green H_2 production** to enable the uptake of FCEVs in heavy-freight and provide low-cost feedstock for sustainable fuel production. Utilisation of green hydrogen in heavy industry vehicles, as well as integrating into South Africa's green hydrogen commercialisation plan could be a mechanism to enhance green hydrogen penetration.
3. Scale **sustainable low-carbon and zero-emission fuel production** to support the local and global decarbonisation of aviation and shipping, and sustain the competitiveness of the local synfuels sector. South Africa has large-scale, high-quality renewable energy potential, sufficient land and unique Fischer-Tropsch expertise to achieve this.

Photo: Shutterstock

CASE STUDY 2: IMPERIAL'S PROJECT BLUE FLEET

When was the project started and how long has it been running?

Project Blue Fleet was initiated in April 2020 as a 'One Imperial' initiative. *It is centred around digitisation of Imperial's fleet to improve overall performance through increased visibility and monitoring, supported by analytics and insights from telematics.*

Key objectives are: safety, enhance monitoring to shift focus from reacting to accidents to proactively avoiding accidents, driver hours, cost competitiveness through strategic sourcing, group standardisation of fleet and systems, deploying best available technologies and systems to improve fleet fuel efficiencies, and focusing on the central availability of data to promote data-driven insights and decision-making.

What does the project entail?

The initial stage of the Project Blue Fleet was data mining, ensuring critical data flows into a central data warehouse from where insights and synergies could be established and analysed. This provided, and continues to provide, data-driven insights into what contributes towards fuel wastage and where focus should be placed to maximise improvement efforts. Similarly, the introduction of enhanced telematics and camera technology enabled the business to focus on driving statistics, fleet utilisation, and information on incidents. The standardised data also enabled the business to set fuel consumption benchmarks and the evaluation of performance against those benchmarks in various levels of detail. Overall, these initiatives positively impact safety and emissions reduction through comprehensive insights, fuel efficiency and improved fleet utilisation.

What are Imperial's long-term climate action/ emissions reduction goals?

Imperial's current aspiration is to achieve net-zero on scope 1 and 2 greenhouse gas emissions by 2050. When combining our scope 1 and 2 emissions, over 90% are direct emissions arising from mobile and stationary fuel combustion and just under 10% from electricity demand.

Our decarbonisation plans therefore centre around two roadmaps: firstly, decarbonising our truck fleet through alternative technologies; and secondly, decarbonising electricity supply through renewables. Short-term targets are set annually to drive improvements in emissions intensity (scope 1 emissions associated with road transport) and contribution of embedded renewables to our electricity demand (scope 2).

In March 2022, Imperial was acquired by DP World. Imperial's ESG strategy will be aligned to the objectives of DP World in time.

How has Project Blue Fleet contributed to the achievement of these goals so far?

Over the past two years the biggest achievements were alignment within the group and the significant focus that is now placed on fuel efficiency improvements, fleet utilisation, driver management and safety, and data across the various businesses.

During F2021, our fleet of vehicles greater than 3.5 tonnes experienced a 5.8 mn litres reduction in fuel consumed due to improved litres per 100 kilometres travelled, resulting in an estimated saving of ~15 000 tonnes of CO_2e emissions. Due to data limitations, the factors leading to the improvement cannot be fully distinguished, although our active focus on fuel efficiency and fleet replacement beneficially contributed. A change in client and product mix remains a significant external driver of changes in fuel efficiency.

What else is Imperial doing in the short-, medium-, and long-term, to achieve their climate commitments?

For the immediate future, our efforts on fuel and fleet efficiency continue. Regarding our commercial fleet's emissions, the solution set currently contains numerous technologies being piloted and implemented. Viable solutions available today, which we have started investing in at scale, include Performance-Based Standards trucks (which reduce emissions per tonne of delivered product by ~20% vs conventional 22 metre diesel trucks, through enabling increased loads per vehicle configuration) and Euro 5 specification vehicles (which improve fuel efficiency and the resultant GHG emissions per kilometre by ~17% vs standard Euro 3 specification technology). For the longer-term, we are piloting alternative energy technologies of the future. This includes pure- and dual-fuel LNG trucks, pure- and dual-fuel CNG trucks, electric trucks (all undergoing current pilots) and hydrogen fuel cell electric trucks (studies ongoing toward a pilot). Key considerations to assess these technologies' viability include: safety; reliable availability of fleet and fuel, related refuelling infrastructure and total cost of ownership; and clients who are prepared to partner with Imperial on a particular technology.

3.2.2 WHAT ARE THE RECOMMENDED NO-REGRET ACTIONS?

> *Immediate next steps and no-regret actions include incorporating EVs in the EU trade agreement to reduce import tariffs, investing in revitalising the rail infrastructure, and improving governance within rail and port management.*

As mentioned above, the path to net-zero by 2050 for South Africa's transport sector will require coordinated action across stakeholder groups to: 1) shift to rail; 2) accelerate ZEV adoption in road transport; and 3) replace remaining fossil fuels with low-carbon fuels. While there is uncertainty on the evolution of decarbonisation technologies and solutions, like the maturity of BEVs relative to FCEVs for heavy-freight for example, there is a set of concrete recommended no-regret actions for the road, rail, and aviation and shipping sectors.

