Climate Action Tracker

Scaling up climate action

Key opportunities for transitioning to a zero emissions society

FULL REPORT

CAT Scaling Up Climate Action series

SOUTH AFRICA

November 2018

NewClimate Institute

Ecofys – A Navigant Company

Climate Analytics

CAT Scaling Up Climate Action series

The Climate Action Tracker (CAT) strives to support enhancing climate action in the context of the Paris Agreement implementation. This analysis contributes to the Talanoa Dialogue at COP24 and future revisions of mitigation targets, and aims at spurring an increase in climate mitigation actions, to close the gap between current emissions projections and required Paris-compatible pathways.

As part of this, we have been researching the potential for countries to scale up climate action in different focus areas. The analysis in this report is relevant to Parties considering revisions to their Nationally Determined Contributions (NDCs) to be submitted under the Paris Agreement by 2020, and also to their submission of long-term low greenhouse gas development plans, also due by 2020.

The result is our **Scaling Up Climate Action** country series, which identifies options for increased sectoral action that would move a country towards a pathway compatible with the Paris Agreement's long-term temperature limit and estimates the impact of those actions on emissions and other benefits.

The first round of our analysis covers **South Africa**, the **European Union**, **Indonesia**, **Turkey**, **Argentina**, and **Australia**.

The consistent method and similar structure for all six reports allows for country-specific insights, while enabling a cross-country comparison to draw general research findings and lessons learnt on global potentials.

www.climateactiontracker.org/publications/scalingup

Executive summary

Introduction and objectives

Under the Paris Agreement, governments have committed to limiting temperature increase to well below 2°C above pre-industrial levels and pursuing efforts to limit it to 1.5°C. Current efforts are insufficient: aggregate mitigation targets, according to Climate Action Tracker (CAT) estimates, result in global warming of about 3.2°C. Implementation of the targets is falling short, with greenhouse gas (GHG) emissions under implemented policies leading to an estimated warming of around 3.4°C.

To stay below the globally agreed limit, the IPCC Special Report on 1.5℃ finds that an increase in efforts is required to peak global GHG emissions as soon as possible, reduce CO_2 emissions to net-zero around 2050 and total GHG emissions shortly thereafter.

In recent years, measures to reduce GHG emissions have, in many cases, become more attractive to policy makers and private investors, both because of falling technology costs, as well as increased awareness for other benefits, such as air quality improvements and job creation in low-carbon-oriented sectors.

We no longer live in a world where climate change mitigation is a burden per se, but where it increasingly becomes the most feasible option when considering all socio-economic aspects. For cost-efficient global mitigation, it will be essential to make those mitigation actions accessible to, and overcome remaining barriers in, all countries.

This report, the first country assessment in the Climate Action Tracker's Scaling Up Climate Action Series, analyses areas where South Africa could accelerate its climate action. The report illustrates GHG emissions reductions from such actions, along with other benefits.

KEY FINDINGS

- Scaling up climate action in South Africa's electricity supply, urban passenger transport, and residential buildings sectors which cover about half of South Africa's 2012 emissions can reduce the country's total greenhouse gas emissions by up to 96% below 2012 emissions in these focus areas by 2050.
- Actions in these areas alone would reduce economy-wide emissions by 17 % below 2012 levels, and bring South Africa close to meeting its 2050 emissions reduction target. While the three focus areas will almost fully decarbonise under our most ambitious scenario, additional action in other sectors and sub-sectors will be needed to decrease economy-wide emissions in line with the Paris Agreement's temperature limit.
- Research from South African institutes indicates that under least-cost scenarios, GHG emissions from electricity generation in South Africa could decrease by up to 83% below 2012 emissions levels by 2050.
- A fully decarbonised electricity sectors is critical for enabling low-carbon electrification trends in urban passenger transport and residential buildings in line with the Paris Agreement temperature limit.
- There is huge potential for (sub-)national actors to accelerate climate action by successfully decarbonising key areas such as urban passenger transport and residential housing, for example by shifting towards public modes of transport and increase electric mobility in Cape Town, Durban, and Gauteng.
- Changing from a high to a low-carbon electricity supply by 2030 is likely to create as many employment opportunities in South Africa as it would make obsolete, and provides jobs in technologies and sectors that are more likely to form the core of future electricity supply, both in South Africa and globally.

The analysis starts with an in-depth review of South Africa's current policy framework and sectoral developments, comparing them with the comprehensive policy packages and the progress of the kind of sector indicators required under Paris-compatible pathways.

The report then focusses on three areas with potential to increase mitigation efforts, selected based on their share of GHG emissions and considering national and even local circumstances: electricity supply, urban passenger transport, and residential buildings. CAT emphasises that other sectors must take similarly ambitious actions to decrease economy-wide emissions in line with the Paris Agreement

It identifies different options of accelerated climate action in each sector informed by insights from three categories: (1) national research and country-specific studies, (2) practices implemented by regional or international frontrunners, and (3) sectoral developments in line with the Paris Agreement's long-term temperature limit.

1 NATIONAL SCENARIOS

2 BEST IN CLASS SCENARIOS

3 1.5°C PARIS AGREEMENT COMPATIBLE SCENARIOS

Sector transitions towards zero-carbon

In South Africa, there is tremendous potential to scale up climate action, including in the focus areas of this study: electricity supply, urban passenger transport, and residential buildings. Increasing climate action now would initiate technically-feasible sectoral transitions towards a zero-emissions society while directly benefiting South Africa's sustainable development agenda.

Our findings confirm that ambitious decarbonisation efforts for the selected sectors at the national and sub-national levels in South Africa are feasible. They would significantly reduce greenhouse gas (GHG) emissions and foster co-benefits such as low-carbon-oriented employment generation, supporting sustainable development goals by reducing the adverse pollution effects of conventional modes of transport and electricity generation, and promoting modern housing facilities.

Electricity supply

A swift energy transition in South Africa is essential for it to be compatible with efforts to limit global warming to 1.5°C below pre-industrial levels, as established in the 2015 Paris Agreement.

The IPCC Special Report on 'Global Warming of 1.5°C' found that limiting warming to 1.5°C will reduce the impacts on vulnerable populations and ecosystems in the South African region, compared to 2°C warming, and that the energy transition required to limit warming to this level will have significant benefits for the access to clean and affordable energy and poverty eradication goals. It also re-emphasised that, globally, the power sector needs to have virtually exited coal by 2050, a finding that has important implications for short- and medium-term policy in South Africa.

Under least-cost scenarios from South African research organisations, the share of renewable energy in electricity generation could increase to 85%, and GHG emissions for electricity generation in South Africa could be reduced by up to 83% below 2012 levels by 2050. Our Paris-compatible scenario leads to an almost complete decarbonisation by 2050.

The proposed update of the Integrated Resource Plan (IRP) in August 2018, if implemented, could constitute a first step moving to a zero-carbon energy system. Additional action to phase out expensive and inefficient coal-based electricity generation, update the grid infrastructure, and ramp-up renewables deployment is needed to ensure a successful transition by mid-century.

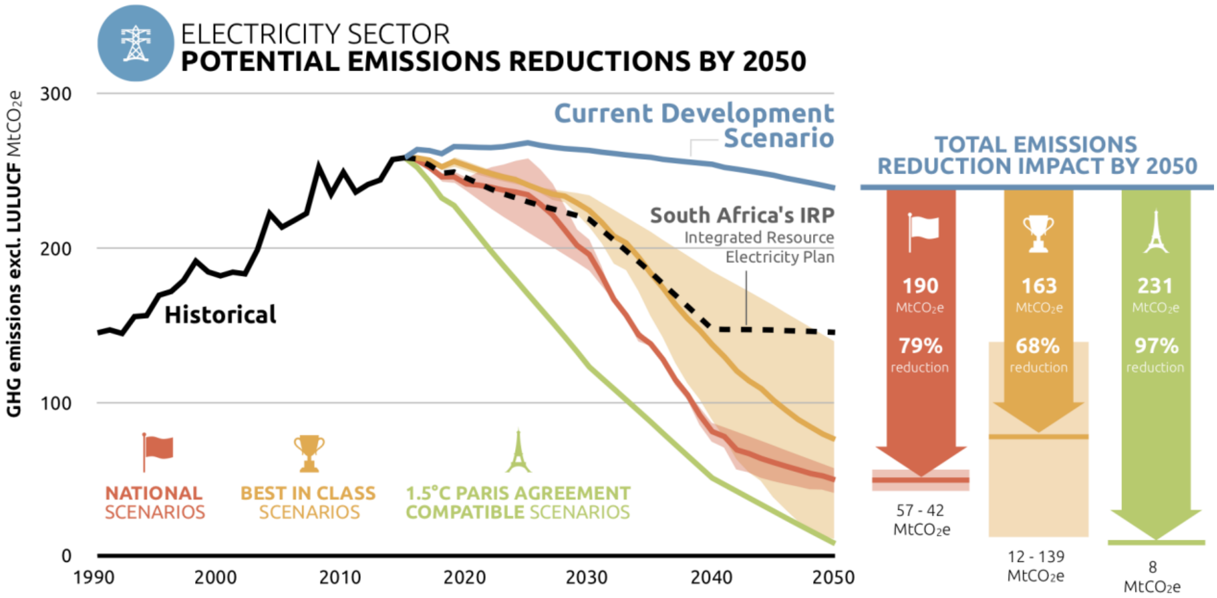


Figure 1: Overview of sectoral emission pathways under current policies and different levels of accelerated climate action in the South African electricity supply. The forecasted electricity demand considers accelerated climate action in the South African residential buildings and urban transport sector in Gauteng, Cape Town, and Durban. All sectoral projections towards 2050 done in the CAT PROSPECTS South Africa scenario evaluation tool.

Shifting South Africa's electricity supply to renewable forms of generation further enables low-carbon electrification trends in urban passenger transport and residential buildings.

Urban passenger transport and residential buildings

There is huge potential for national and sub-national actors to accelerate climate action by successfully decarbonising key sub-sectors such as urban passenger transport and residential housing.

In the most ambitious scenario compatible with the Paris Agreement temperature goal, the urban passenger transport in three urban areas of Cape Town, Durban, and the Gauteng province, including Johannesburg and Pretoria, fully decarbonises by 2050 through shifting towards public modes of transport and increased electric mobility.

Achieving this critically hinges on the electricity supply sector decarbonising in line with the Paris Agreement temperature goal. Although these three major urban areas cover only about 25% of ground transportation emissions in 2012, ambitious policies in these areas alone can stabilise the total emission levels of the South African ground transportation sector (including freight transport) at around today's emission levels, by 2050. Although not quantified in this study, it is expected that translating such measures to the entire ground transportation sector would result in substantial emission reductions compared to recent levels by 2050.

Similarly, energy efficiency gains through tighter building codes for new residential buildings, increased rates of thermal retrofits, and more efficient appliances can fully decarbonise the residential buildings sector by mid-century if the electricity were to be decarbonised in line with the Paris Agreement temperature goal.

If the electricity supply sector continues current trends of policies implemented today, increased action in residential buildings in South Africa could still reduce GHG emissions associated with the sub-sector by up to 35% below today's levels by 2050. These transitions entail key opportunities to advance socially-just urban mobility and housing, while generating local employment opportunities and attenuating the adverse health effects of conventional forms of passenger transport and inappropriate housing.

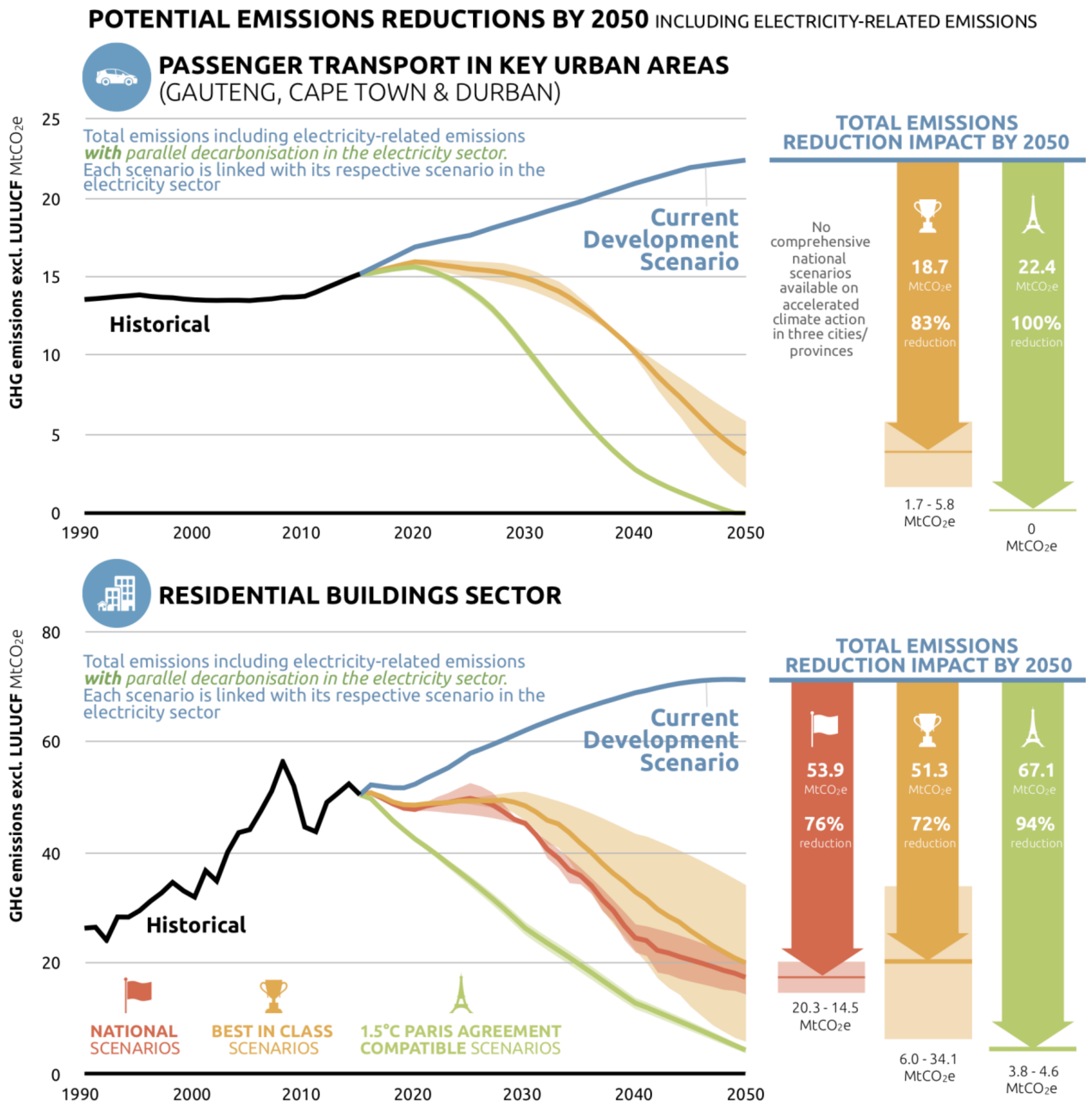


Figure 2: Overview of sectoral emission pathways under current policies and different levels of accelerated climate action in the urban passenger transport in Gauteng, Cape Town and Durban (upper graph), and residential buildings sector (lower graph). All historical data and sectoral projections towards 2050 from the CAT PROSPECTS South Africa scenario evaluation tool. Data includes electricity related emissions.

Accelerated climate action and South Africa's emission reduction targets

Scaling up climate action in South Africa's electricity supply, urban passenger transport, and residential buildings sector alone can reduce South Africa's total greenhouse gas emissions by up to 17% below 2012 levels by 2050.

While this still leaves South Africa short of achieving the upper bound of its emissions reduction target range in 2050, it would allow the nation to reach its 2030 targets and be within range of reaching its 2040 targets. In the Climate Action Tracker's country assessment, the upper end of the reduction target in 2030 falls into the "Highly insufficient" rating category, for 2050 in the "Insufficient" category. The lower end falls in the 2°C compatible range in all years. To be Paris compatible, the ambition of the target would need to increase further.