Table 2 shows a long-list of these actions along three key dimensions: 1) physical infrastructure; 2) public transport systems; and 3) policy and regulation. The most critical of these actions include:

1. Negotiating favourable import terms for ZEVs in the EU trade agreement with a target to reduce import tariffs to at least similar levels as ICE. For example, reducing the general import duties for light passenger BEVs to 18% from 25%.
2. Fixing rail and port infrastructure to realise the full export potential of the country by establishing a task team that will identify key problems, identify solutions, and source investment to fund implementation of the solutions.
3. Piloting the use of ZEV buses in existing Bus Rapid Transit systems in Cape Town, Durban, or Johannesburg to enable zero-emission public transport in the short-term.

Table 2: No-regret actions by transport modes

	Short-term: 2020–2030	Medium- to long-term: Beyond 2030
ROAD TRANSPORT		
Physical infrastructure	■ Project **EV charging infrastructure** requirements over time and develop roadmap with construction targets per geography. Initial projections show ~100 000[34] public charging units required by 2030 at a cost of ~ZAR4 bn[35] ■ Assess the **Green H_2 refuelling** needs of South Africa's freight parc over time and develop a corresponding roll-out plan. ■ Partner with the petrochemicals sector for **flexible, short-term LNG refuelling solutions** for select fleets (until parc is fully electrified). ■ Build and improve non-motorised transport infrastructure such as biking lanes, walking bridges, lanes, etc., to reduce demand for motorised transport.	■ Develop Green H_2 refuelling infrastructure. ■ Continue upgrading physical infrastructure to maximise efficient spatial planning.
Public transport systems	■ **Pilot green BRT system in major cities**, like Johannesburg, learning from lessons of e.g. MyCiti roll-out in Cape Town.	■ Overhaul the GHG-emitting public transport system with ZEV alternatives.

34 Based on the AFID target for EU public charging infrastructure

35 International Council on Clean Transport, 2021

	Short-term: 2020–2030	Medium- to long-term: Beyond 2030
Policy and regulation	■ Establish the enabling **policy to manage the roll-out of the BRT system** and its integration with informal MBT system. ■ Roll-out second version of the r**ecapitalisation programme for MBT and bus fleets** to support the financing of ZEVs; secure critical demand for e-MBTs to incentivise local OEM production. ■ Negotiate **favourable import terms for BEVs** with major markets (like ICE vehicles). ■ **Adjust weight restrictions** for ZEV heavy freight to enable adoption of BEVs and FCEVs. ■ Partner with the finance sector to provide bespoke **financial products for EVs** (e.g. green discount on EV lending rates to reduce upfront cost burden on consumers). ■ **Set EV procurement targets for government fleets by 2030** to stimulate short-term EV demand. ■ Start education and marketing campaigns on the benefits of EVs environmentally and economically. ■ Pilot emissions-free zones in select areas of large metros, such as Johannesburg or Cape Town, reinforced by financial incentives to consumers.	■ **Ban ICE vehicle sales** for passenger (public and private) and freight use from 2035 and hybrid vehicle sales by 2040. This needs to be supported with the development of supporting ZEV infrastructure
RAIL TRANSPORT		
Physical infrastructure	■ Assess **environmental impact of HSR** and develop plan to mitigate any negative impact. ■ Develop clear **electrification targets for passenger and freight rail** over time. ■ Research the **potential for Green H_2 trains** in South Africa, and identify potential pilot routes. ■ Refurbish existing rail lines and locomotives for passenger and commercial rail lines and locomotives. ■ Establish task team to optimise rail operations, with a short-term focus on **maintenance and addressing safety and security challenges.**	■ Establish **public-private partnerships to enable the construction of the HSR infrastructure** from JNB–DBN–CPT. ■ Develop high-speed rail infrastructure for feasible routes between JNB–DBN–CPT.
Policy and regulation	■ Introduce **electrification targets** and mandates for passenger and freight rail. ■ Kick-off **rail sector market study to pilot the open-access rail market and ownership structure** outlined in the National Rail Policy White paper of 2022. ■ Implement interventions to arrest the loss of competitiveness of the rail sector in the short term, as outlined by the President's 2022 SONA; ensuring a road to rail shift in both passenger and freight rail.	■ Implement future market structure as per the National Rail Policy White paper (2022).
AVIATION AND SHIPPING		
Physical infrastructure	■ Retrofit existing aviation and shipping refuelling infrastructure for lower- and zero-emission fuels	■ Develop distribution systems and infrastructure for green fuels (pipelines or otherwise).
Policy and regulation	■ Introduce **gradual blending mandates** to promote the uptake of SAF in aviation and e-methanol and e-ammonia in shipping (with 100% blends required in 2050 if no DACCS).	

4. OUTLOOK

As was stated in the foreword of this report, South African business commits unequivocally to supporting South Africa's commitment to find ways to transition to a net-zero emission economy by 2050. Furthermore, business would support an enhanced level of ambition in the NDC that would see the country committing to a range of 420–350 Mt CO_2e by 2030. However, this enhanced ambition would have to be conditional on the provision of the requisite means of support by the international community. In this light, the business community will play its part to work with international and local partners to develop a portfolio of fundable adaptation and mitigation projects that would build resilience and achieve deep decarbonisation.