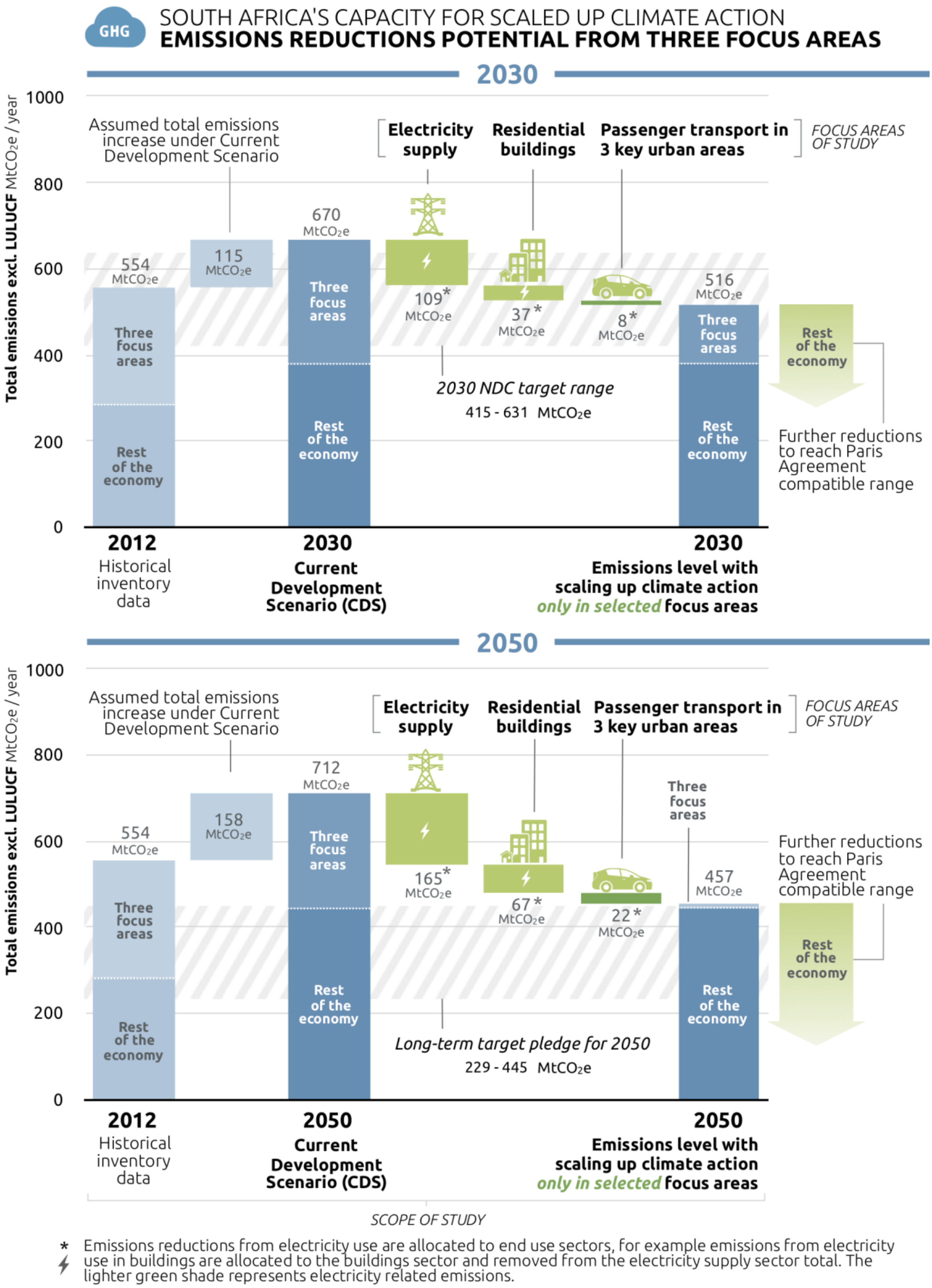


Figure 3: Overview of total emission levels (excl. LULUCF) under historical inventory data in 2012 (left bar), under a current development scenario in 2050 (middle bar), and most ambitious levels of accelerated climate action by 2050 in the electricity supply, the residential buildings sector, and the urban passenger transport in Gauteng, Cape Town and Durban (right bar). All electricity-related emission reductions from the residential buildings and urban transport sectors are allocated as emissions reductions under these two end-use sectors.

These findings emphasise that for South Africa to reach its 2050 targets means it must also undertake more ambitious climate action in sectors other than the three analysed in this study, even more so to achieve an economy-wide decarbonisation by mid-century or shortly thereafter.

The status of sectoral transitions: opportunities for accelerating climate action

Table 1: Summary table for sectoral policy activity and gap analysis in South Africa for electricity supply, transport and buildings sector. 1.5°C compatible benchmarks relate to most important short-term steps for limiting global warming to 1.5°C identified by the Climate Action Tracker (Kuramochi et al., 2018). Percentages in the first column indicate the share of national GHG emissions in 2012, calculated based on the Draft Inventory Report of 2016.

Sector	1.5 °C-consistent benchmark	Overall evaluation based on policy activity and gap analysis	Policy rating
Electricity supply sector (45% of GHG emissions)	Sustain the global average growth of renewables and other zero and low-carbon power until 2025 to reach 100% by 2050	• Projected share of low-carbon electricity generation is 23%–26% by 2030—this deviates from a transition pathway to 100% low-carbon by 2050. • Uncertainty about future capacity extension of renewables and future energy planning with proposed update of Integrated Resource Plan (IRP) of August 2018 still pending • Significant untapped potential for renewable electricity generation and positive cost developments for renewable technologies in South Africa	Getting Started
	No new coal plants, reduce emissions from coal power by at least 30% by 2025	• New coal capacity of 6.35 GW currently under construction with an additional 3.24 GW in the pipeline with no intention of revising their construction in proposed IRP update of August 2018 • Up to 12% reduction in emissions from coal combustion by 2030 compared to 2014 (based on recent forecasts), which is not in line with the world average 1.5°C compatible benchmark of 30% by 2025 • High historical importance of coal in the electricity mix and for socio-economic development, which necessitates a socially just transition	Getting Started
Road transport sector (8% of GHG emissions)	Last fossil fuel car sold before 2035	• Overarching Green Transport Strategy (GTS) defines policy priorities for each area of transport until 2050, but no overarching 1.5°C compatible vision for transport sector • Low projected growth in electric vehicle uptake, similar at best to projections for Rest of World in BNEF 2017 with around 1% EV share in new car sales by 2020 and share of 40–50% by 2040 • Several policies in transport sector aim to reduce emissions from passenger vehicles and freight transport, however, relatively low level of expected impact (e.g. for biofuel quota programme)	Getting Started
Residential buildings sector (4% of GHG emissions)	All new buildings fossil free and near zero energy by 2020	• No expectation of tightening of building efficiency standards to levels beyond those currently implemented until 2050 • Improvements in emissions intensity per m² over last years, but buildings emissions intensity/capita continues to increase • Several positive policy developments (e.g. mandatory labelling for household appliances or to*ols to measure and certify near zero energy buildings), but lack of enforcement of existing regulation*	Getting Started
	Increase building renovation rates from <1% to 5% by 2020	• *No country-specific forecast available, but roughly estimated to be around 1–2% per year* • *Significant barriers for renovation rate uptake such as high upfront costs, high borrowing rates, long payback periods, and restricted access to financial incentives/support for retrofitting* • *Demand for buildings retrofit is still comparatively low given split incentives*	No Action

The transitions towards zero-emissions in the South African electricity supply, urban passenger transport, and residential buildings sectors have all shown slow progress or have barely started. Given the status in the three focus sectors, more accelerated and stringent climate action is required to initiate meaningful sectoral transitions.

Table 1 is an overview of this study's evaluation for the three sectors compared with sector-specific benchmarks. These benchmarks represent the most important short-term steps for limiting global warming to 1.5°C identified by the Climate Action Tracker (Kuramochi et al., 2018). The full results of this analysis for all sectors are detailed in the full report.

Co-benefits of upscaled climate action: employment

Accelerated climate action in South Africa can generate significant socio-economic co-benefits that help promote the national sustainable development agenda. Such co-benefits comprise low and high-skilled employment in low-carbon-oriented sectors, a reduction in adverse health impacts from air pollution, and increased participation and social justice in mobility and housing.

These co-benefits directly enable South Africa to progress towards key national sustainable developments goals (SDG) such as ensuring access to affordable, reliable, sustainable and modern energy for all (SDG 7) or making cities and human settlements inclusive, safe, resilient and sustainable (SDG 11). For example, the study's findings on employment generation in low-carbon-oriented sectors from scaled up climate action in electricity generation (see below) supports South Africa's aim to promote inclusive and sustainable economic growth, full and productive employment, and decent work for all as anchored in SDG 8.

The findings emphasise the employment potential of accelerated climate action in the electricity generation sector, particularly in low-carbon-oriented fields, while at the same time highlighting the need for a "just transition" for those communities affected by diminishing mining jobs by 2030 and beyond. This study's quantification of employment impacts for several electricity supply sector scenarios indicates that changing from a high to a low-carbon electricity supply by 2030 is likely to create as many employment opportunities in South Africa as it would make obsolete.

Under a current development scenario, approximately 106,000 people a year are directly employed in the development of new electricity supply capacity and the operation and maintenance of both existing and new capacity on average over the period between 2016 and 2030. We estimate that these investments would stimulate a further 180,000 indirect and induced jobs on average a year, for example jobs in the production of cement for the concrete foundations of wind turbines.

The estimated employment impact across all other scenarios is of a similar order of magnitude. They range between approximately 100-130,000 direct jobs a year and 275-350,000 jobs when considering the wider indirect and induced impacts of the investments.

Electricity supply sector scenarios with accelerated renewables deployment gradually substitute most coal mining jobs with jobs in manufacturing, and construction of renewables, combined cycle gas and peaking generation capacity. These jobs are in technologies and sectors that are more likely to form the core of future electricity supply, both in South Africa and globally.

Scenarios where renewable capacity is expanded to meet the increase in electricity demand generate equivalent levels of more sustainable employment, such as under the 1.5°C Paris Agreement compatible scenario. Investing today in growing the value chain of low carbon electricity supply technologies will allow South Africa to manage a gradual, just transition away from coal sector employment.

The current development scenario with high coal dependence continues to support significant local employment, particularly in coal mining throughout the period to 2030 (see upper right graph in Figure 4). If South Africa and the world implement the Paris Agreement, jobs in coal mining and fossil fuel-based electricity generation will be reduced everywhere, including in South Africa. The challenge in this context is to develop "just transitioning" frameworks that enable the workforce and dependent communities to affect a sustainable and positive transition to a sustainable economy.

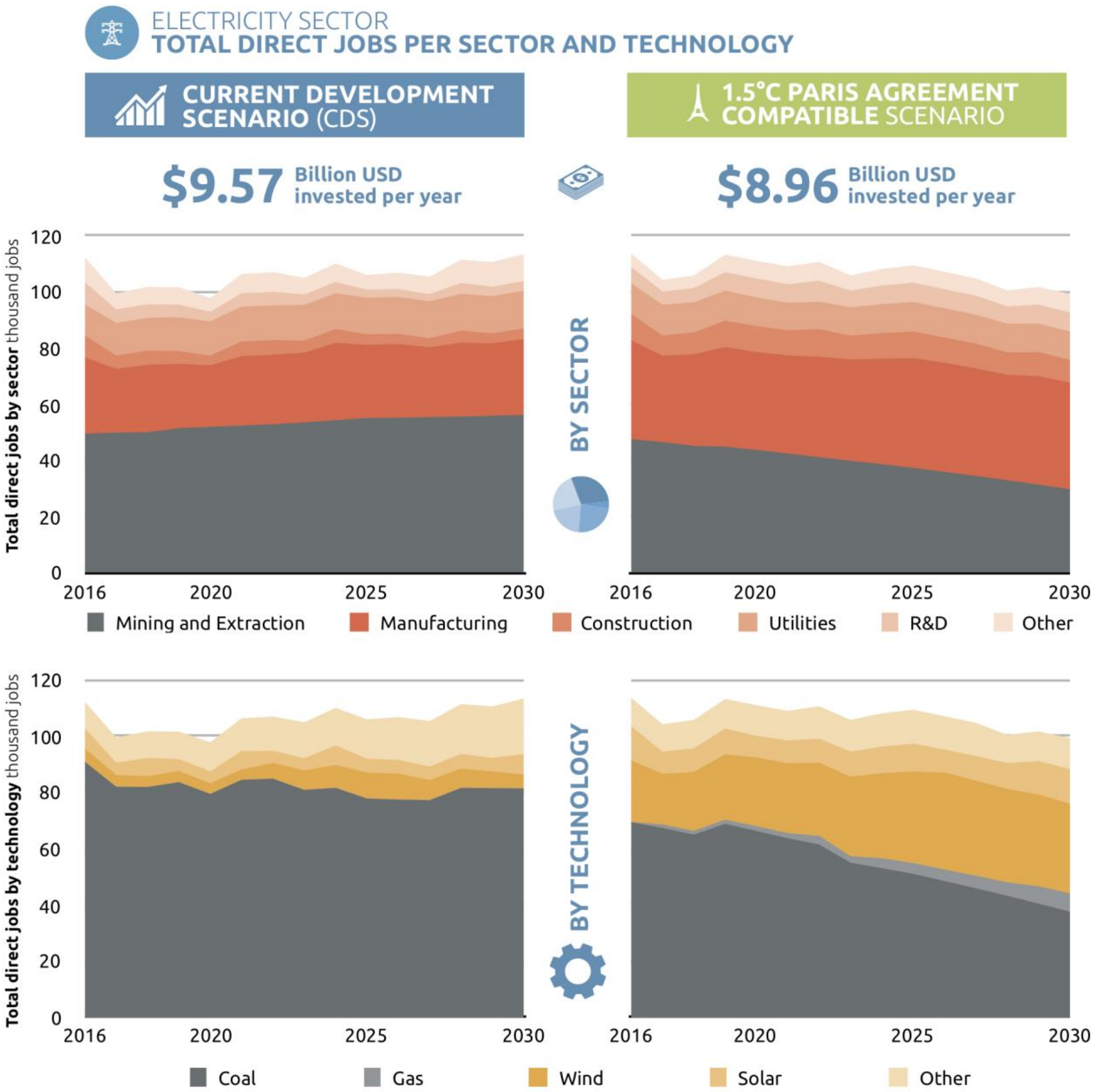


Figure 4: 'Total direct jobs per employment sector' and 'Total direct jobs per generation technology' between 2016-2030 for the Current Development Scenario (CDS) (graphs on left) and the 1.5°C Paris Agreement compatible scenario for the South African electricity supply sector (graphs on right). Direct employment estimates reflect energy supply sector investments linked to planning, construction, the manufacturing of component parts, operation (including fuel supply such as coal mining, where relevant) and maintenance of power plants.

Estimates of direct job creation under different electricity generation scenarios in Figure 4 do not consider overall productivity improvements in the South African (coal) mining sector. Our findings remain conservative in nature as they do not account for 'natural' job loss in coal mining related to such productivity improvements in the current development scenario.

Overall investment under different scenarios critically links to employment generation. Investment requirements per unit of electricity generation is lowest in scenarios with high shares of wind and solar PV through the entire period until 2030 and beyond. Heavily coal-based scenarios such as the current development scenario or the upper bound of the national scenario range are more expensive per unit of output. These differences might critically enable South Africa to promote access to affordable, reliable, sustainable and modern energy for all in the nearby future (SDG 7), especially when considering that these differences might further substantiate beyond 2030.

Abbreviations

BRT systems	Bus rapid transit systems
BUR	Biennial Update Report
CAPEX	Capital expenditure
CDS	Current development scenario
CPP	Current policy projection
ESCO	Energy Service Companies
GHG	Greenhouse Gases
IPP	Independent Power Producer
IRP	Integrated Resource Plan
LCOE	Levelised costs of electricity
LTMS	Long-term mitigation strategy
MBT	Mini-bus taxi
NDC	Nationally Determined Contribution
NPCP-SA	National Cleaner Production Centre South Africa
OPEX	Operational expenditure
PPD	Peak-plateau-decline
REIPPPP	Renewable Energy Independent Power Producer Procurement Programme
RES	Renewable energy share

Contents

Introduction

Background and objectives

Under the Paris Agreement, governments have committed to limiting temperature increase to well below 2°C above pre-industrial levels and pursuing efforts to limit it to 1.5°C. Current efforts are insufficient: aggregate mitigation targets, according to Climate Action Tracker (CAT) estimates, result in global warming of about 3.2°C (Climate Action Tracker, 2017c). Implementation of the targets is falling short, with greenhouse gas (GHG) emissions under implemented policies leading to an estimated warming of around 3.4°C.

To stay below the globally agreed limit, the IPCC Special Report on 1.5°C finds that an increase in efforts is required to peak global GHG emissions as soon as possible, reduce CO_2 emissions to net-zero around 2050 and total GHG emissions shortly thereafter (IPCC, 2018).

In recent years, measures to reduce GHG emissions have, in many cases, become more attractive to policy makers and private investors, both because of falling technology costs, as well as increased awareness for other benefits, such as air quality improvements and employment benefits in low-carbon-oriented sectors.

We no longer live in a world where climate change mitigation is a burden per se, but where it increasingly becomes the most feasible option when considering all socio-economic aspects. For cost-efficient global mitigation, it will be essential to make those mitigation actions accessible to and overcome remaining barriers in all countries.

This report, the first country assessment in the Climate Action Tracker's Scaling Up Climate Action Series, analyses areas where South Africa could accelerate its climate action. The report illustrates GHG emissions reductions from such actions, along with other benefits.

Approach

The analysis starts with an in-depth review of South Africa's current policy framework and sectoral developments, comparing them with the comprehensive policy packages and the progress of the kind of sector indicators required under Paris-compatible pathways.

The report then focuses on three areas we have identified with promising potential to increase mitigation efforts, also considering national and even local circumstances: electricity supply, urban passenger transport, and residential buildings.

For these areas, we research different pathways which go beyond current efforts, explain the feasibility of such increased action, and quantify resulting emission reductions and employment benefits. We consider three types of scenarios: (1) Outputs from national research institutions analysing alternative scenarios to current government projections, (2) Paris-compatible benchmarks from international sources such as the IPCC Special Report on 1.5°C (IPCC, 2018) or the CAT's report on short-term steps (Kuramochi et al., 2018), and (3) Best-in-class levels from regional or global frontrunners (compare (Fekete et al., 2015; Roelfsema et al., 2018).

The external scenarios provide trajectories of sectoral indicators, for example for the share of renewable energy. For the quantification of sectoral and total emission trajectories until 2050, the Scaling Up Climate Action series uses the CAT's PROSPECTS scenario evaluation tool. To estimate domestic employment impacts of different electricity supply sector development, we use a spreadsheet-based economic model developed by NewClimate Institute under the "Ambition to Action" project, the Economic Impact Model for Electricity Supply (EIM-ES).

A methodological annex presenting the tools' methodologies and key assumptions for data filling can be accessed under **climateactiontracker.org/publications/scalingup/methodology**.

1 Context for scaling up climate action in South Africa

While the scientific community is continuously highlighting severe risks related to manmade climate change based on recent academic findings, the translation into actionable policies to effectively combat in South Africa and other countries remains inadequate. Recent research suggests that climate change has multiple adverse effects for the Southern African region, including a significant change in surface temperatures, seasonal rainfall patterns, and vegetation loss (Davis-Reddy & Vincent, 2017). It is likely that the Southern African region will be disproportionally affected, in comparison to expected global consequences.

The IPCC Special Report on 1.5°C has found that limiting warming to 1.5°C will reduce the impacts on vulnerable populations and ecosystems in the South African region, compared to 2°C warming (IPCC, 2018). Furthermore, the report finds that the energy transition required to limit warming to this level will have significant benefits for access to clean and affordable energy, and poverty eradication — both sustainable development goals.

South Africa is one of the few countries that specify an absolute emission reduction target following a peak-plateau-decline (PPD) trajectory range. The Climate Action Tracker rates the higher end of the emissions range for 2025–2030 as "Highly insufficient", with the lower end being "2°C compatible". Implemented policies would bring South Africa close to reaching the higher end of the range by 2030. The "Highly insufficient" rating indicates that South Africa's climate commitment in 2030 is not consistent with holding warming below 2°C, let alone limiting it to 1.5°C as is required under the Paris Agreement. This implies that more ambitious climate policy across all sectors is required. South Africa is one of the 20 largest emitters of greenhouse gasses (GHG) worldwide.

The present research aims to identify potential for scaled-up climate action in the South African electricity supply, residential buildings, and urban passenger transport sectors in Gauteng, Cape Town and Durban. The report illustrates mitigation opportunities in these sectors, with the objective to show policy makers and the public the feasibility and benefits of such actions. The results may also serve as an input to future revisions of Nationally Determined Contributions (NDCs) under the Paris Agreement. While countries prepare for a next round of NDCs, the Talanoa Dialogue in 2018 provides relevant and timely information on the type and scope of climate action required and available on a global level. This independent assessment provides similar information on a country level.

In 2018, South Africa published two pieces of relevant legislation: a draft climate law and the draft IRP update of 2018. Those policies have the potential to initiate a transformation of some sectors towards a low-emission trajectory, provide stringent implementation, and incentivise ambitious future revisions. Further efforts will be necessary to fully decarbonise for a Paris-compatible pathway. South Africa has implemented several overarching climate change policies (see Table 2). Most recently, South Africa has released a draft climate law in June 2018, which had been open for public consultation until August 2018 (Department of Environmental Affairs, 2018). The draft law aims for the establishment of a Ministerial Committee on Climate Change to oversee and coordinate the activities across all sectoral departments. Under the proposed legislation, the Minister of Environment Affairs together with the Ministerial Committee on Climate Change would have to set sectoral emission targets (SETs) for each greenhouse gas emitting sector and in line with the national emission target every five years.

Table 2: Overview of existing and implemented overarching climate change policies in South Africa

<table>
<tr><th colspan="5">OVERARCHING CLIMATE CHANGE POLICIES OF SOUTH AFRICA</th></tr>
<tr><th>Changing activity</th><th>Energy efficiency</th><th>Renewables</th><th>Nuclear or CCS or fuel switch</th><th>Non-energy</th></tr>
<tr><td colspan="5">Climate Strategy
▪ Climate Change Bill (planned)
▪ Climate Change Mitigation System (2015)
▪ National Climate Change Response Policy (NCCRP) (2011)
▪ Vision, Strategic Direction and Framework for Climate Policy (2008)</td></tr>
<tr><td colspan="5">GHG reduction target
▪ Copenhagen Accord Pledge (2010)
▪ Nationally Determined Contribution (NDC) (2016)</td></tr>
<tr><td colspan="5">Coordinating body for climate change
▪ Inter-Ministerial committee on Climate Change (IMCCC) (2009)
▪ Intergovernmental Committee on Climate Change (IGCCC) (2008)
▪ National Committee on Climate Change (NCCC) (n/a)</td></tr>
<tr><td colspan="5">Support for low-emission R&D
(none)</td></tr>
<tr><td></td><td>National energy efficiency target
▪ Post-2015 National Energy Efficiency Strategy (NEES) (planned)
▪ Energy Efficiency Strategy of South Africa (2005)</td><td>National renewable energy target
(none)</td><td></td><td></td></tr>
</table>

No policies currently exist and a similar policy gap exists in all other countries

No policies currently exist however South Africa could adopt policies from other countries

Existing and planned policies for South Africa

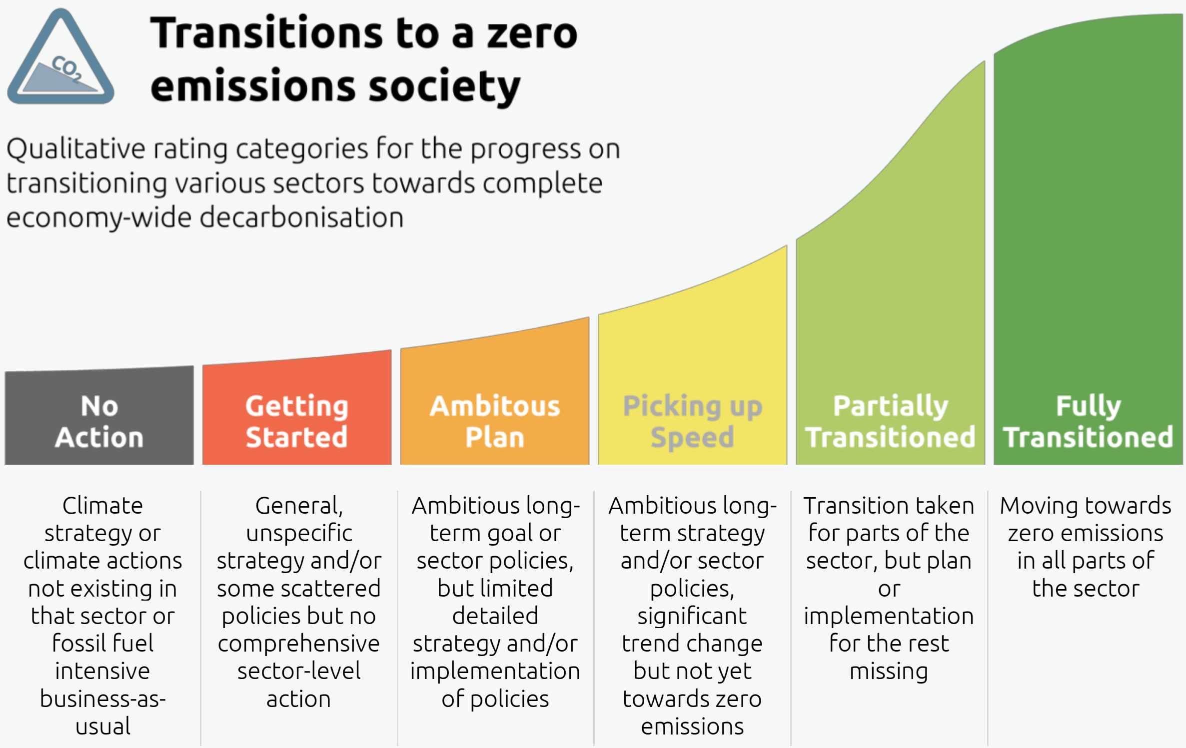
2 Overview of national climate policy actions and gaps

This chapter provides a comprehensive overview of existing and planned climate policies at the national level in South Africa. The first part overviews all existing climate change mitigation policies in South Africa and their implementation status, analysing climate policy activity on a sector-level. The second part identifies gaps of existing policies compared to required policy action for a Paris Agreement compatible pathway. The policy ambition analysis assesses how South Africa's implemented policies compare to the most important short-term steps for limiting global warming to 1.5°C compared to pre-industrial levels that the Climate Action Tracker has identified (Kuramochi et al., 2018). We compare policy progress to actionable benchmarks in each sector and rate it according to a qualitative policy rating (see Box 1 below).

The policy ambition analysis compares historical and projected developments under current policies to the global indicators without any further adjustments of the indicators to country-specific circumstances, such as for example the respective capabilities of countries. The policy ambition analysis mainly provides an indication to which degree current trends in each sector align with required steps on a global level and presents a standardised approach for all countries analysed in the CAT Scaling Up Climate Action series. The in-depth analysis in Section 0 addresses country specific circumstances and considerations for South Africa and specific sectors.

Box 1 Qualitative policy rating for sectoral transition to zero-emissions society

The qualitative analysis of policy activity and ambition of this analysis for South Africa results in a rating of each sector. The rating aims to reflect the sector's current transition state towards 1.5°C Paris Agreement compatibility. For this purpose, the rating accounts for existing sectoral long-term strategies and/or policies, their status of implementation, as well as the general state of transition of the sector under analysis.



Key findings of policy activity and policy ambition analysis

Table 3 summarises the key findings of the policy activity and gap analysis for each of the sectors and the respective sectoral benchmarks. The qualitative rating evaluates the current sectoral status in transitioning to 1.5°C Paris Agreement compatibility.

Table 3: Summary table for sectoral policy activity and gap analysis in South Africa

Sector	1.5 °C-consistent benchmark	Overall evaluation based on policy activity and gap analysis	Policy rating
Electricity and heat sector	Sustain the global average growth of renewables and other zero and low-carbon power until 2025 to reach 100% by 2050	• Projected share of low-carbon electricity generation of 23%–26% by 2030 deviates from a transition pathway to 100% low-carbon power by 2050 • Uncertainty about future capacity extension of renewables and future energy planning with proposed update of Integrated Resource Plan (IRP) of August 2018 still pending • Significant untapped potential for renewable electricity generation and positive cost developments for renewable technologies in South Africa	Getting Started
	No new coal plants, reduce emissions from coal power by at least 30% by 2025	• New coal capacity of 6.35 GW currently under construction with an additional 3.24 GW in the pipeline with no intention of revising construction in proposed IRP update of August 2018 • Up to 12% reduction in emissions from coal combustion by 2030 compared to 2014 (based on recent forecasts), which is significantly higher than the world average 1.5°C compatible benchmark of 30% already by 2025 • High historical importance of coal in the electricity mix and for socio-economic development, which aggravates transition	Getting Started
Transport sector	Last fossil fuel car sold before 2035	• Overarching Green Transport Strategy (GTS) defines policy priorities for each area of transport until 2050, but no overarching 1.5°C compatible vision for transport sector • Low projected growth in electric vehicle uptake, similar at best to projections for Rest of World in BNEF 2017 with around 1% EV share in new car sales by 2020 and 40%-50% by 2040 • Several policies in place in transport sector aim to reduce emissions from passenger vehicles, however, relatively low level of expected impact (e.g. for biofuel quota programme) • Freight transport related emissions expected to increase substantially under currently implemented policies with the growing use of road networks for freight transportation	Getting Started
	Aviation and shipping: Develop and agree on a 1.5°C compatible vision	• Expected increase of international aviation emissions by 75% until 2030 and 289% until 2050 compared to 2016 under currently implemented policies in South Africa • South Africa engages in ICAO's initiatives to reduce emissions (prioritising ATM and infrastructure use), but no intention to participate in ICAO's CORSIA carbon offsetting scheme • There are no strategy or policies on sustainable maritime shipping	Getting Started

Buildings sector	All new buildings fossil free and near zero energy by 2020	• Tightening of building efficiency standards to strict levels beyond those currently implemented is unforeseeable up to 2050 • Improvements in emissions intensity per m² over last years, but buildings emissions intensity per cap continues to increase • Several positive policy developments (e.g. mandatory labelling for household appliances or tools to measure and certify near zero energy buildings), but lack of enforcement of existing regulation	Getting Started
	Increase building renovation rates from <1% to 5% by 2020	• No country-specific forecast available, but roughly estimated to be around 1–2% per year • Significant barriers for renovation rate uptake such as high upfront costs, high borrowing rates, long payback periods, and restricted access to financial incentives/support for retrofitting • Demand for buildings retrofit is still comparatively low given split incentives	No Action
Industry sector	All new installations in emissions-intensive sectors are low-carbon after 2020, maximise material efficiency	• No projections available on emissions intensity, but very low emission reduction impact of implemented voluntary projects • No legally binding efficiency standards and no regulation or financial support for deployment of low carbon technologies • No commercial CCS deployment technologically and financially feasible on a large scale in the nearby future	No Action
LULUCF	Reduce emissions from forestry and other land use to 95% below 2010 by 2030, stop net deforestation by 2025	• No conclusion possible whether benchmark will be met due to high data uncertainty and no projections available • Continuously decreasing forest area through pressure from fuel wood needs, but substantial efforts for afforestation • Forestry sector net-negative in inventory years	Getting Started
Commercial Agriculture	Keep emissions in 2020 at or below current levels, establish and disseminate regional best practice, ramp up research	• Decrease of emissions from commercial agriculture by 2% up to 2020 below 2010 levels and by another 2% up to 2030 • Emission reductions rather induced due to shift of consumer preferences rather than improved practices • Emission intensity as well as meat consumption significantly above world average and no focus on mitigation in the sector	No Action

2.1 Electricity and heating supply sector

The electricity supply sector is the largest source of GHG emissions in South Africa accounting for approximately 45% of total emissions in 2012 (Department of Environmental Affairs, 2016a). Between 2012 and 2015, emissions from electricity generation have further increased by around 9 $MtCO_2e/yr$ (IEA, 2018).

The emissions stem from a predominantly coal-based electricity supply sector. In 2015, coal-based generation accounted for 91.6% of all electricity output. Renewables including hydro only contributed 3.4% and nuclear 4.9% (IEA, 2017a) of the national supply budget. Given this dependence on coal, the electricity emission intensity is high in South Africa, and there is significant mitigation potential in the electricity supply sector. Heat generation plays a negligible role in South Africa; IEA reports no information on heating-related activity and emissions reported (IEA, 2017a). Table 4 summarises South Africa's progress on the most important steps to decarbonise the electricity sector.

Table 4: South Africa's progress on the most important indicators in the electricity and heating supply sector to limit temperature increase to 1.5°C

Sector	1.5 °C-consistent benchmark	Projection(s) under current policies	Gap assessment (qualitative)	Policy rating
Electricity and heat sector	Sustain the global average growth of renewables and other zero and low carbon power until 2025 to reach 100% by 2050	• Projected share of low carbon electricity generation of 23%–26% by 2030, which deviates from a transition pathway to 100% low-carbon by 2050 (world average) • No current policy projections available until 2050	+ High growth rate in installed capacity between 2012-2017 due to successful procurement under REIPPP + First four bidding rounds under REIPPP all significantly oversubscribed and fifth round announced for 2018 + Positive price developments of tendered capacities + *Comprehensive assessment of capacity planning with IRP and regular updates* - *Significant delay in connecting renewable capacity procured under REIPPP to grid* - *High uncertainty about future energy planning with pending adoption of IRP update of 2018* - *Significant untapped potential for renewable power, especially solar power*	Getting Started
	No new coal plants commissioned, reduce emissions from coal power by at least 30% by 2025	• 6.35 GW of coal plants under construction and 3.24 GW in the pipeline either being permitted, pre-permit or announced • Projected emissions by CAT of 221 MtCO2e/yr from coal-based electricity generation by 2030, implying reduction of 12% in emissions from coal combustion compared to 2014	+ IRP update of 2018, if adopted, aims for decommissioning a total of 35 GW (of 42 GW currently operating) of coal generation capacity by 2050, starting with 12 GW by 2030, 16 GW by 2040 and 7 GW by 2050 + Air quality standards (not including CO_2) might have indirect effects on CO_2 emission levels (if strictly applied) • Government explores options for CCS - Ongoing construction of new coal plants in Medupi and Kusile (4.5 GW each) - Capacity procurement programmes for coal, cogeneration and gas capacity (1st procurement round for coal and cogeneration planned for 2020 and 2021) - High historical importance of coal in the electricity mix and for socio-economic development	Getting Started

2.1.1 Actionable benchmarks in electricity and heat sector

The Climate Action Tracker identified two short-term benchmarks for the electricity sector at the global level to limit warming to 1.5°C (Kuramochi et al., 2018):

- Sustain the growth rates of renewables and other zero and low-carbon power until 2025, and reach a 100% share of electricity generation by 2050.
- No new coal capacity to come online as of 2017, emissions from coal combustion need to be reduced by at least 30% by 2025. A more recent CAT publication supports this direction, and suggests reducing the use of coal in electricity by two-thirds between 2020–2030 and phase out coal globally by 2050 (Climate Action Tracker, 2018c). This is in line with the IPCC Special Report on 1.5°C (IPCC, 2018).

The following gap analysis compares historical and projected developments in the South African electricity and heat sector to these global benchmarks. It uses the global benchmarks to allow for comparison between countries in the CAT Scaling Up Series. The in-depth analysis in the following chapters addresses country-specific circumstances.

2.1.2 Recent policy developments

South Africa has implemented several climate policies in the electricity supply sector, most importantly the Integrated Resource Plan (IRP) from 2010, with a draft update published in 2018 (Department of Energy, 2018). In addition, the South African government is currently discussing the implementation of several other policies such as a carbon tax, whose initial implementation had already been planned for 2015 and is currently still envisioned for introduction in 2018 (Department of Treasury, 2017).