A managed Just Transition is important, and such a transition is impossible without a broad multi-stakeholder effort. National government, through the Presidential Climate Commission and the National Planning Commission, and supported by key government ministries, is leading this effort.

In support of this national programme, the NBI membership together with BCG and BUSA are running a multi-year project to understand net-zero decarbonisation pathways, sector by sector. This will provide a solid input into national and local dialogues, as well as identify critical investment areas. Furthermore, this level of detail enables policy frameworks and engagement with providers of international support to maximise the potential to leverage concessional finance and trade support to attract local public and private finance.

This work is ongoing and is intended as a basis for further consultation and a foundation for future work. The work on each sector will be released in stages as it is completed and will form a basis on which others can build. Ultimately a final body of work of the combined sector content will be made up of reports on the following:

- An introduction to the project and to a managed Just Transition, including analysis from our economic modelling
- Electricity
- Petrochemicals and chemicals
- The role of gas
- The role of Green H_2
- Mining
- Transport
- Agriculture, Forestry and Other Land Use
- Construction
- Heavy industry
- Financing
- A concluding chapter highlighting key investment opportunities and no-regret decisions.

Each of these reports will be published via our Just Transitions Web Hub (http://jthub.nbi.org.za). Please monitor this website for the latest report versions, supporting data and presentation material, as well as news of other Just Transition initiatives and a wide range of current opinion and podcasts on a Just Transition for South Africa.

We invite you to engage with us and to provide comment and critique of any of our publications via info@nbi.org.za.

Kalkbult, Northern Cape. Photo: scatec.com/locations/south-africa

APPENDIX

Analytical approach

The analysis for the transport sector study was developed to answer five key questions, as discussed in Section 2.4. This section outlines the detailed analytical pathway used to answer these five key questions, summarised in Figure 22 below.

Figure 22: Analytical pathway for the transport sector analysis

Strategic options on South Africa's transport sector:

1 Starting point and context of the sector

Assess the **emissions baseline** of the transport sector across modes.

Quantify **baseline transport demand** across passenger and freight modes.

Assess, at a **high level**, the broader **socio-economic context** of South Africa's transport sector.

2 Impact of global trends on the local sector

Assess impact of **global tech trends, T&L standards and international bans and regulations** on South Africa's transport sector.

3 Net-zero pathways for South Africa's transport sector

Identify **net-zero levers to fully decarbonise South Africa's transport sector**.

Develop net-zero pathway, assess implications and identify key milestones.

For base cases and NZ pathway, quantify for 2020–2050:

- Volume of transport demand across modes
- Impact on car parc for the road sector
- Impact on liquid fuel demand across modes
- Emissions impact across modes.

4 Key enablers of a just net-zero transition

Identify **key enablers for a just net-zero transition of South Africa's transport value chain**.

Define 2–3 critical strategic choices for South Africa to prioritise along the **transport value chain**.

5 Recommended no-regret actions

Define **recommended no-regret actions** across stakeholder groups with a focus on the short-term:

- Infrastructure
- Policy and measures
- Systems.

Source: NBI-BCG project team.

Starting point and context of the transport sector

To assess the emissions baseline of South Africa's transport sector across the four major modes, we leveraged data sourced from the 2017 Greenhouse Gas National Inventory, the International Energy Association, the Department of Energy, and the Department of Transport. From this we have built the 2019 view of direct transport emissions (see Figure 22 and Figure 23).

Figure 23 shows the projected trajectory of the passenger and commercial transport demand in South Africa across the four modes of transport from 2019 to 2050. This is baselined from the 2019 passenger and commercial demand levels through data from the IEA, Transnet, and StatsSA. The trajectory from 2020 to 2050 is based on projected demand growth through GDP and population growth as proxies (Figure 24).

Impact of global trends on the local sector

Global trends will affect the local transport sector especially regarding technological maturity and consumer choice; exogenous variables, such as transport and logistics standards; and policy choices.

Figure 23: Transport demand project trajectory

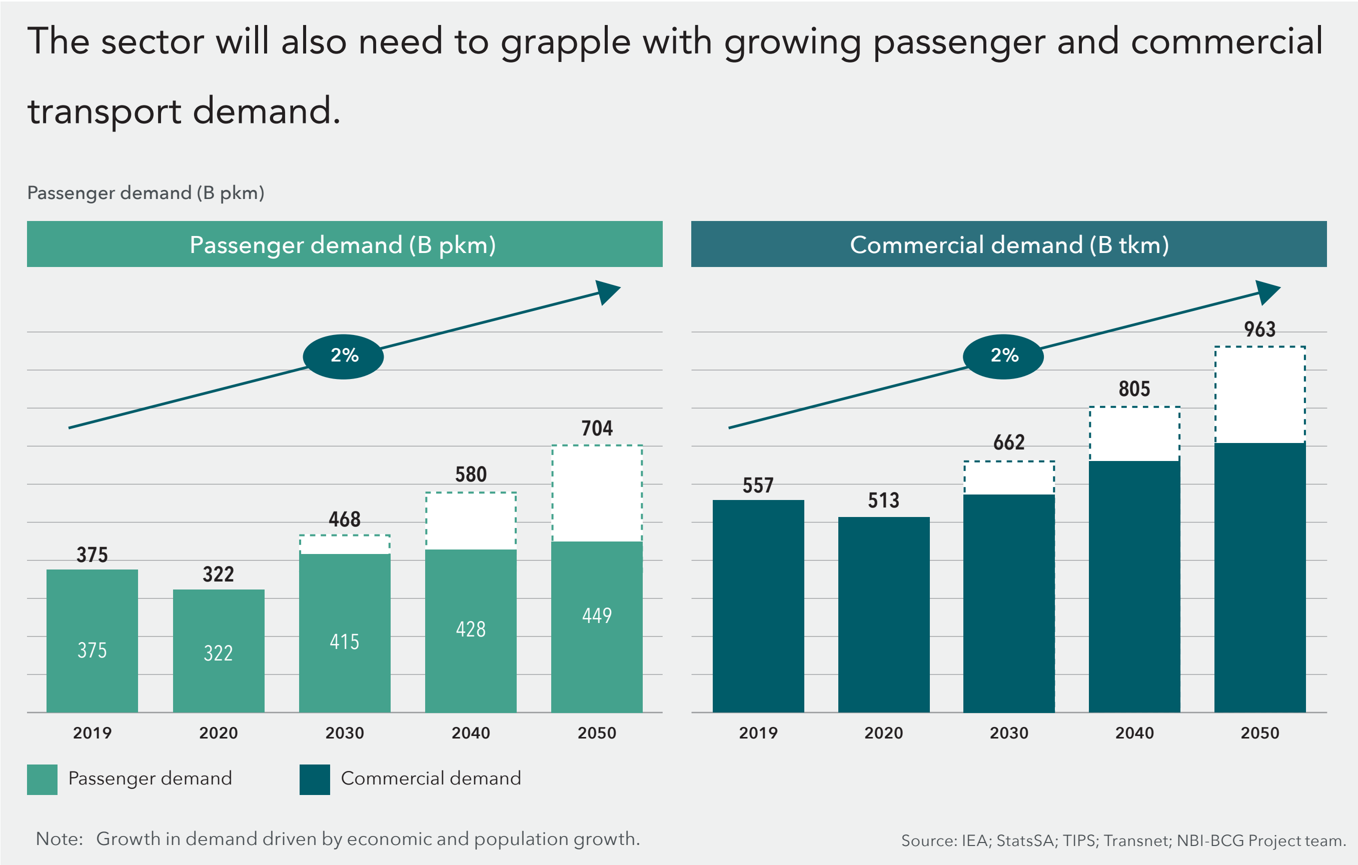
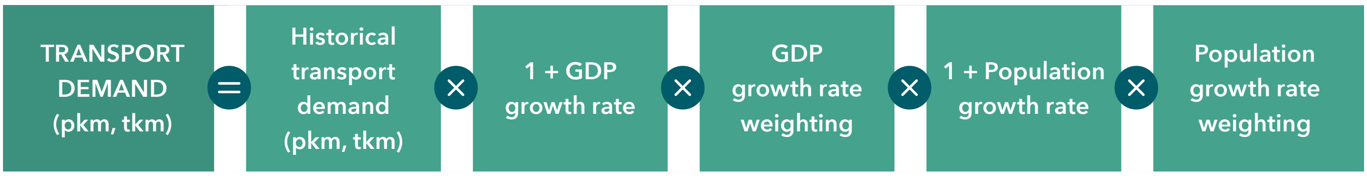


Figure 24: Transport demand projection methodology



Methodology	
Transport demand – baseline	Passenger-km or tonne-km in the reference scenario by mode
GDP growth rate	South Africa GDP projected to grow at 2% p.a. through to 2050
Population growth rate	South Africa population expected to grow from 59 mn in 2020 to 75 mn in 2050
Weighting	Weightings based on how well GDP/population growth tracks demand historically

Source: NBI-BCG project team.

Deep dive: TCO assessment of different vehicle classes for road transport

Approach

As shown below, the TCO is equal to the sum of the purchase costs, taxes, energy consumption and infrastructure costs, and maintenance and insurance costs, less the terminal value of the vehicle after a five-year period.

TOTAL COST OF OWNERSHIP

=

Purchase cost
(Manufacturing cost + additional equipment cost)

+

Tax
(excluding carbon tax, with sensitivities on import tariffs)

+

Energy consumption and infrastructure costs

+

Maintenance insurance and externalities costs

–

Terminal value after five years

The costs are calculated as follows:

- The **purchase costs and taxes** for each vehicle type include the manufacturing and additional equipment costs and taxes, including the sales tax but excluding the carbon tax. A range of sensitivities on the import tariffs are assessed, including no import tariffs, import tariffs in line with current levels across vehicle classes, and technologies and comparable tariffs across technologies (i.e. BEV and ICE vehicles).
- The **energy consumption and infrastructure** costs include the cost of fuel, electricity and/or hydrogen consumption based on energy efficiency, cost per unit of energy, and the infrastructure costs.
- The **maintenance and insurance costs** estimate the annual maintenance costs on the basis of general repair costs, part changes required, tyre and battery changes, and year of ownership for each vehicle class and technology separately. The cost of insurance is estimated as a percentage of the purchase cost.
- The **terminal value** is the resale value of the vehicle reflecting depreciation after five years. The battery replacement cost is subtracted from the BEV resale value.