Table 5 provides a comprehensive overview of the implemented and planned climate policies in the electricity and heat sector. The paragraphs below the table provide further detail on key policies.

The **Integrated Resource Electricity Plan (IRP) 2010–2030** introduced in 2010 constitutes the government's long-term capacity expansion plan for the electricity sector (Department of Energy, 2011). The IRP 2010-2030 aims to more than triple the installed renewable capacity from to 17.8 GW in 2030, in its 'Base Case' scenario. This entails an additional 8.4 GW added capacity for both wind and solar PV, and an additional 1 GW for concentrated solar power. In addition, the 2010 IRP intents to increase nuclear capacity by an additional 9.6 GW coal capacity by an additional 6.3 GW by 2030.

As part of regular updates mandated in the IRP 2010–2030, the Department of Energy released a proposal for an **IRP update report of 2018** in August 2018 (Department of Energy, 2018). Updating key assumptions such as technology costs and electricity demand forecasts, the IRP update suggests decommissioning 12 GW of coal power by 2030, while still completing coal capacity under construction (5.7 GW) and adding another 1 GW of new coal capacity. The plan also proposes a significant increase in renewables-based generation from wind and solar to a total of 20 GW by 2030 as well as natural gas-based generation capacity of 8.1 GW by 2030. According to this IRP update, South Africa would not pursue further procurement of nuclear power plants. Until formal adoption, it remains unclear whether the government will update its renewable targets based on the draft IRP update.

Table 5: Overview of existing and planned climate change policies in the electricity and heat sector in South Africa

OVERVIEW OF EXISTING, PLANNED AND POTENTIAL CLIMATE CHANGE POLICIES FOR THE ELECTRICITY AND HEAT SECTOR IN SOUTH AFRICA				
Changing Activity	**Energy efficiency**	**Renewables**	**Nuclear or CCS or fuel switch**	**Non-energy**
	Support for highly efficient power plants (none)	**Renewable energy target for electricity sector** ▪ IRP 2018 update (planned) ▪ National Integrated Energy Plan (IEP) (planned) ▪ Integrated Resource Electricity Plan (IRP) 2010–2030 (2010) ▪ Renewable Energy White Paper (2003)	**CCS support scheme** (none)	
	Reduction obligation schemes (none)	**Support scheme for renewables** ▪ Renewable Energy Independent Power Producer Procurement Programme (REIPPPP) (2012) ▪ Integrated National Electrification Programme (2011) ▪ Eskom Solar Water Heating Rebate Programme (2008)		
		Grid infrastructure development ▪ Integrated National Electrification Programme (2011) ▪ Free Basic Alternative Energy Policy (2007)		
		Sustainability standards for biomass use (none)		
Overarching carbon pricing scheme or emissions limit ▪ Carbon tax (planned) ▪ National Greenhouse Gas Emission Reporting Regulations (2017) ▪ Carbon budgets (2015)				
Energy and other taxes (none)				
Fossil fuel subsidies ▪ IPP Procurement Programme for gas-fired power generation capacity (planned) ▪ Coal Baseload IPP Procurement Programme (2016) ▪ Cogeneration IPP Procurement Programme (2012) ▪ Basic electricity allowance for low-income households (2003)				

No policies currently exist and a similar policy gap exists in all other countries | *No policies currently exist however South Africa could adopt policies from other countries* | *Existing and planned policies for South Africa*

Under the **Independent Power Producer (IPP) Procurement Programme**, the Department of Energy, the National Treasury and the Development Bank of Southern Africa manage various procurement programmes for the different electricity generation technologies included in the IRP 2010–2030. Introduced in 2012, the **Renewable Energy Independent Power Producer Procurement Programme (REIPPPP)** procures renewable capacity through open and public bidding rounds. The renewable capacity additions between 2011 and 2016 under this programme accumulate to 14.7 GW (GreenCape, 2017). As of October 2017, 6.4 GW in renewable capacity from 102 IPPs has been procured from Bid Windows 1 to Bid Window 4 and the '1S2 Smalls Programme' (GreenCape, 2017; Independent Power Producers Office, 2017). The government announced a new bidding round to launch in November 2018 with an estimated size of 1.8 GW in renewable energy capacity (Njobeni, 2018; Reuters, 2018).

Apart from large-scale and small-scale renewables, the IPP Procurement Programme includes coal, cogeneration, and gas with a total planned procurement of 6.43 GW. The South African government directly supports the capacity expansion of fossil fuel-based generation capacity through the following procurement programmes:

- The **Coal Baseload IPP Procurement Programme** is designed to procure 2.5 GW coal capacity. In the first procurement round in 2016, the programme procured 0.86 GW to two bidders to begin commercial operations in December 2020 and March 2021 (ESI Africa, 2016; Government of South Africa, 2016b). No information has been released on a second procurement round under the Coal Baseload IPP Procurement Programme as of September 2018.
- A ministerial declaration in 2012 announced the procurement of 0.8 GW of cogeneration capacity under the **Cogeneration IPP Procurement Programme**. In a first procurement round, 11.2 MW of combined heat and power capacity has been procured to one bidder (Department of Energy, 2016a). No information is available on a second procurement round as of September 2018.
- The **IPP Procurement Programme for gas-fired power generation capacity** will be set up to implement the Gas Utilisation Master Plan. The programme is intended to procure 3.13 GW of baseload and/or mid-merit energy generation capacity of gas-fired power generation (Independent Power Producers Office, 2017). No start date for the first procurement phase for the Gas to Power Programme has been announced as of September 2018.

As part of the Climate Change Mitigation System Framework, South Africa introduced **company-level carbon budgets** in 2015 as a mechanism through which South Africa's mitigation commitments could be translated to emissions targets for subsectors and companies (World Bank, 2017). The first phase of carbon budgets from 2016 until 2020 is a voluntary pilot, the subsequent second phase starting in 2021 is mandatory. The South African government has further approved the **National Greenhouse Gas Emission Reporting Regulations** as of April 2017 (Department of Environmental Affairs, 2017a), governing the reporting of emissions emanating from a spectrum of activities related to energy, industrial processes and product use, agriculture, forestry and other land use and waste.

South Africa is planning on introducing a **carbon tax** covering fossil fuel combustion emissions, industrial processes and product use emissions, and fugitive emissions (e.g. fugitive emissions from coal mining). Originally, the 1st of January 2015 was set to be the start date, but since then, it has suffered repeated delays (The Carbon Report, 2015). The Department of Treasury published a Second Draft Carbon Tax Bill for introduction in the South African parliament in December 2017 with formal adoption expected by end of 2018 (Department of Treasury, 2017).

2.1.3 Comparison of recent developments and projections to benchmarks

2.1.3.1 **Actionable indicator #1**: Growth of renewables and other zero and low-carbon power

Considering recent developments and projections under currently implemented policies, South Africa clearly fails to meet the benchmark to sustain growth rates of renewables and other zero and low-carbon power sources until 2025, and to reach a 100% share of electricity generation by 2050. Recent projections of low-carbon electricity generation under implemented policies in South Africa forecast a 23%–26% share of low carbon electricity generation by 2030 (Climate Action Tracker, 2018d; Kuramochi et al., 2017). Assuming implementation of the Draft IRP update 2018, the share would be at 28% (Climate Action Tracker, 2018a). This significantly deviates from a transition pathway to 100% low-carbon by 2050 (see Figure 5). The share of electricity generation from renewables will significantly increase compared to low historical levels of 3% in 2015 to 10%–18.5% by 2030. This growth will be insufficient to bring South Africa on a 1.5°C compatible pathway. It is also highly uncertainty given the current political and institutional setting as explained in more detail below.

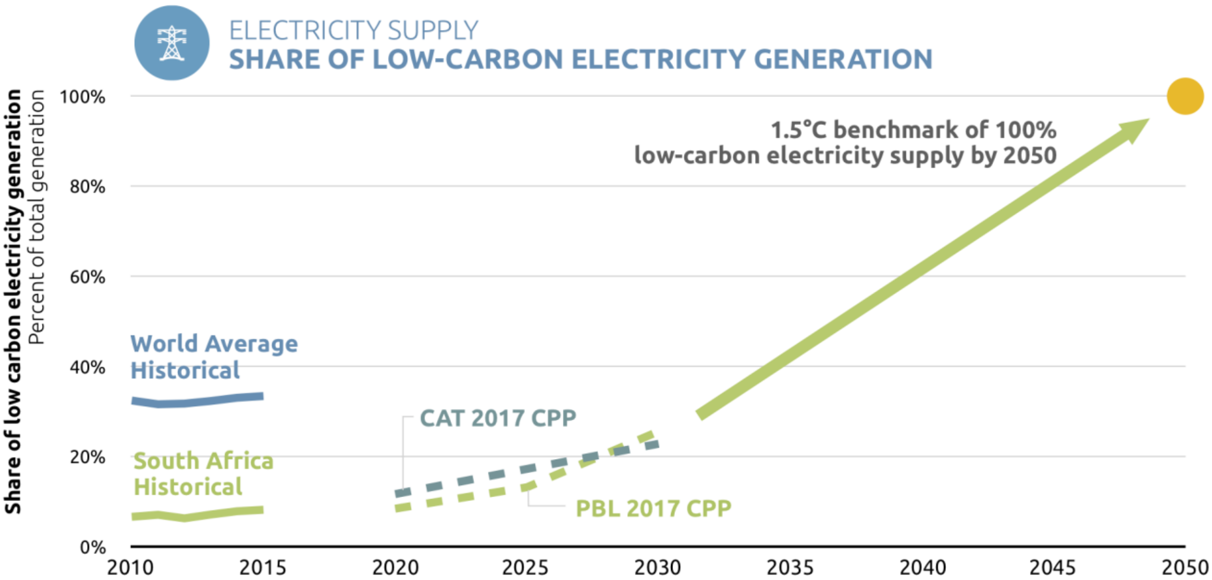


Figure 5: Historic and projected share of low carbon electricity generation in South Africa between 2010-2050 including projections by Climate Action Tracker (2018d) *and PBL Netherlands Environmental Assessment* (2017). *1.5°C Paris Agreement compatible benchmark stems from Figure 3B of the IPCC Special Report on the impacts of global warming of 1.5 °C* (IPCC, 2018).

Growth in renewable electricity generation

The implementation of the IRP 2010 and the REIPPPP successfully initiated the accelerated uptake of renewable-based generation capacity between 2010 and 2017, which increased from 0.8 GW in 2010 to 5.4 GW in 2017 (IRENA, 2018a). The future energy planning and the related support of renewable electricity generation has been facing substantial obstacles over the last two years. Eskom—South Africa's grid operator and its largest utility company, which also owns most of the country's coal-fired power plants—had stalled on signing power purchase agreements, which guarantee grid access for renewable energy projects (Groenewald, 2017). In February 2018, the Department of Public Enterprises finally approved the signing off on power-purchase agreements (PPAs) related to REIPPP bid-windows in terms of the Public Finance Management Act (Deign, 2018). Eskom signed the remaining 27 PPAs of Bid Windows 3.5 and 4 with a total capacity of 2.3 GW in April 2018 (Creamer, 2018). In June 2018,Energy Minister Jeff Radebe announced a new bid round for renewable energy projects to launch in November 2018 with an estimated size of 1.8 GW in renewable energy capacity and a potential investment volume of up to USD 3.95 billion (R 50 billion) (Njobeni, 2018; Reuters, 2018).

Eskom's ongoing financial solvency and managemental issues, the pending adoption of the IRP update of 2018, and pushback from unions and industry still exposes the future of the REIPPP and PPAs to high uncertainty. Recent action under Energy Minister Jeff Radebe to sign outstanding power purchase agreements with renewable energy companies, the announcement of a new bid round for November 2018, and the release of the IRP update of 2018 seem promising. The revised IRP, if adopted, would mark a major shift in energy policy by decommissioning significant amount of old coal generation capacity and significant increase in renewables-based generation from wind and solar as well as gas-based generation capacity by 2030 and beyond, with no further new nuclear capacity being procured. The question remains whether this draft plan will come into force—the last two IRP updates in 2013 and 2016 were never adopted by Joseph Zuma's Cabinet.

Despite these institutional problems, most recent projections on the share of renewable electricity in the total electricity mix in South Africa assume that the share will increase over the upcoming years due to newly connected capacity. The share of renewable electricity generation in total electricity generation including hydro is projected to increase to 6.6% by 2020 and 18.5% by 2030 including hydro (to 5.4% by 2020 and to 17.2% by 2030 respectively excluding hydro) according to the latest current policy scenario projections of the Climate Action Tracker from August 2018.[1] The IRP update of 2018, if adopted, could further increase the projected share to 24% by 2030.

The CAT assessment accounts for the deployment of 8.4 GW of solar PV and wind capacity each and 1.2 GW in solar CSP capacity as outlined in the original IRP 2010–2030 and subsequent ministerial declarations. This implies that under such an optimistic scenario (i.e. assuming full implementation of the IRP 2010-2030), only round one fifth of total electricity supply by 2030 will be supplied by renewables - not accounting for all currently existing institutional and financial problems with regards to the renewables' extension outlined above. Under the proposed IRP update of 2018 installed capacity targets would be revised to 8.0 GW of solar PV, 11.4 GW of wind, and 0.6 GW of CSP (Department of Energy, 2018).

The increase of the share in renewable electricity in total electricity generation under the CAT's current policy scenario by 2030 constitutes a significant improvement in comparison to historical levels. Due to the very low current share of renewable electricity generation in total generation as of 2017, South Africa is about to experience high year-to-year growth rates of over 20% until 2020, while growth rates between 2025 and 2030 are expected to be around 10% year-to-year.

These growth rates are too low to achieve a full decarbonisation of the South African energy sector by mid-century with South Africa remaining significantly behind the world average share of electricity generation for a 1.5°C compatible trajectory. Other recent scenario modelling results from the PBL Netherlands Environmental Assessment Agency and the Facilitating Implementation and Readiness for Mitigation (FIRM) project confirm these findings. Using the integrated assessment model IMAGE, PBL assesses the impact of national current policies on South Africa's emission trajectory, including the full implementation of the IRP 2010–2030 (Kuramochi et al., 2017). PBL projects the share of renewable electricity generation in total electricity generation including hydro to reach 4% by 2020 and 10% by 2030.

Using the SATIM model, FIRM's projection until 2050 find that electricity generation from PV technologies in South Africa will only contribute marginally to total generation by 2050 with around 3%–5% of total generation (FIRM, 2016). The uptake of CSP capacity is subject to substantial uncertainty with a likelihood of only 10% that CSP technologies will contribute to 10% to total electricity generation by 2050. Even as certain renewable energy technologies have not been included in the scenario modelling (e.g. wind), the projected growth in renewable generation is not in line with the full decarbonisation of the power sector as fossil-based electricity generation will remain the dominating form of generation in most scenario projections. Important to mention, domestic climate policies in South Africa have not been considered in the underlying business-as-usual scenario of the FIRM projections, thus the share of renewables might be significantly lower as only market considerations for capacity additions are accounted for.

Growth of other zero and low-carbon technologies

As for the share of other zero and low-carbon technologies in the total electricity mix, an ongoing political discussion concerns the potential deployment of nuclear capacity. Whereas the original IRP 2010–2030 of 2010 intended nuclear capacity additions of 9.6 GW until 2030, the IRP update of 2018 includes no new nuclear capacity procurement. The government under President Cyril Ramaphosa seems to have shifted away from the plan to add new nuclear capacity that was still backed by the previous government under President Jacob Zuma (National Assembly of South Africa, 2017). Given this uncertainty, the nuclear capacity target stated in the 2010 IRP is excluded from the Current Development Scenario in this report.

The large-scale application of CCS to coal power plants as another low-carbon technology is currently not feasible. The CCS Roadmap introduced by the South African Centre for Carbon Capture & Storage (SACCCS) aims for a commercial CCS deployment of over 1 $MtCO_2e$/yr by 2025.

[1] http://climateactiontracker.org/countries/southafrica.html

However, such emission mitigation potential through CCS critically depends on technological progress, cost developments for such technologies, and the results of the CCS demonstration plants in the South African. Even though the South African government reemphasised their intention to explore the application of CSS in November 2017, a larger-scale application might not be feasible in the nearby future and induce significant costs for retrofit and installations of such technologies.

2.1.3.2 **Actionable indicator #2**: Reduce emissions from coal power plants

The proposed IRP update of 2018, if adopted, could mark a start for a transition away from a predominately coal-based electricity generation. The plan released by the Ministry of Energy for public comment until November 2018 aims to decommission a total of 35 GW (of 42 GW currently operating) of coal generation capacity from state-owned Eskom by 2050, starting with 12 GW by 2030, 16 GW by 2040, and a further 7 GW by 2050. The 5.7 GW of coal capacity currently under construction would be completed and another 1 GW of new coal capacity would be commissioned until 2030. This means that if the Draft IRP update was implemented, it would be a significant step in the right direction. Still, some coal-fired power plants would either remain online beyond 2050 and conflict with a Paris compatible pathway or need to retire early and risk becoming stranded assets.

Until formal adoption of the IRP update, high uncertainty remains on the exact planning by the South African government in terms of coal capacity procurement. Without the update, coal generation capacity would grow substantially with no intention to decommission older coal plants before schedule, as per the energy planning by the previous South African government under President Jacob Zuma. Under this scenario, South Africa would be far away from meeting the benchmark of no additional coal capacity beyond the current stock, nor a reduction by at least 30% emissions from coal combustion by 2025.