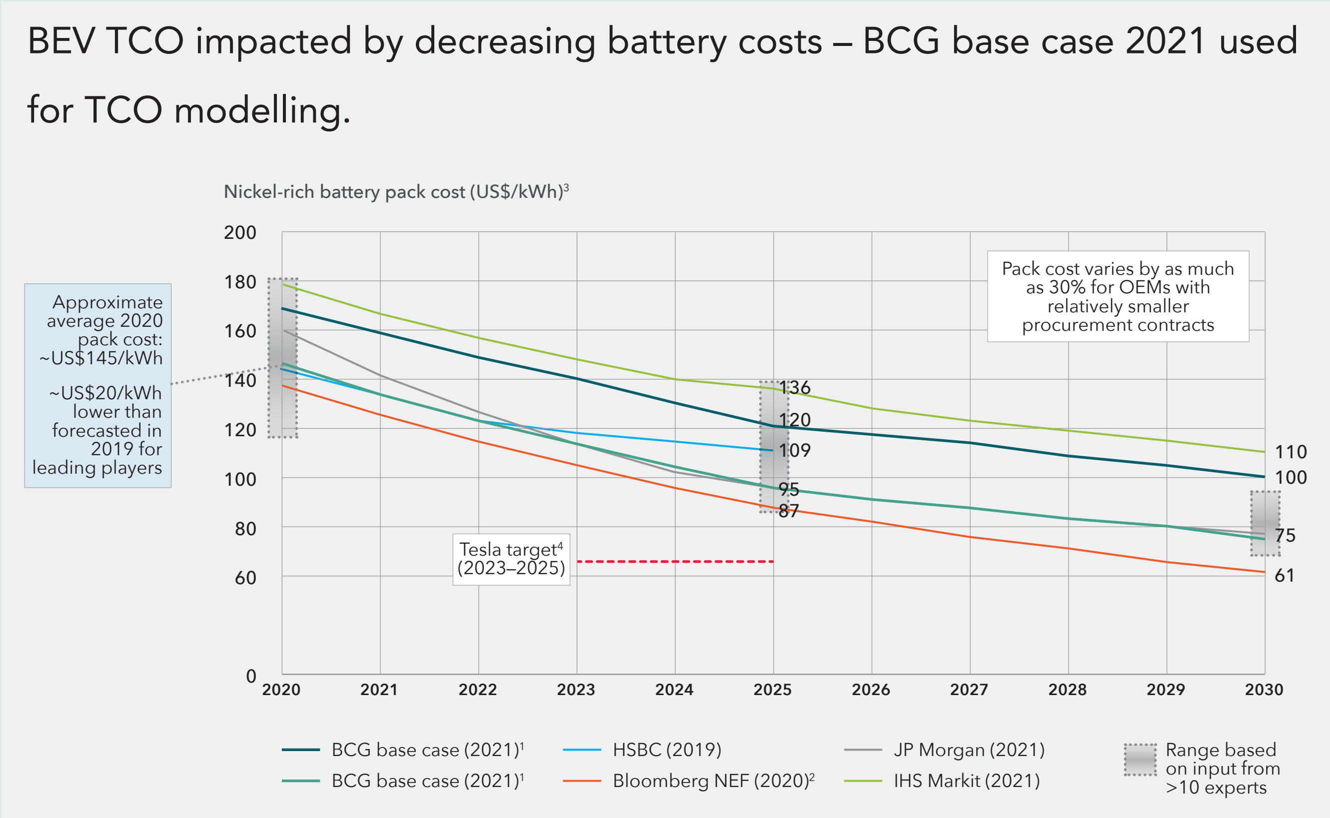
The evolution of the TCO, reflecting predominantly global technology trends and global regulation and standards, is assessed for each vehicle class. For passenger vehicle classes, light private vehicles and MBTs, the TCO is assessed on a total cost basis (i.e. measured in ZAR) and for light- to heavy-freight vehicles, the TCO is measured on a cost per kilometre basis.

Key assumptions

The effect of inflation is not accounted for. The analysis only reflects functional changes in prices of commodities, vehicle purchases, etc.

- The cost and size of batteries will continue to decrease – with a 50% reduction in prices from a 2020 base level reached by the end of the decade (2030) (see Figure 25)
- The adoption of powertrains follows a normal distribution also known as the technology adoption curve (S-curve), based on global benchmarks across developed and developing markets.
- Consumers will start to adopt EVs when the ICE–EV TCO parity point is reached, where the total cost of ownership of a BEV is equal to that of an ICE vehicle.
- Steady-state adoption of EVs in South Africa will favour ZEVs (BEVs and FCEVs) instead of hybrid vehicles with global bans on HEVs projected to influence OEM decisions.
- The adoption of diesel vehicles after the parity point is reached will follow an exponential reduction due to diesel ICE vehicles being more expensive than petrol ICE vehicles.

Figure 25: Battery cost assumptions



Base case definition and approach

The global base case was developed to project the uptake of green transport solutions in South Africa as driven only by global technological change, transport and logistics standards, and international bans and regulations. Two global technology scenarios are considered based on IEA Reference Technology Scenario and the IEA Sustainable Development Scenario. Figure 26 summarises the key assumptions that define each base case.