Recent analysis suggests that additional coal power plants currently under construction or additionally procured in the future will be significantly more costly than zero-carbon alternatives (Ireland & Burton, 2018; Paton, 2018). As of July 2018, 6.35 GW of coal plants were under construction in South Africa, with a further 3.24 GW in the pipeline either being permitted, in the pre-permit development phase or announced (CoalSwarm, 2018). The coal capacity currently under construction mainly comprises the Medupi and Kusile power plants with a planned capacity of 4.8 GW each (Eskom, 2017b, 2017a), some of which has already come online. Recent analysis and statements by governmental official indicates that Eskom runs an significant overcapacity of electricity generation of around 4 GW to 5 GW (Steyn, Burton, & Steenkamp, 2017), which might become even bigger as soon as the Kusile and the Medupi power plants will fully go online. The delays in construction of new power plants as well as the costly overcapacity represents a high financial burden to Eskom, which has led to a significant increase in electricity prices.

The share of coal electricity generation in total electricity generation is projected to decrease to 74% by 2030 according to the latest current policy projections of the Climate Action Tracker from August 2018.[2] Total emissions from coal combustion are projected to decrease by 12% from 252 $MtCO_2e$/yr in 2014 to 221 $MtCO_2e$/yr in 2030. As explained in the previous section, this scenario assumes the full deployment of solar PV, CSP and wind capacities as outlined in the Integrated Resource Electricity Plan (IRP) 2010–2030 and therefore represents a rather optimistic scenario as it does not account for potential grid connection delays of new renewable capacity due to existing institutional problems with the REIPPPP. The IRP update of 2018, if adopted, could further decrease the projected share by 2030 and total emissions from coal combustion for electricity generation.

Like the projected trends of the share in renewable electricity generation, other recent scenario modelling results from the PBL Netherlands Environmental Assessment Agency and the

[2] http://climateactiontracker.org/countries/southafrica/2017.html

Facilitating Implementation and Readiness for Mitigation (FIRM)[3] project are in line with these findings. Assessing the impact of national current policies, including the full implementation of the original IRP 2010–2030, PBL's projections show that the share of coal generation in total electricity generation will decline to 82% by 2020 and 71% by 2030 (Kuramochi et al., 2017). The median trajectory projections for coal in the FIRM study predicts that coal contributes 70% of South Africa's total electricity generation (FIRM, 2016). There is a one-in-10 chance that coal-based generation will account for less than 25%, however, this is mainly due to a simultaneous strong increase in gas-based electricity generation.

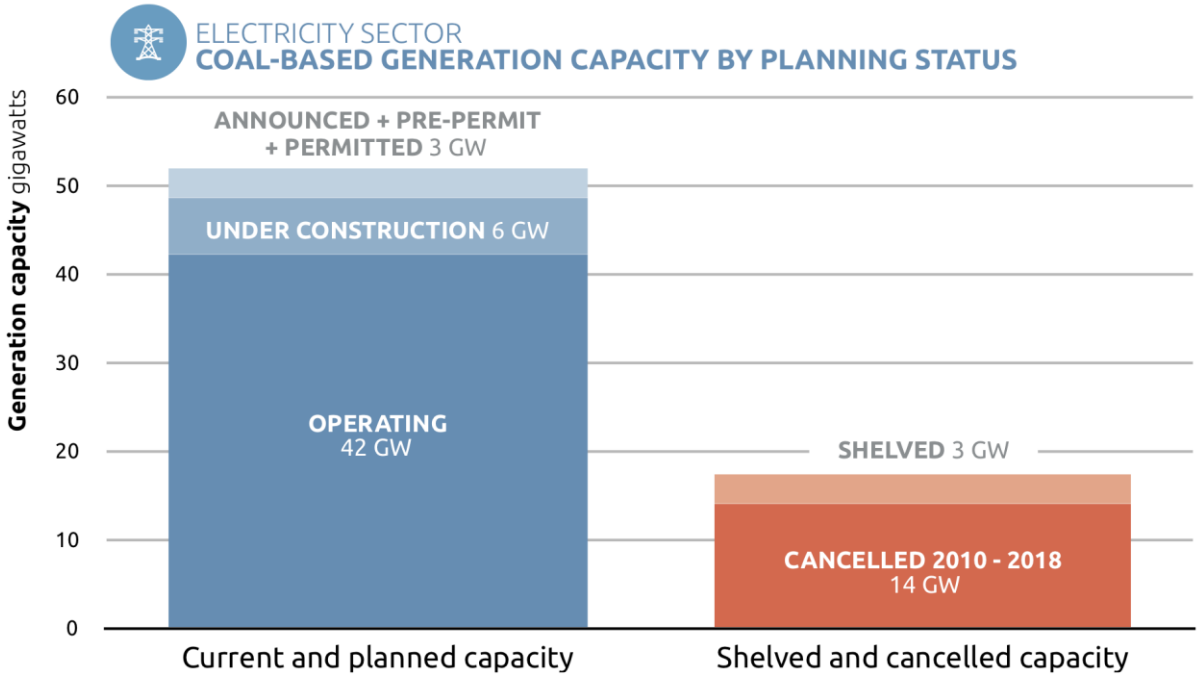


Figure 6: Coal-based electricity capacity in South Africa as of July 2018 (CoalSwarm, 2018)

Due to the absence of CO_2 emission standards, the emission efficiency levels of coal plants currently operational in South Africa is mainly driven by potential indirect effects of plant retrofits to comply with the Minimum Emission Standards (MES) for other air pollutants (Government of South Africa, 2012), advances of technologies applied in newly commissioned plants, as well as the potential application of CCS technology in the future. The retrofitting of coal power plants under operation, under construction, or planned with CCS technology is currently not technologically and financially feasible on a large-scale in South Africa as outlined in Section 2.1.3.1. Any future CO_2 mitigation from coal combustion critically depends on technological progress, cost developments for such technologies, and the outcomes of the CCS demonstration plants.

Given the pending adoption of the IRP update of 2018, it remains uncertain how exactly the Government of South Africa will pursue the decommissioning of old coal power plants. Eskom has developed a complete schedule of air quality retrofits and decommissions (assuming a 50-year life decommissioning of units) for all other Eskom plants. However, Eskom has requested MES exemptions for 16 of its plants as well as the coal-based electricity plant Medupi currently under construction. Further exemptions are expected to be granted before the April 2020 deadline for existing plants to meet the regular MES (Strydom, 2017). Given Eskom's current financial obstacles and overcapacities it remains to be seen whether this planning of retrofits and decommission can be maintained or will require revision. Unless older coal plants will be decommissioned at earlier dates than scheduled as of today, no significant improvement on total CO_2 emission level can be expected for South Africa over the upcoming decades.

With an accelerated speed of coal phase-out proposed in the IRP update of 2018 and low growth rates of renewables, the South African government currently considers gas capacity

[3] http://www.lowcarbondev-support.org/participating-countries

as an important gap-filling electricity generation capacity. The IRP 2010–2030 initially planned for the instalment of an additional 6.3 GW in gas capacity under the Base Case by 2030 compared to 2010 (Department of Energy, 2011). The proposed IRP update of 2018 intents to increase installed gas capacity deployment to a total of 8.1 GW by 2030 (Department of Energy, 2018). In this context, the South African government currently develops a Gas Utilisation Master Plan (GUMP) as a roadmap for the development of a gas economy.

The IPP Procurement Programme for gas-fired power generation capacity will procure gas capacity to implement the Gas Utilisation Master Plan. The programme is currently intended to procure 3.13 GW of baseload and/or mid-merit energy generation capacity of gas-fired power generation (Independent Power Producers Office, 2017). Gas capacity to be procured might be drastically revised upward if the IRP update of 2018 is to be adopted. The large-scale deployment of gas capacity might reduce the emission intensity of South African electricity generation in comparison to coal-based generation. However, the significant expansion of gas capacity might induce an emission lock-in not compatible with the full decarbonisation required for a 1.5°C compatible trajectory (Climate Action Tracker, 2017b).

2.1.4 Conclusion

The IRP update of 2018, if adopted, presents an opportunity to initiate a sector transition away from coal and towards renewables-based electricity generation. The deployment of renewable energy has been facing significant hurdles over the last two years due to institutional problems to implement the REIPPPP linked to the state-owned utility Eskom as well as high uncertainty about the energy planning and the revision of the Integrated Resource Plan (IRP) by the Ministry of Energy. Current policy projections indicate that the share of low-carbon electricity generation will reach between 23%–26% by 2030, which deviates from a transition pathway to 100% low-carbon by 2050 (Climate Action Tracker, 2018d; Kuramochi et al., 2017). If the IRP update of 2018 is adopted, this increases to 28%. High uncertainty around this policy update remains given historical pushback by unions and industry as well as Eskom's financial and managemental struggles.

The new Minister of Energy Jeff Radebe has taken some promising steps to support renewable energy. It seems unlikely that the growth of these technologies will be sustained over the upcoming decades to be in line with required growth of renewable energy. South Africa had successfully initiated and accelerated the deployment of renewable energy capacity since 2012 with the introduction of the REIPPPP procurement program. After almost two years of stalling, the Department of Energy and Eskom finally signed power purchase agreements with renewable energy companies. The Ministry of Energy has announced that a new bid round for renewable energy projects will open in November 2018. The use of CCS technology in coal-based generation is currently not feasible in South Africa due to financial and technological barriers.

Given recent developments and current capacity planning, South Africa will likely not achieve a phase-out of coal-related emissions by mid-century but would start a transition away from coal if the IRP update of 2018 was adopted. About 6 GW of coal-fired capacity are under development, and additional coal and cogeneration capacity is planned. The share of coal-based electricity generation reaches 71%–74% by 2030 under the optimistic scenario of full implementation of the renewable energy targets of the IRP 2010–2030 (Climate Action Tracker, 2018d). The phase-out of coal-fired power plants will crucially depend on the adoption of the IRP update of 2018 and subsequent decommission of coal capacity beyond 2030. Additional uncertainty remains about plans to extend gas generation capacity.

Besides energy planning and supply security considerations, the socio-economic aspects of coal mining and access to electricity play an important role in the public debate. The political task to reconciling the needs (1) to eradicate (energy) poverty and provide clean and affordable power, (2) to provide reliable employment opportunities during the recent economic crisis, (3) to manage a "just transition" for all communities affected by a potential coal phase-out, and (4) to protect the South African eco-system services and natural resources, remains a challenge that needs to be integrally considered in any discussion about phasing-out coal (Sartor, 2017).

2.2 Transport sector

The transport sector carries significant importance for economic and social development in South Africa (Department of Transport, 2017b). The sector accounted for roughly 9% of total emissions in 2012 (Department of Environmental Affairs, 2016a). Emissions from road transport account for more than 90% of all transport related emissions. Between 2000 and 2012, total road transport-related emissions increased by around 30% from 33 $MtCO_2e$/yr in 2000 to 44 $MtCO_2e$/yr in 2012 (Department of Environmental Affairs, 2016a). With additional growth expected in public and commercial road transport demand, emissions will further increase over the next decades, unless policy makers provide alternatives to emission-intensive transportation. South Africa faces the needs to modernise and expand its transport infrastructure while simultaneously significantly reduce transport-related emissions. Table 4 summarises South Africa's progress on most important steps to decarbonise the transport sector.

Table 6: South Africa's progress on the most important steps in the transport sector to limit temperature increase to 1.5°C

Sector	1.5 °C-consistent benchmark	Projection(s) under current policies	Gap assessment (qualitative)	Policy rating
Transport sector	Last fossil fuel car sold before 2035	• Low projected growth in electric vehicle uptake, similar at best to projections for Rest of World in BNEF 2017 with around 1% EV share in new car sales by 2020 and share of 40%–50% by 2040 (BNEF, 2017)	+ Overarching Green Transport Strategy (GTS) until 2050 defining policy priorities for each area of transport in South Africa + Several policies in place in transport sector aim to reduce emissions from passenger vehicles, however, relatively low level of expected impact - No overarching 1.5°C compatible vision for transport sector in South Africa - Uncertainty about enforcement of biofuel quota programme due to sustainability concerns, but only marginal impact if fully implemented - Insignificant share of electric vehicles sales and no policies in place to promote and incentivise the use of EVs - Freight transport related emissions expected to increase substantially under currently policies with the growing use of road networks for freight transportation	
	Aviation and shipping: Develop and agree on a 1.5°C compatible vision	• Expected increase of international aviation emissions by 75% until 2030 and 289% until 2050 compared to 2016 under currently implemented policies in South Africa • No projections available for maritime shipping in South Africa	+ Department of Transports actively engages in ICAO's initiatives to reduce emissions, while currently prioritising Improved Air Traffic Management (ATM) and infrastructure use for South Africa - No intention announced to participate in ICAO's CORSIA carbon offsetting and reduction scheme - Relatively small emission reductions of currently implemented measures in aviation sector, whereas other measures for use of alternative fuels and airport improvements are only in early planning stage - There are no strategy or policies on greener or sustainable maritime shipping in South Africa - Inadequate policy initiative to improve rail freight transport to enable modal shift in freight transport sector	

2.2.1 Actionable benchmarks in transport sector

The Climate Action Tracker identified two short-term actionable benchmarks for the transport sector to limit warming to 1.5°C at a global level (Kuramochi et al., 2018):

- The last fossil car needs to be sold before 2035 to achieve car fleets consisting of 100% zero-emission cars by 2050.
- A 1.5°C compatible vision for the aviation and shipping needs to be developed and agreed upon.

With the findings from the IPCC report on achieving net-zero CO_2 emissions around 2050 and the rapid update electric vehicles of the last years in mind, this analysis decides to strengthen the benchmark for the vehicle sales to a fully 100% zero-emissions car stock by 2050, meaning the last fossil car needs to be sold before 2035.

The following gap analysis compares historical and projected developments in the South African transport sector to these global benchmarks without any further adjustment to allow for comparison between countries under analysis. Country specific circumstances will be addressed in the in-depth analysis on scaling up climate action in the following chapters. Please refer to Kuramochi et al. (2018) for more detailed explanation on each indicator.

Additionally, the freight transport needs to decarbonise: Freight trucks need to be almost fully decarbonised by around 2050 (Climate Action Tracker, 2018c).

2.2.2 Recent policy developments

South Africa has implemented several climate strategies and policies in the transport sector, which have been implemented to a variable degree. Table 7 provides a comprehensive overview of the currently implemented and planned sectoral climate policies.

Table 7: Overview of existing and planned climate change policies in the transport sector in South Africa

OVERVIEW OF EXISTING, PLANNED AND POTENTIAL CLIMATE CHANGE POLICIES FOR THE TRANSPORT SECTOR IN SOUTH AFRICA				
Changing Activity	**Energy efficiency**	**Renewables**	**Nuclear or CCS or fuel switch**	**Non-energy**
Urban planning and infrastructure investment to minimise transport needs ▪ Draft Green Transport Strategy (GTS) 2017–2050 (2017) ▪ National Rail Policy Green Paper (2015) ▪ National Transport Master Plan (2010) ▪ Public Transport Strategy (2007)	**Minimum energy/emissions performance standards or support for energy efficient for light duty vehicles** ▪ Vehicle labelling scheme (2008) ▪ Vehicle fuel economy norms and standards (since 2005)	**Biofuel target** ▪ Regulations Regarding the Mandatory Blending of Bio-fuels with Petrol and Diesel (2012) ▪ Biofuels Industrial Strategy (2007)	**Support for modal share switch** ▪ Draft Green Transport Strategy 2017–2050 (2017) ▪ National Transport Master Plan (2010) ▪ Bus Rapid Transit Systems (BRT) on city-level (since 2010)	
	Minimum energy/emissions performance standards or support for energy efficient for heavy duty vehicles (none)	**Support schemes for biofuels** ▪ Regulations on Mandatory Blending of Bio-fuels with Petrol and Diesel (2012) ▪ Biofuels Industrial Strategy (2007)	**E-mobility programme** ▪ Electric Vehicle Industry Roadmap (2013)	
		Sustainability standards for biomass use (none)		
Tax on fuel and/or emissions ▪ Carbon Emissions Motor Vehicles Tax (2010) ▪ General Fuel Levy (1983)				
Fossil fuel subsidies (none)				

No policies currently exist and a similar policy gap exists in all other countries

No policies currently exist however South Africa could adopt policies from other countries

Existing and planned policies for South Africa

In August 2017, the Ministry of Transportation released a Draft **Green Transport Strategy (GTS) 2017–2050** (Department of Transport, 2017b). Without specifying a specific emission reduction target, the draft strategy aims to promote sustainable and cleaner mobility development, to initiate the low carbon transition of the sector, and to facilitate the sector's just transition. For this purpose, the GTS 2017–2050 summarises existing policies and initiatives and adopts key recommendation for different implementation themes. While the prioritised policy interventions aim to address South Africa's transport needs and to directly combat emissions in the transport sector, efficient implementation of proposed measures and sufficient funding remain critical challenges (Department of Transport, 2017b).

The **Biofuels Industrial Strategy** introduced in 2007 and the **Regulations Regarding the Mandatory Blending of Bio-fuels with Petrol and Diesel** of 2012 under the Petroleum

Products Act mandate a biofuel blending of 2%–10% for bio-ethanol and minimum 5% for biodiesel from 2015 onwards (Department of Energy, 2007, 2012). Even though this policy has been legally put into force, it has not been enforced as of July 2017, mainly due to concerns over the impact of large-scale biofuels production on food security and the biofuels financial support or subsidy mechanisms (Fundira & Henley, 2017).

Since 2005, South Africa introduced **vehicle fuel economy norms and standards** for newly manufactured passenger and commercial vehicles (Rayner, 2012; Vosper & Mercure, 2016). A **vehicle labelling scheme** was simultaneously mandated in 2008 to align with these emissions standards. Under the Draft GTS 2017–2050, the Ministry of Transport currently states its intention to revise the level of vehicle fuel economy standards (Department of Transport, 2017b). Introduced in 2010, a **carbon emissions motor vehicles tax** further imposes an environmental levy on passenger vehicles with emission levels above certain thresholds (SARS, 2017), thus constituting an ad valorem taxation system. Apart from fuel economy standards, labelling requirements and vehicle emissions taxation, South Africa prohibits the import of used vehicles, opposite to most Sub-Saharan African countries.

South Africa's **Electric Vehicle Industry Roadmap** introduced by the Department of Trade and Industry in 2013 aims to introduce electric vehicles as part of South Africa's road transport mix, especially by the establishment of incentives for the local manufacture of electric vehicles and possible tax incentives for consumers. Under the road map's terms, manufacturers would need to produce at least 5,000 electric vehicles to qualify for consideration for the incentive with the government reimbursing them for 35% of their production costs over three years (The South African, 2013). However, such incentives have not been introduced as of November 2017. In addition, an import and ad valorem tax of 41% for imported electric vehicles makes the purchase of such vehicles in South Africa financially unattractive (Snyman, 2017).

A switch in modal share of passenger transport has mainly be initiated by **Bus Rapid Transit Systems (BRT)** that have commenced operation or are currently under consideration in public transportation planning in several South African urban areas (Department of Transport, 2017a). Initiatives to implement and expand BRT systems are currently taking place in eight cities and municipalities. Other model switch policy initiatives mentioned in the Draft GTS 2017-2050 aim to upgrade mini-bus taxi industry, intelligent urban transport systems integrating public transport and the minibus industry, and non-motorized transport infrastructure (Department of Transport, 2017b). No information is available on how such initiatives are currently addressed or already operationalised in urban planning.

No modal shift policies have been implemented for the freight transport as of December 2017. The policy objective behind the **National Rail Policy Green Paper** of 2015 is to proactively facilitate shifting freight and passengers from road to rail and to promote rail as the mode of choice by providing an efficient, reliable and safe setting for passengers and freight (Department of Transport, 2015). However, no concrete policy action currently takes place.

2.2.3 Comparison of recent developments and projections to benchmarks

2.2.3.1 **Actionable indicator No.3:** Last fossil fuel car sold before 2035–2050

The rapid introduction of zero-emissions vehicles is key to decarbonise the transport sector with the last fossil fuel car being sold between 2035 and 2050, assuming an average life time of 15 years. **In South Africa, there is no coherent policy framework that addresses these challenges in the transport sector – neither from a travel demand nor technology supply side perspective.** The Draft GTS 2017–2050 represents a first approach by the Ministry of Transportation to define key priorities until 2050 to reduce transport-related emissions while at the meantime addressing South Africa's needs for an improved transportation system to meet their sustainable development goals (Department of Transport, 2017b).

The Draft GTS 2017–2050 defines key recommendations for each area of transportation in South Africa, which are partially based on currently implemented or planned policies but does not define a comprehensive 1.5°C compatible vision for the South African transport sector. Forecasts suggest that emission levels might increase to almost 140 $MtCO_2e$/yr until 2050 under currently implemented polices (Figure 7). Passenger and commercial road transport is responsible for the highest share of CO_2 emissions in the South African transport sector, accounting for roughly 90% of total transport-related emissions (Department of Environmental Affairs South Africa, 2014). The demand of passenger and freight road transport is expected to further increase in South Africa beyond 2018 (Department of Transport, 2017b).

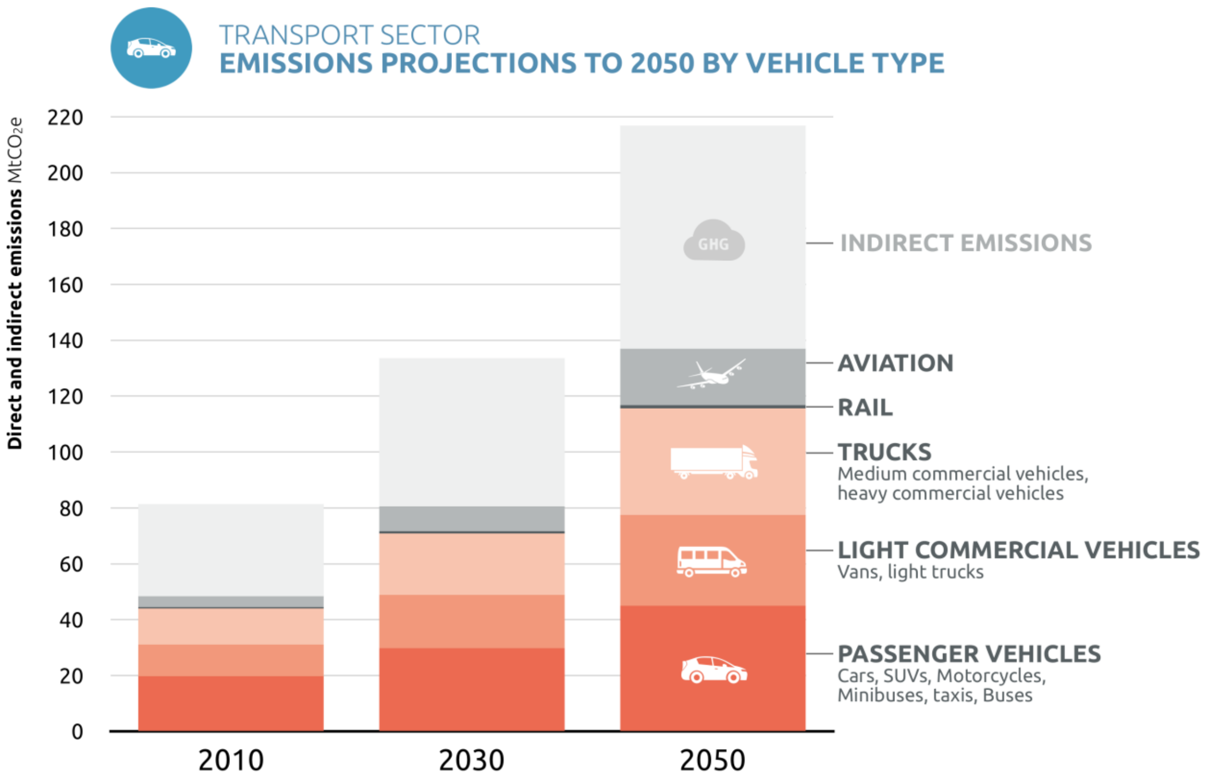


Figure 7: GHG emissions projections for the South African transport sector by mode of transport between 2000 and 2050 taking into account existing and currently planned policies (Department of Transport, 2017b).

South Africa introduced vehicle fuel-economy norms and standards for newly manufactured passenger and commercial vehicles from 2005 onwards (Rayner, 2012; Vosper & Mercure, 2016). Under the Draft GTS 2017–2050, the Ministry of Transport currently states its intention to revise the level of vehicle fuel economy emission standards with unclear implications for transport-related CO_2 emissions (Department of Transport, 2017b). However, a gradual tightening of general emission standards will not be sufficient to be in line with required 1.5°C trajectory (Climate Action Tracker, 2016c; Sterl et al., 2016).

Even if South Africa introduced higher carbon emissions motor vehicle tax levels, such improvements would not be enough to curve emissions downwards until 2050 in line with a 1.5°C trajectory. The carbon emissions motor vehicles tax further induces the payment of an environmental levy for passenger vehicles with emission efficiency below certain thresholds (SARS, 2017). Since its latest revision in April 2016, the tax rate for passenger cars is set at R100 (~USD 7) for every g/km above the CO_2 emissions threshold of 120 g/km, while the tax rate for double cabs remains at R100 for every g/km above the CO_2 emissions threshold of 175g/km. Passenger cars and double cabs that cannot provide certified CO_2 vehicle emissions data will be subject to a tax based on a proxy CO_2 emission calculation, largely based on engine size. The proxy tax includes a significant penalty provision.

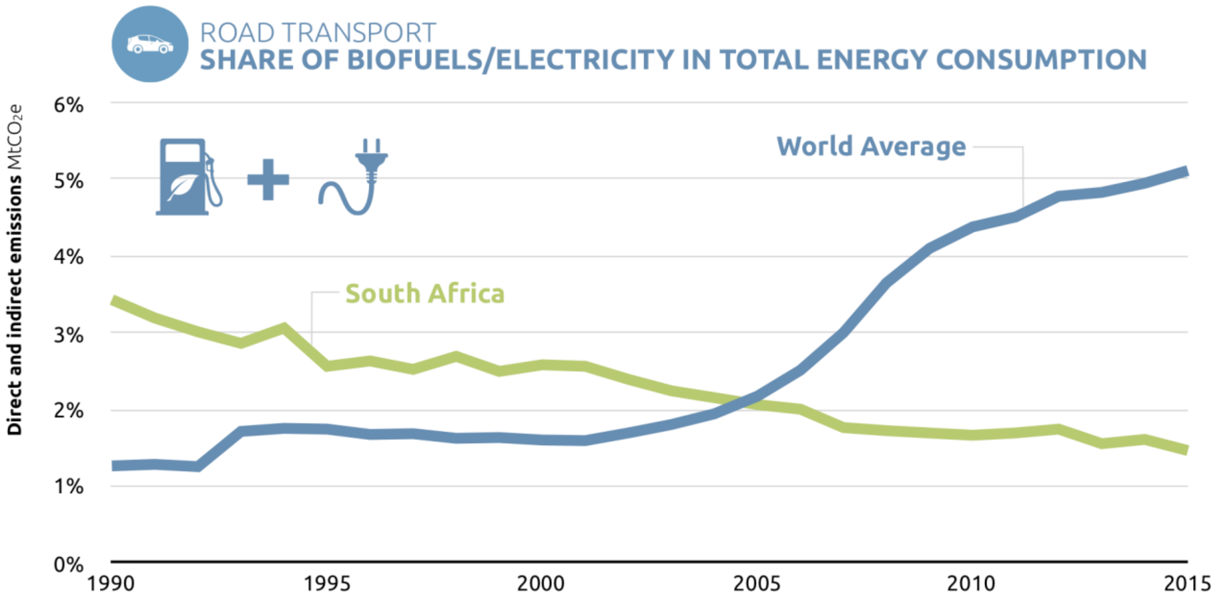


Figure 8: Share of biofuels and electricity in the total energy consumption in the transport sector (road and rail) in South Africa between 1990 and 2015 (Climate Action Tracker, 2017a).

As shown in Figure 8, the share of biofuels and electricity in the total energy consumption in the transport sector is below 2% in 2014, including both road and rail transport. The use of biofuels has only a very limited scope in South Africa. The mandated biofuel blending of 2%–10% for bio-ethanol and minimum 5% for biodiesel has not been enforced as of December 2017, even as this policy on the mandatory blending of biofuels has been legally put into force. This is mainly due to concerns over the impact of large-scale biofuels production on food security and the biofuels financial support or subsidy mechanisms (Fundira & Henley, 2017). Due to the lack of enforcement, the mandatory blending of biofuels has not been included in the current policy projections of the Climate Action Tracker. [4] If the policy targets are met, this would lower emissions only by up to 2.0 $MtCO_2e$/yr by 2020 and 2.6 $MtCO_2e$/yr by 2030.

As for electric vehicles, the total number of such vehicles sold in South Africa remains marginal with only 170 registered vehicles in South Africa in 2015 and an increase to about 500 in 2017 (IEA, 2016b; Snyman, 2017). The government has not yet introduced the manufacturing incentives envisioned in South Africa's Electric Vehicle Industry Roadmap to support local industrial development as of October 2018. Only a limited number of South African entrepreneurs have moved ahead with electric mobility innovations such as three-wheel, two-seater commuter car with an 80 km range, and a light electric utility vehicle (Snyman, 2017). The import and ad valorem tax for imported electric vehicles of 41% makes electric vehicles financially unattractive (Snyman, 2017).

Currently there are no incentives in place to stimulate an increased update of electric vehicles and promote the development of electrical charging infrastructure. Therefore, the share of electric vehicles in new car sales might at best reach projected levels for the 'Rest of the World' forecasts in BNEF's Electric Vehicles Outlook 2017 with around 1% EV share in new car sales by 2020 and share of 40%–50% by 2040 (BNEF, 2017). The absence of policy incentives combined with the projected low share of electric vehicles in South Africa's vehicle fleet means that it is likely that fossil fuelled cars will still be sold in South Africa after 2035–2050, making South Africa's road transport sector incompatible with a 1.5°C pathway.

[4] http://climateactiontracker.org/countries/southafrica/2017.html

Freight transport

Freight transport related emissions are expected to increase substantially under currently implemented policies with the growing use of road networks for freight transportation (see Figure 7 in Chapter 2.2.3.1). Road freight transport accounted for around 86% of the total land-based freight transport in 2015 with only 13% transported by rail (Department of Transport, 2017b). This trend is amplified due to growth in economic production in the Southern African Development Community (SADC) for which South Africa provides important transit corridors to enable shipping via South African ports. The National Rail Policy Green Paper highlights the need to modernise and expand South Africa rail transport system to shift modes of freight transport from road to rail (Department of Transport, 2015), also in context to further expand certain industry and mining activities requiring reliable freight transportation.

The Draft GTS 2017–2050 lists several key recommendations and policy initiatives to initiate a model shift in the freight transport sector, such as the potential introduction of road freight permits and several incentives to use rail modes of transportation (Department of Transport, 2017b). High uncertainty remains whether and to which degree this intended model shift in freight transport and required infrastructure improvements can be realised in due time. Currently implemented policies and incentives clearly fall short to initiate the required decarbonisation of the freight transport sector by mid-century (Climate Action Tracker, 2018e). Stringent policy strategies for decarbonising freight vehicles and to incentivise modal shift would be required to achieve this goal, none of which are currently under implementation in South Africa.

2.2.3.2 **Actionable indicator No.4:** Develop a 1.5°C compatible vision in aviation and shipping

Aviation

There is no strategy in the South African aviation sector fostering a 1.5° compatible development while South African passenger demand for air travel is expected to continue to growth over the upcoming decade in line with the global trends (Department of Transport, 2017b). Emissions from domestic aviation have almost doubled between 2010 and 2015 in South Africa, even as total emissions from domestic aviation still only account for less than 8% of total transport GHG emissions. This share might significantly increase with the expected growth in air travel demand in South Africa. In its State Action Plan submitted to ICAO, the Department of Transport decided to focus on *Improved Air Traffic Management (ATM) and infrastructure use* to reduce emissions from aviation as an immediate priority to reduce emissions in the aviation sector (Department of Transport, 2016).

The Department of Transport expects that these currently implemented ATM improvement measures will result in only small emission reductions (Figure 9). Under implemented policies, international aviation emissions might increase by 75% until 2030 and 289% until 2050 compared to 2016 levels. Other action fields under long-term consideration are the use of alternative fuels and airport improvements.

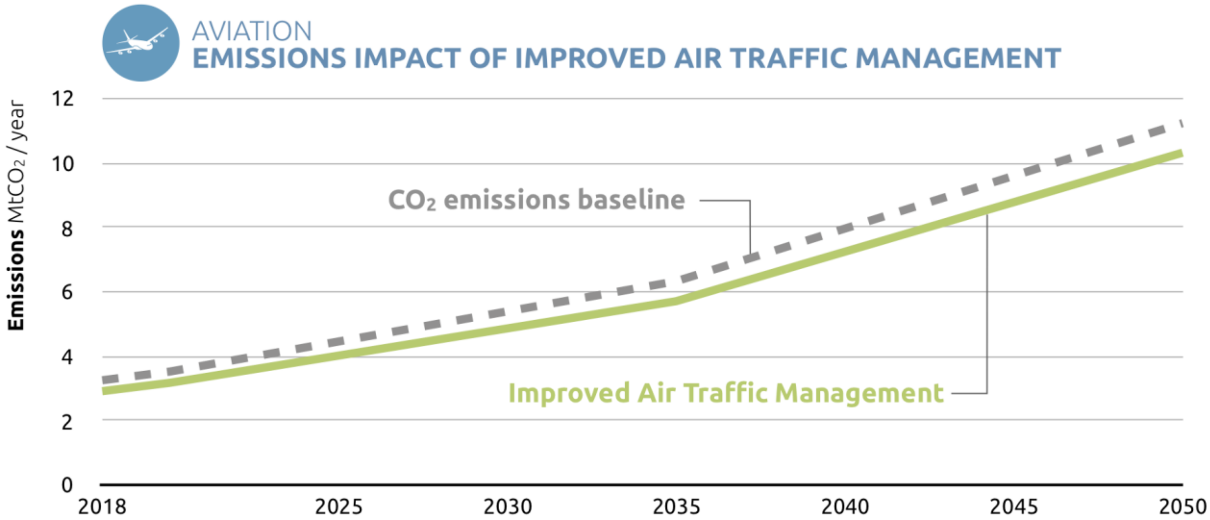


Figure 9: Expected reduction in CO_2 emissions through implemented Improved Air Traffic Management (ATM) and infrastructure use to reduce emissions from aviation (Department of Transport, 2016).