We quantify the following key variables to assess the adoption of green transport solutions in the base case for 2020–2050:

- Impact on car parc for the road sector
- Impact on liquid fuel demand across mode
- Emissions impact across modes.

Figure 26: Key assumptions for each base case

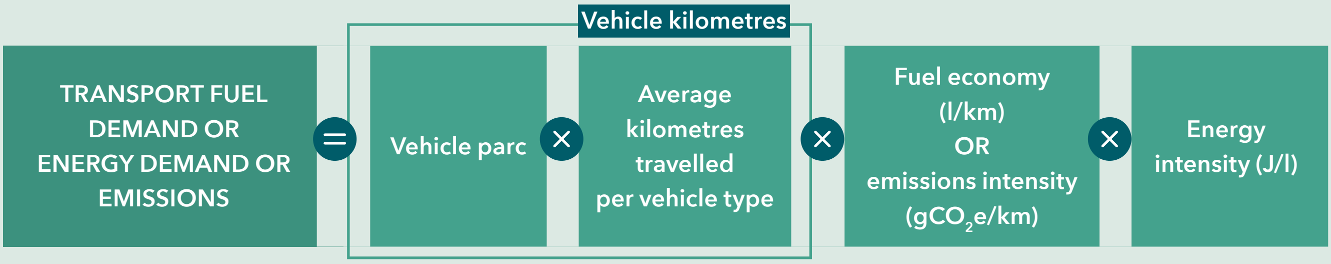
	IEA RTS base case	IEA SDS base case
Transport demand	■ Growth in line with GDP and population ■ Passenger and commercial modes grow at comparable rates ■ Pandemic-related behavioural shifts are reversed	■ Demand growth aligned to RTS in aggregate and for passenger vs. commercial ■ Pandemic-related behavioural shifts are maintained
Sector structure	■ No major infrastructure changes ■ No major supply changes, but rail capacity utilisation increases	■ Minimal expansion of rail infrastructure ■ Supply changes in line with RTS
Policy and strategic choices	■ Strategic choice/policy to enable decarbonisation e.g. the removal of today's EV import tax ✪ **Passenger: 40% import tariff on EVs (25% + 15% luxury tariff), 18% import tariff on ICE vehicles (25%–7% discount from EU)** ✪ **Freight: 20% import tariff on EVs, 12% import tariff on ICE vehicles (20%–8% discount from EU)**	■ Strategic choice/policy as in the RTS ■ Import tariff as per the RTS
Technology and tech adoption	■ Road: adoption of cost competitive of ZEVs ■ Rail: electrification in line with global trends, with 1%–2% increase in rail passenger demand (from 4%) and ~4% increase in freight rail, due to mode shifting ■ Air and sea: uptake of zero-carbon fuels	■ As in the RTS, but faster uptake of ZEVs in road due to earlier cost competitiveness

✪ **Key update**

Figure 27: Vehicle parc methodology

Methodology	
Vehicle parc	The number of vehicles in South Africa by fuel type by year
Transport demand	Passenger-km or tonne-km in the reference scenario by mode – split across technologies informed by TCO model
Vehicle occupancy rate/ load factor	Assumption made on the average number of passengers occupying an operating passenger vehicle/ average tons loaded per operating commercial vehicle
Average kilometres travelled per vehicle	Assumptions made on the average annual kilometres travelled by each type of car (car, minibus, bus, etc.)

Figure 28: Methodology for fuel demand, energy demand and emissions



Methodology	
Transport fuel demand	Amount of fuel needed to meet transport demand in the baseline scenario
Vehicle parc	The number of vehicles in South Africa by fuel type through to 2050 as modelled in the BCG TCO model
Average kilometres travelled per vehicle	Assumptions made on the average annual kilometres travelled by each type of car (car, minibus, bus, etc.)
Fuel economy	Assumptions made on the fuel efficiency by fuel type and its evolution over time
Emissions/energy intensity	Assumptions made on the conversion factor of fuel demand into emissions or energy demand by fuel type

Key assumptions for the energy demand and direct emissions

Figure 29: Passenger vehicle energy consumption assumptions

	Liquid fuels	Hydrogen	Electricity
Cars	■ 8 L/100 km of **diesel** in 2020, 4 L/100 km by 2050 ■ 9 L/100 km of **petrol** in 2020, 5 L/100 km by 2050	■ 1 kg/100 km in 2020, 1 kg/100 km in 2050	■ 19 kWh/100 km in 2020, 10 kWh/100 km in 2050
MBTs	■ 15 L/100 km of **diesel** in 2020, 11 L/100 km by 2050 ■ 17 L/100 km of **petrol** in 2020, 9 L/100 km by 2050	■ 1 kg/100 km in 2020, 1 kg/100 km in 2050	■ 30 kWh/100 km in 2020, 26 kWh/100 km in 2050
Buses	■ 40 L/100 km of **diesel** in 2020, 26 L/100 km by 2050 ■ 42 L/100 km of **LNG** in 2020, 28 L/100 km by 2050	■ 8 kg/100 km in 2020, 6 kg/100 km in 2050	■ 140 kWh/100 km in 2020, 129 kWh/100 km in 2050

Note: Fuel consumption for LNG stated in diesel litre equivalent of the gas consumption.