The Department of Transport signalled need for assistance by the international community to implement other emission reduction initiatives proposed by ICAO in research, , education, finance, and technical support (Department of Transport, 2016). As of August 2018, South Africa has not announced its intention to participate in ICAO's Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA).[5]

Maritime shipping

There are no strategy or policies on greener maritime shipping in South Africa (Department of Transport, 2016). This being said, maritime transport and fishing activities only contribute marginally to South Africa's overall emission profile with less than 1% (Department of Environmental Affairs South Africa, 2014), mainly due to the international nature of maritime emissions. South Africa is a member of the International Maritime Organization (IMO), which engages in emission reduction through the following (IMO, 2017):

i. Adoption of regulations to address the emission of air pollutants from ships
ii. Adoption of mandatory energy-efficiency measures to reduce emissions of greenhouse gases from international shipping
iii. Global capacity-building projects to support the implementation of those regulations and encourage innovation and technology transfer

There is no information or analysis to which degree South Africa engages in these different work streams and whether these initiatives might reduce emissions from the South African maritime transport and fishing.

2.2.4 Conclusion

South African transport sector is not expected to meet either of the two actionable benchmarks in the transport sector. The recent submission of the Draft GTS 2017–2050 by the Ministry of Transport indicates long-term planning to mitigate GHG emissions while modernising and expanding South Africa's transport infrastructure to meet its sustainable economic and social development objectives. However, the GTS 2017–2050 does not provide a comprehensive 1.5°C compatible vision of the transport sector.

5 https://www.icao.int/environmental-protection/Pages/market-based-measures.aspx

Implemented polices such the mandated biofuel blending and fuel-economy norms and standards are projected to have very limited impact on overall emission levels of the South African vehicle fleet. Due to a lack of incentives for the promotion of zero-emission vehicles and required infrastructure, South Africa currently makes no progress to phase out fossil fuel car sales between 2035 and 2050 in order to significantly increase the share of non-emission vehicles. In the field of aviation and shipping, South Africa initiated some minor activities to reduce emissions in the domestic aviation sector in line with ICAO's priority action fields. However, South Africa has neither signalled its intent to join the CORISA as of December 2017 nor made efforts to develop 1.5°C compatible vision in aviation and shipping.

As highlighted by the Transport of Ministry in its most recent submissions, South Africa would require substantial financial funds to initiate and realise a 1.5°C compatible transition in the transport sector (Department of Transport, 2016, 2017b). This constitutes a major barrier to initiates a successful transition of the transport sector within the upcoming years.

2.3 Buildings sector

The buildings sector accounted for 25% of South Africa's final energy consumption in 2012. Residential buildings are the biggest contributor to final energy consumption with around 17%, followed by commercial buildings with 5% and public buildings with 3% (Department of Energy, 2016b). Traditional biomass is still commonly used for cooking and heating, especially in low-income households. An ongoing moderate switch to modern electric appliances leads to increased use of electricity (IEA, 2013).

GHG emissions from direct energy use of the South African building sector accounted for about 7% of total emissions in 2012 (Department of Environmental Affairs, 2016a). Between 1990 to 2014, the buildings emission intensity per capita increased by 36%, almost double the increase at global level (Climate Action Tracker, 2017a). The social housing segment accounts for approximately 10% of annual GHG emissions from buildings (SANEDI, 2014). Table 4 summarises South Africa's progress on the most important steps to decarbonise the buildings sector to limit temperature increase to 1.5°C.

Table 8: South Africa's progress on the most important steps in the buildings sector to limit temperature increase to 1.5°C

Sector	1.5 °C-consistent benchmark	Projection(s) under current policies	Gap assessment (qualitative)	Policy rating
Buildings sector	All new buildings fossil free and near zero energy by 2020	• The literature suggests that building efficiency standards stricter than the ones currently implemented is unforeseeable up to 2050 (Altieri, Trollip, & Caetano, 2015; Ürge-Vorsatz et al., 2012)	+ Improvements in emissions intensity per m^2 + Strong business case for green building[6] + Increased demand for green certified buildings + Tools in place to measure and certify near zero energy buildings, including a Net Zero Pilot Certification Scheme and specialised training for building professionals + Initial mandatory labelling for household appliances in place - Buildings emissions intensity per cap continues to increase - Lack of enforcement of existing regulation - High degree of unawareness of green building legislation among construction companies and site-based staff - Although improving, continued lack of expertise among green building professionals - First four net-zero buildings projects have only been announced recently (Oct 2017) - Continued high cost of energy efficient appliances - Continued high use of traditional biomass for cooking and water heating	Getting Started
	Increase building renovation rates from <1% to 5% by 2020	• No country-specific data available, estimated around 1–2%/year (Ürge-Vorsatz et al., 2012)	+ The green retrofitting of existing buildings is expected to be the largest sector of the green building industry in South Africa within the next three years + Some pilot initiatives in the social housing segment - Demand is still comparatively low given split incentives - High upfront costs, high borrowing rates and long payback periods - Financial incentives/ support programmes for retrofitting are not accessible to all market players	No Action

2.3.1 Actionable benchmarks in buildings sector

The Climate Action Tracker identified two short-term actionable benchmarks for the buildings sector to limit warming to 1.5°C at a global level (Kuramochi et al., 2018):

- All new buildings ought to be fossil-free and near zero energy by 2020.
- The annual retrofit rates of existing building stock need to increase from less than 1% in 2015 to 5% by 2020.

The following gap analysis compares historical and projected developments in the South African buildings sector to these global benchmarks without any further adjustment to allow for comparison between countries under analysis. Country specific circumstances will be addressed in the in-depth analysis on scaling up climate action in the following chapters. Please refer to Kuramochi et al. for more detailed explanation on each indicator.

[6] Which buildings qualify as green and/or can be (voluntarily) certified as such is (currently only) defined by the Green Building Council for South Africa along a series of categories (e.g. emissions, water, health) which each comes with a checklist of items for each of the different housing segments (e.g. office, residential) (Green Building Council for South Africa, 2017). Each item is linked to a specific score. The more items are implemented, the higher the score. There are thresholds for different "levels of green".

2.3.2 Recent policy developments

South Africa has implemented several climate strategies and policies in the transport sector, which have been implemented to a variable degree. Table 9 provides a comprehensive overview of the currently implemented and planned sectoral climate policies.

Table 9: Overview of implemented climate change policies in the buildings sector in South Africa

OVERVIEW OF EXISTING, PLANNED AND POTENTIAL CLIMATE CHANGE POLICIES FOR THE BUILDINGS SECTOR IN SOUTH AFRICA				
Changing Activity	**Energy efficiency**	**Renewables**	**Nuclear or CCS or fuel switch**	**Non-energy**
Urban planning strategies (none)	**Building codes and standards and fiscal/financial incentives for low-emissions choices** ▪ Post 2015 National Energy Efficiency Strategy (2015, planned) ▪ Retrofit plan and zero energy buildings standards (2014, planned) ▪ SANS 1544: Energy Performance Certificates for Buildings (2014) ▪ National Building Regulation (2011) ▪ SANS 10400-XA: Energy usage in Buildings (2011, update in 2017) ▪ SANS 204: Energy efficiency in Buildings (2011)	**Support scheme for heating and cooling** ▪ Eskom Solar Water Heating Rebate Programme (2008, updated 2015)		
	Minimum energy performance and equipment standards for appliances ▪ Compulsory Specification for Energy Efficiency and Labelling of Electrical and Electronic Apparatus (2014) ▪ SANS 941: Energy efficiency of electrical and electronic apparatus (2012, updated 2014) ▪ Product Standards and labelling (2005)	**Support scheme for hot water and cooking** ▪ Solar hot heating programme (2008)		
		Sustainability standards for biomass use (none)		
Energy and other taxes ▪ Section 12L: Tax deductions for energy efficiency measures (2013)				
Fossil fuel subsidies (none)				

No policies currently exist and a similar policy gap exists in all other countries — *No policies currently exist however South Africa could adopt policies from other countries* — *Existing and planned policies for South Africa*

South Africa's building sector is a key source of emissions. The energy and water crisis faced by the country is driving regulation and consumer choices in the building sector. The government explicitly mentioned the sector as priority in its 2030 Vision included in its Biennial Update Report, and the focus is placed on the regulation to promote green buildings and construction practices (Department of Environmental Affairs, 2014a; UNSCF, 2012). Several provinces (e.g. Gauteng, KwaZulu-Natal) pursue development priorities which are explicitly linked to increasing energy efficiency in buildings (Department of Environmental Affairs, 2014b). Achieving a zero-emission building standard by 2030 is identified in the country's National Development Plan. The actions to achieve this include (UNSCF, 2012):

1. All new buildings to meet the energy efficiency criteria set out in South Africa's National Standard 204

2. Carbon price, building standards and municipal regulations to achieve scale in stimulating renewable energy, waste recycling and retrofitting buildings.

The following regulations and support schemes are currently being implemented and/ or are planned in the field of major buildings regulations and codes as well as appliances.

Major building regulations and codes

The **SANS 204: 2011 Energy efficiency in buildings** supports the energy efficiency targets in the 2005 National Energy Efficiency Strategy. It specifies maximum energy demand and maximum annual energy consumption per building classification type for each of the climate zones. It applies to all new buildings and major refurbishments of old buildings (Sustainable Energy Africa, 2017).

The **SANS 10400-XA: 2011 Energy usage in Buildings** summarises and references SANS 2014 and other similar standards into one single reference to ensure compliance with the energy efficiency requirements of the National Building Regulations (GBPN, 2014; Sustainable Energy Africa, 2017). South Africa updated the SANS 10400 XA building code to take into account a new detailed climate zone map finalised in 2016.

The planned **retrofit plan and zero energy buildings standards** from 2014 is a five-year government project to retrofit 1,450 buildings with energy efficient installations, about 270 with water saving installations and about 120 with waste management installations (Grantham Research Institute on Climate Change and the Environment, 2017). The implementation status of the standard is uncertain with no up-to-date information available.

In 2013, the Treasury agreed on **income tax deductions for energy efficiency saving measures** available to tax payers (Section 12L). Due to international tax laws, Real Estate Investment Trusts (REITs) cannot access those deductions (GBPN, 2014).

The **SANS 1544 Energy Performance Certificates (EPCs) for Buildings** are currently only required for publicly-owned buildings (Department of Energy, 2016b). Besides the regulation provides recommendations for other buildings as well.

The **Draft Post-2015 National Energy Efficiency Strategy** foresees reductions of the final energy consumption of 33% in the residential sector and 37% in the public and commercial sector by 2030, compared to the 2015 baseline (Ibid).

Appliances

Lighting, appliances and services equipment were responsible for around 20% of building energy use in 2010 and are expected to increase as per capita GDP is increasing and use of biomass is decreasing (IEA, 2013).

The **SANS 941: 2012 Energy efficiency of electric and electronic apparatus** covers energy efficiency requirements, measurement methods and energy efficiency labelling to ensure compliance with the 2005 National Energy Efficiency Strategy. It provided the basis for subsequently introduced mandatory labelling (SABS, 2014).

The **Compulsory Specification for Energy Efficiency and Labelling of Electrical and Electronic Apparatus 2014** introduces mandatory minimum energy performance standards (MEPS) for a range of appliances (Götz, Tholen, & Adisorn, 2016).

2.3.3 Comparison of recent developments and projections to benchmarks

2.3.3.1 **Actionable indicator No.5:** All new buildings fossil free and near zero energy by 2020

South Africa is unlikely to meet the benchmark of all new buildings to be fossil free and near zero energy by 2020, although some considerable progress has been made. While green building and construction practices are identified as priority in the country's Biennial Update Report, its National Development Plan and with a series of policies targeting the building sector underway, considerable progress can be observed, but is not yet enough. This is particularly relevant as residential as well as commercial floor space will increase considerably by 2050 compared to 2010 values, by 90% and 186% respectively (IEA, 2013).

The buildings emissions intensity per capita, which includes electricity related emissions, increased by 36% from 1990 to 2015 and after peaking in 2008 (2.2 tCO_2e/cap) is now slowly decreasing and reached 1.8 tCO_2e/cap in 2015 (Climate Action Tracker, 2018b). This is significantly higher than a 2°C-compatible pathway which would require the buildings emissions intensity to reach 1.1 tCO_2e/cap or lower in 2020 (Wouters et al., 2016). The high building emissions intensity indicator is linked to the high emissions intensity of electricity in the country whose emissions intensity has slightly decreased, mainly due to the energy efficiency improvements (Climate Action Tracker, 2016a). The energy intensity in the residential sector at floor area ($kgCO_2/m^2$) has improved by 28.2% from 2000 to 2015, almost three times the target South Africa had set itself. Progress in the commercial and public sector however was notably below target (0.3% against a target of 15%, 2003–13, electricity only) (Department of Energy, 2016b).

Research expects that in 2018, the proportion of green buildings will climb from 2017's 41% to 61% of all South African building activity (World Green Building Council, 2016a). The demand for voluntary green certified new buildings is also increasing due to cheaper operations costs and higher returns on investments compared to conventional buildings. For example, in 2015 the average financial return for top quartile energy efficient buildings in year stood at 12.5% against 11.5% for conventional buildings (GBCSA, 2017). Cost premia for green buildings are also decreasingly rapidly (GBCSA, 2017). Need for resource efficiency due to country's energy and water crisis will continue to provide the business case for green buildings. The first four net zero buildings projects have been announced in October 2017 (GBCSA, 2017).

These trends are mirrored in planned regulation which (tentatively) targets a 49% reduction of energy consumption per m^2 in public buildings by 2030 compared to 2015. In the residential sector, there are two objectives: increase the average energy performance of new residential buildings by 38% and decrease energy consumption of new household appliances by 33% by 2030, against the 2015 baseline. Average energy consumption in the commercial sector should decrease by 54% (Department of Energy, 2016b). Targets should be achieved through successive tightening of standards, greens leases and Energy Service Companies (ESCOs) (Sustainable Energy Africa, 2017).

The Green Building Council of South Africa (GBCSA) has been successful in promoting and increasing the uptake of voluntary green building certificates in the country (300 certified buildings since 2007, with own-reported energy savings equivalent to of 500 $ktCO_2$/yr), mainly for commercial buildings (GBCSA, 2017). Energy performance certificates are currently only mandatory for government-owned buildings, which makes it more difficult to monitor progress and enforce green building regulation. There is a voluntary green building certificate scheme ("Edge") for the residential building sector, but with little uptake so far. In addition, the GBCSA has introduced a voluntary Net-Zero Pilot Certification Scheme which is also offering specialised training for building professionals to overcome the shortage of sufficiently skilled/ educated green professionals, and the high degree of unawareness of green building legislation among construction companies and site-based staff. Initial mandatory labelling for household appliances is in place and expected to lead to further energy efficiency savings in the future.

As the sector is a high consumer of energy, moving away from coal and other fossil fuels for electricity generation will be key to meet the target of net zero buildings by 2020. To meet the above-mentioned benchmark, increasing the energy efficiency and decreasing energy demand of the residential sector will be critical, given its share in total energy consumption and consumption trends (consumption in the sector increased by 45% from 1990 to 2000). But energy efficiency improvement will not be enough.

2.3.3.2 **Actionable indicator No.6:** Increase building renovation rates from <1 to 5% by 2020

South Africa is not likely to meet the benchmark of increasing building renovation rates up to 5%/year by 2020. The demand for retrofitting is still comparatively low given, especially in the residential and commercial sector which collectively constitute well over 90% of South Africa's building sector. There are a few initiatives in the public sector as well some targeted small-scale projects in the growing publicly subsidised social housing segment which are dependent on international support (Krog, 2015).

SANS regulations and the GBCSA rating system only apply to new buildings and to major refurbishments of old buildings but not to the existing building stock that makes up around 95% of all buildings (Sustainable Energy Africa, 2017).

The main barriers for an increased rate of building renovations are the high upfront costs as well as high borrowing rates and long payback periods. Further limiting factors are the lack of capacity and technical expertise (World Green Building Council, 2016b). In the residential sector the split incentives between investors and tenants persist, although further facilitating ESCO activities and more stringent energy savings requirements planned under the draft post-2015 National Energy Efficiency Strategy could help overcome that challenge. Financial incentives/ support programmes for retrofitting are not accessible for all market players (e.g. Real Estate Investment Trusts – REITs – are currently excluded as they are not the final tax payers) (Department of Energy, 2016b).

Nevertheless, the green retrofitting of existing buildings is expected to be the largest sector of the green building industry in South Africa within the next three years (World Green Building Council, 2016b). This is likely to be related to the persisting energy and water crisis and soaring energy prices in the country.

2.3.4 Conclusion

South Africa has made improvements to the building sector by increasing the energy efficiency per m^2, while the buildings emissions intensity per capita is only slowly decreasing. The move away from biomass use for cooking and heating towards the use of more modern appliances which require electricity, which in turn is largely generated by fossil fuels, makes it more difficult for South Africa to meet the target of achieving new near zero-energy buildings by 2020. The energy and water crisis accelerates the trend to more energy efficient buildings. Pending regulation on tightened building and appliances standards and certifications can further speed up this trend.

South Africa is likely to also miss the target of retrofitting 5% of its existing building stock per year by 2020. The main barriers are in the residential sector where tenants and building owners face high borrowing costs for energy efficiency improvements, coupled with split incentives between investors and tenants.