Source: ICCT, IEA, OEM websites.

Figure 30: Commercial vehicles energy consumption assumptions

	Liquid fuels	Hydrogen	Electricity
LCVs	■ 9 L/100 km of **diesel** in 2020, 7 L/100 km by 2050 ■ 8 L/100 km of **LNG** in 2020, 6 L/100 km by 2050	■ 2 kg/100 km in 2020, 1 kg/100 km in 2050	■ 19 kWh/100 km in 2020, 10 kWh/100 km in 2050
MCVs	■ 14 L/100 km of **diesel** in 2020, 9 L/100 km by 2050 ■ 13 L/100 km of **LNG** in 2020, 9 L/100 km by 2050	■ 4 kg/100 km in 2020, 3 kg/100 km in 2050	■ 30 kWh/100 km in 2020, 26 kWh/100 km in 2050
HCVs	■ 42 L/100 km of **diesel** in 2020, 32 L/100 km by 2050 ■ 42 L/100 km of **LNG** in 2020, 32 L/100 km by 2050	■ 8 kg/100 km in 2020, 6 kg/100 km in 2050	■ 140 kWh/100 km in 2020, 129 kWh/100 km in 2050

Note: Fuel consumption for LNG stated in diesel litre equivalent of the gas consumption.

Source: ICCT, IEA, OEM websites.

Figure 31: Passenger vehicle emissions assumptions

	Emissions intensities
Cars	■ 154 gCO_2e/km for **diesel** in 2020, 120 gCO_2e/km by 2050 ■ 166 gCO_2e/km for **petrol** in 2020, 150 gCO_2e/km by 2050
MBTs	■ 200 gCO_2e/km in 2020 for **diesel**, 164 gCO_2e/km by 2050 ■ 180 gCO_2e/km for **petrol** in 2020, 148 gCO_2e/km by 2050
Buses	■ 480 gCO_2e/km in 2020 for **diesel**, 394 gCO_2e/km by 2050 ■ 500 gCO_2e/km in 2020 for **petrol**, 410 gCO_2e/km by 2050

Source: ICCT, IEA, OEM websites.

Figure 32: Passenger vehicle emissions assumptions

	Emissions intensities
LCVs	■ 200 gCO_2e/km for **diesel LCV** in 2020, 120 gCO_2e/km by 2050 ■ 166 gCO_2e/km of **LNG** in 2020, 150 gCO_2e/km by 2050
MCVs	■ 200 gCO_2e/km in 2020 of **diesel**, 164 gCO_2e/km by 2050 ■ 180 gCO_2e/km of **LNG** in 2020, 148 gCO_2e/km by 2050
HCVs	■ 480 gCO_2e/km in 2020 of **diesel**, 394 gCO_2e/km by 2050 ■ 500 gCO_2e/km in 2020 of **LNG**, 410 gCO_2e/km by 2050

Source: ICCT, IEA, OEM websites.

Net-zero approach and assumptions

The analytical approach for the net-zero pathway follows the same methodology as shown in the base case with the additional assumption that policy mechanisms are put in place to accelerate the decarbonisation to reach net-zero by 2050. These are defined in Figure 33 below.

Figure 33: Pathway to net-zero for South African transport

SA's path to net-zero combines all 3 levers, with rail prioritised first followed by road and then aviation.

By merit order:

1. First, shift road and aviation to efficient, low-carbon, low-cost rail.
2. Then, accelerate the uptake of economically viable EVs in road transport.
3. Finally, phase-out jet fuel with relatively costly SAF-blends and SAF.

	Shift road and aviation to rail	Accelerate EV adoption	Green remaining fossil fuels
Passenger	**Rail reaches 15%–20% of total passenger demand**[1] ■ First shift aviation demand to rail given price elasticity of 0.4–0.9[2] & 5%–25% increase in aviation prices[3]	**EVs reach 100% adoption in road transport, with new ICE vehicle sales bans from 2035** **Comparable ICE and EV import tariffs (25% 7% = 18%)**	**100% SAF by 2050 for aviation**
Freight	**Rail reaches 30%–40% of total freight demand** ■ All demand shifted from road with no freight aviation in baseline	**Comparable ICE and EV import tariffs (20%–8% = 12%)**	***As per passenger transport***

Notes: 1. As per the IEA NZ scenario for rail.
2. As per the International Air Transport Association (IATA) estimated price elasticities for passenger demand in Sub-Saharan Africa.
3. 5%–15% price increases in the low scenario with lower Green H_2 and therefore lower SAF prices vs 5%–25% price increases in the high scenario with higher Green H_2 and therefore higher SAF prices.

Source: IEA Net Zero report, International Air Travel Association – 2022, NBI-BCG project team.

Figure 34: Disaggregated assumptions of rail demand

	2020	2030	2040	2050	Infrastructure implications
INDIVIDUAL (PASSENGER)					
Share of passenger demand (%)	5%	6%	9%	15%–20%	
Short (intra-city)	<1%	5%	10%	15%	■ *Current infrastructure*: **Gautrain and Metrorail** (550+ mn passengers p.a.). ■ *New infrastructure/system requirements*: Optimise (utilisation only ~50%) and fully electrify (currently 80%) existing rail and develop green BRT system integrated with rail network.
Regional (inter-city) and long (inter-province)	<1%	5%	10%	15%	■ *Current infrastructure*: **Shosholoza Meyl** with 5 main routes (1 mn passengers p.a.).[1] ■ *New infrastructure/system*: HSR infrastructure for JNB–DBN–CPT route, with shifts from road and aviation to rail.
COMMERCIAL (FREIGHT)					
Share of freight demand (%)	22%	24%	27%–31%	30%–40%	
Short (intracity)	0%	0%	0%	0%	■ *Current infrastructure*: n/a. ■ *New infrastructure/system requirements*: EV charging and Green H_2 refuelling infrastructure for BEVs and FCEVs.
Regional (inter-city) and long (inter-province)	100%	100%	100%	100%	■ *Current infrastructure*: **Transnet freight rail**. ■ *New infrastructure/system*: Similar to passenger transport, optimise (utilisation only ~50%) and fully electrify (currently 80%) existing rail. Also, leverage the HSR infrastructure for JNB–DBN–CPT route.

Note: 1. Inter-city and inter-province transport demand also met with aviation.

Source: Transnet (2022), National Rail Policy – Green Paper (2015), NBI-BCG project team.

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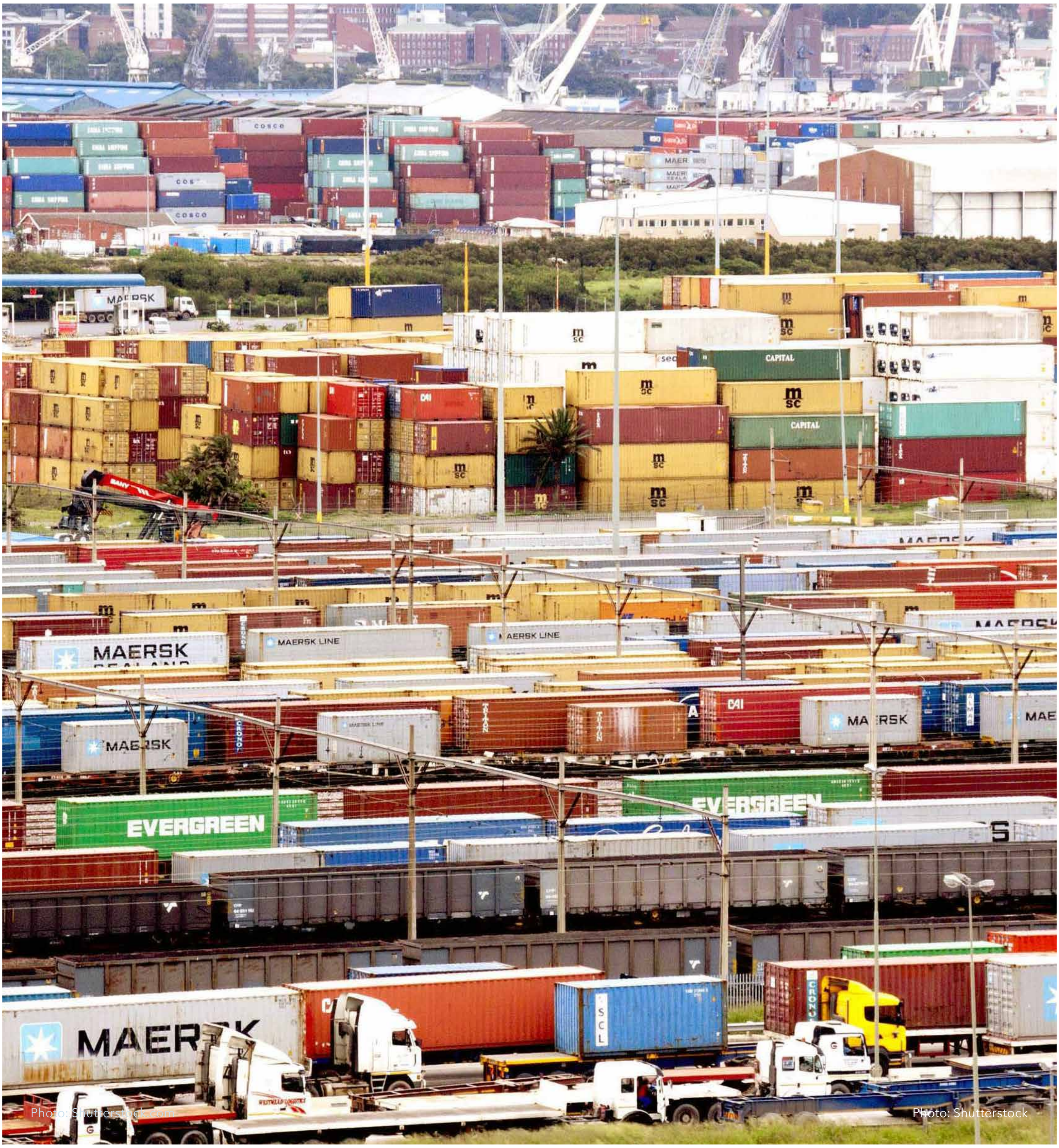

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