2.4 Industry sector

South Africa's industry sector accounted for 26% of total GDP in 2016 with significant contributions originating from mining, steel and iron production and metalworks (StatsSA, 2013, 2017). Direct and indirect emissions attributable to the industry sector added up to approximately 280 $MtCO_2e$ in 2010, comprising 140 $MtCO_2e$ of indirect emission from electricity generation, 44 $MtCO_2e$ of emissions from industrial processes and product use, and 41 $MtCO_2e$ from direct fuel combustion (Department of Environmental Affairs South Africa, 2014). These emissions represent more than 50% of South Africa's total GHG emissions, excluding LULUCF (Department of Environmental Affairs South Africa, 2014).

The present high energy use in the South African industry sector offers significant mitigation potential through implemented energy efficiency measures. Mining, quarrying, and iron and steel production as the most energy consuming sub-sectors offer significant abatement potentials (IEA, 2017a). The industry sector's deep decarbonisation requires the reduction of industrial process related emissions by introducing new low-and zero-carbon technologies and innovative production methods. Table 10 summarises South Africa's progress on the most important steps to decarbonise the industry sector.

Table 10: South Africa's progress on the most important steps in the industry sector to limit temperature increase to 1.5°C

Sector	1.5 °C-consistent benchmark	Projection(s) under current policies	Gap assessment (qualitative)	Policy rating
Industry sector	All new installations in emissions-intensive sectors are low-carbon after 2020, maximise material efficiency	• No projections available	+ Voluntary pilot project to foster resource and production efficiency + Overarching emissions reporting scheme + Obligation for large emitters to submit non-binding mitigation plans + *Promotion of ISO 50001 certification of energy efficiency* - *Low emission reduction impact of voluntary projects* - *No legally binding efficiency standards* - *No regulation and only little financial support schemes for deployment of low carbon technologies* - *Historically energy intensive industrial base* - *High historical importance of (coal) mining for socio-economic development in South Africa and severe implications of required coal phase-out* - *No commercial CCS deployment technologically and financially feasible on a large scale in the nearby future*	No Action

2.4.1 Actionable benchmarks in industry sector

The Climate Action Tracker identified one short-term actionable benchmark for the industry sector to limit warming to 1.5°C at a global level (Kuramochi et al., 2018):

- All new installations in emissions-intensive sectors need to be zero or low-carbon after 2020 such as zero-carbon steelmaking technologies, including carbon capture and storage (CCS) and material efficiency needs to be maximised.

The following gap analysis compares historical and projected developments in the South African industry sector to this global benchmark without any further adjustment to allow for comparison between countries under analysis. Country specific circumstances will be addressed in the in-depth analysis on scaling up climate action in the following chapters. Please refer to the publication for more detailed explanation on each indicator.

2.4.2 Recent policy developments

National policy documents have articulated the need for sustainable industrial development in South Africa for more than a decade (Department of Economic Developement, 2011; Department of Environmental Affairs, 2011; Department of Environmental Affairs and Tourism - Republic of South Africa, 2008; Department of Minerals and Energy, 2005; National Planning Commission, 2012). **These policy and planning documents address sustainable industrial economic development, however, scarcely specify actionable mitigation targets for the industry sector or concrete measures for implementation.** The Industrial Policy Action Plan of 2017 mainly focus on industrial development and socio-economic equality, whereas the reduction of industrial emissions is only discussed at its margins (Department of Trade and Industry of South Africa, 2017b, 2017a). Table 11 provides an overview of implemented policies that foster the development towards a low-carbon industry in South Africa.

Table 11: Overview of implemented climate change policies in the industry sector in South Africa

OVERVIEW OF EXISTING, PLANNED AND POTENTIAL CLIMATE CHANGE POLICIES FOR THE INDUSTRY SECTOR IN SOUTH AFRICA				
Changing Activity	**Energy efficiency**	**Renewables**	**Nuclear or CCS or fuel switch**	**Non-energy**
Strategy for material efficiency ▪ National Cleaner Production Centre (since 2002), incl. National Symbiosis Program and Industrial Energy Efficiency Project (IEE)	**Support for energy efficiency in industrial production** ▪ Energy Efficiency Strategy (2005–2015) ▪ Post 2015 Energy Efficiency Strategy (not yet in force) ▪ Industrial Energy Efficiency Program (2010)	**Support schemes for renewables** (none)	**CCS support scheme** ▪ Centre for Carbon Capture & Storage (2009)	**Landfill methane reduction** (none)
	Energy reporting and audits ▪ National Greenhouse Gas Emission Reporting Regulations (2017) ▪ National Pollution Prevention Plans Regulation (2016)	**Sustainability standards for biomass use** (none)		**Incentives to reduce CH4 from oil and gas production** (none)
	Minimum energy performance and equipment standards (none)			**Incentives to reduce N2O from industrial processes** (none)
	Incentives to reduce fluorinated gases (none)			
Overarching carbon pricing scheme or emissions limit ▪ Carbon Tax (planned) ▪ Voluntary carbon budgets on company level (2017)				
Energy and other taxes (none)				
Financial Support Schemes for Sustainable Development ▪ The Green Fund South Africa (2012)				
No fossil fuel subsidies (none)				

No policies currently exist and a similar policy gap exists in all other countries

No policies currently exist however South Africa could adopt policies from other countries

Existing and planned policies for South Africa

The overall number of measures and support schemes for GHG emission mitigation in the industry sector is very limited with no specification of direct sectoral abatement targets. Introduced in 2005, the **Energy Efficiency Strategy of South Africa** proposes several measures to enhance energy efficiency in the industry and mining sector in South Africa targeting a 15% reduction of the final energy demand in the sector compared to a business as usual scenario by 2015 (Department of Minerals and Energy, 2005). This target translated into envisaged energy savings of 280 PJ in the year 2015.

The draft **Post-2015 National Energy Efficiency Strategy (NEES)** proposes a reduction of the weighted mean specific energy consumption in industrial manufacturing of 16% by 2030 below 2015 levels and total cumulative annual energy saving of 40 PJ by 2030 resulting from specific energy saving interventions in the mining sector (Department of Energy, 2016b). For comparison, the mining and quarrying sector's energy use amounted to 185 PJ in 2015 (IEA, 2017a). Total final energy consumption of the industry sector is expected to be reduced by 15% by 2030 below 2015 levels by the implementation of efficiency measures. The South African government intends to achieve these targets through the implementation of several proposed measures outlined in the following.

The **National Cleaner Production Centre South Africa (NPCP-SA)** promotes the implementation of energy efficiency measures in the industry sector and facilitated savings of 7.6 $MtCO_2e$ between 2010 and 2016 (NCPC-SA, 2017). The centre aims to raise awareness amongst companies for resource management and energy efficient production via trainings and energy consultancies. The NPCP-SA's associated program **Industrial Energy Efficiency Project (IEE)** promotes energy management systems and corresponding certifications (NCPC-SA, 2017). A mandatory submission of energy management plans for enterprises whose annual energy consumption exceeds 180 TJ is still under discussion (Department of Energy of South Africa, 2015). The NCPC-SA further launched an industrial symbiosis program under which companies increase their resource efficiencies by exploiting synergies in production (National Cleaner Production Centre South Africa, 2015).

The **National Pollution Prevention Plans Regulation** obligates companies from several industrial sectors whose GHG emissions exceed the threshold of 0.1 MtCO2e/yr to submit a plan for mitigation interventions to reduce GHG emissions over the five-year period (Department of Environmental Affairs, 2016b). In addition, the **National Greenhouse Gas Emission Reporting Regulations** introduced in 2017 as part of the Climate Change Mitigation System Framework obligates emitters to report on their GHG emissions under a comprehensive framework. The regulation applies to many relevant sectors and facilitates the monitoring of GHG emissions. Even though these regulations directly address the sectors GHG emissions, they do not introduce any legally binding reductions and have not contribute to emissions abatement as of 2017. Apart from the National Greenhouse Gas Emission Reporting Regulations, **company level carbon budgets and carbon tax** expected by mid-2018 are two other cross-sectoral policies in the industry sector (please refer to Section 2.1.2. for a more explanation).

Although the Post-2015 NEES directly mentions mandatory minimum design standards for industrial boilers and labels for high energy performance to run alongside minimum energy performance standards (MEPS), no information is available on any plans to introduce such labels as of August 2018. Furthermore, there are no specific regulations on carbon intensive sub-sectors, such as steel or cement production or mining.

2.4.3 Comparison of recent developments and projections to benchmark

2.4.3.1 **Actionable indicator No.7:** All new installations in emissions-intensive sectors are low-carbon after 2020, maximise material efficiency

The absence of legally binding emissions reduction policies in the industry sector make it highly unlikely that newly installed manufacturing capacity coming online from 2020 onwards will be low carbon. Industry emission intensity in South Africa has been stable over the last decade as shown in Figure 10. Recent energy demand projections forecast an increase of total industrial energy demand by around 10% by 2030 compared to 2016 levels and by 20% by 2040 (IEA, 2017b). Even as no projected emission scenarios under current policies are currently available for the South African industry sector, this increase in energy demand implies a further increase in industry-induced emissions unless energy supply is significantly decarbonised.

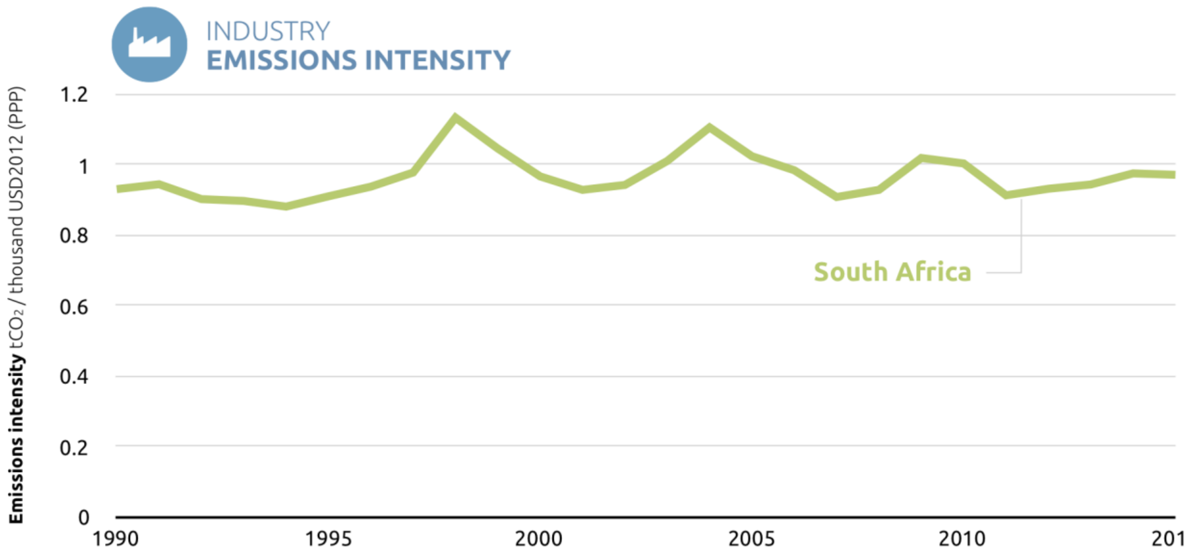


Figure 10: Industry emission intensity between 1990-2014 in South Africa (Climate Action Tracker, 2018b)

The Deep Decarbonisation Pathway Project (DDPP) models 2°C decarbonisation scenarios for South Africa's energy systems while accounting for national political economy circumstances and the fulfilment of domestic development priorities (Altieri et al., 2015). For the scenarios analysed, industry sectors energy related direct and indirect emissions continue to increase and almost double by 2030. Only after 2030 sectoral emissions significantly decrease. The reductions of sectoral GHG emissions in this modelling exercise are mainly driven by the decarbonisation of the electricity sector and efficiency measures. As current policies are not sufficient to reduce emissions to be in line with the modelling exercise's 2°C sectoral pathways, future emissions in the industry sector are likely to exceed these projections. Correspondingly South Africa is far from reaching 50%–75% reduction of industry related emissions by 2050 below 2010 levels required for 1.5° compatible pathway (Climate Action Tracker, 2016c).

Regarding emission intensive subsectors as steel production and mining, there are no indications for policy-driven emission reduction in the nearby future. Instead, the South African government has set up a package of policy measures to rescue the existing steel industry from the immediate threat of closure and to prevent an accompanying loss of capacity (Department of Trade and Industry of South Africa, 2017b). For instance, total crude steel production in South Africa has been significantly declining from 9.1 Mt in 2007 to 6.1 Mt in 2016 mainly due to global overcapacities (Worldsteel, 2017).

2.4.4 Conclusion

Current developments in the South African industry sector are not compatible with the 1.5°C compatible benchmark of only utilising zero and low-carbon installations in emissions-intensive sectors after 2020 and maximising material efficiency in industrial processes. Despite the manifold high-level strategic planning of the Post-2015 NEES, the South African government has not yet implemented any overarching binding regulations on emission and/or efficiency standards in fear of hampering volatile economic development. No legislation has been adopted that makes the deployment of low-carbon technologies mandatory as of August 2018. Implemented voluntary programmes only induced marginal emission reduction impacts. The application of CCS technology in the South African industrial sector will not be feasible in financial and technological terms on a large scale in the nearby future.

The South Africa government has established some first support schemes to improve energy and resource use performance. Such energy efficiency programs implemented by the NPCP-SA have triggered cumulative emission savings of 7.6 $MtCO_2e$ between 2010 and 2016 and have demonstrated pilot cases for efficiency improvements (NCPC-SA, 2017). However, the impact of these voluntary programs is almost negligible compared to total direct and indirect emissions and does not trigger the required sectoral transformation to be in line with 1.5°C compatible benchmark. Therefore, the South African industry is likely to remain energy and resource intensive for upcoming future.

Coal mining in South Africa's north-eastern provinces continues to be an important socio-economic driver in the South African industry sector. In 2014 alone, South Africa produced around 260 Mt of coal with roughly 70% being sold domestically and 27% being exported (Chamber of Mines in South Africa, 2017). With coal-based electricity generation being the predominant form of electricity generation in South Africa today, Eskom purchased a total 122 Mt of thermal coal (~47% of total production) in the fiscal year 2014. In context of the required energy sector decarbonisation (see Section 0), coal mining faces a high risk of strong decline in domestic and international demand. This implies severe socio-economic consequences for South Africa in managing a "just transition" for communities affected by a potential coal phase-out and create alternative employment opportunities (Sartor, 2017).

2.5 Agriculture and forestry

The forestry sector is of economic interest for South Africa, with a focus on timber production. Afforestation of industrial forests has thus been an important topic for many decades, as timber demand has grown. Burning of biomass through forest fires is the main source of emissions. There is still some fuelwood consumption in South Africa, although its relevance is not as high as in other sub-Saharan countries (Idiata, Ebiogbe, Oriakhi, & Iyalekhue, 2013). Overall forest continues to shrink, although at a lower rate as in the previous decade (Department of Environmental Affairs, 2013; FAOSTAT, 2017). Still, net emissions in this sector are negative.

Agriculture is commercialised to a large extent in South Africa. The share of small scale agriculture is less than 20% (Hachigonta, Nelson, Thomas, & Sibanda, 2013). The agricultural sector is highly vulnerable to climate change, with a particularly low adaptive capacity in South Africa. One example is variable rainfalls. Only a small share of the agricultural land is irrigated, still agriculture is responsible for about half of the countries surface water consumption (Hachigonta et al., 2013). Water is scarce, and a large amount of the crops depend on regular rainfalls.

The agriculture and forestry sector's share of emissions was 5% in 2012 in South Africa (Department of Environmental Affairs, 2016a). Table 12 summarises South Africa's progress on the most important steps to decarbonise the LULUCF and commercial agriculture sectors to limit temperature to 1.5°C.

Table 12: South Africa's progress on the most important steps in the LULUCF and commercial agriculture sectors to limit temperature increase to 1.5°C

Sector	1.5 °C-consistent benchmark	Projection(s) under current policies	Gap assessment (qualitative)	Policy rating
LULUCF	Reduce emissions from forestry and other land use to 95% below 2010 by 2030, stop net deforestation by 2025	• No projections available	+/- Data uncertainty high, unclear whether benchmark is met. + Forestry sector net-negative in inventory years + Substantial efforts for afforestation - Continuously decreasing forest area through pressure from fuel wood needs.	Getting Started
Commercial Agriculture	Keep emissions in 2020 at or below current levels, establish and disseminate regional best practice, ramp up research	• Decrease of emissions by 2% up to 2020, by another 2% up to 2030	+ Emissions projected to decrease - Emission reductions rather due to shift if consumer preferences (move to poultry) rather than improved practices - Emission intensity as well as meat consumption significantly above world average - *No strong focus on mitigation in the sector*	No Action

2.5.1 Actionable benchmarks in agriculture and forestry

The Climate Action Tracker identified two short-term actionable benchmarks for the agriculture and forestry sector to limit warming to 1.5°C at a global level (Kuramochi et al., 2018):

- Emissions from forestry and other land use needs to be reduced to 95% below 2010 by 2030 and a stop of net deforestation to be achieved by 2025.
- Emissions from commercial agriculture in 2020 need to be kept at or below current levels with the simultaneous establishment and dissemination of regional best practice and a ramp up of research.

The following gap analysis compares historical and projected developments in the South African LULUCF and commercial agriculture sectors to these global benchmarks without any further adjustment to allow for comparison between countries under analysis. Country specific circumstances will be addressed in the in-depth analysis on scaling up climate action in the following chapters. Please refer to Kuramochi et al. for more detailed explanation on each indicator.

2.5.2 Recent policy developments

South Africa has few climate strategies and policies in the agriculture and forestry sectors, which have been implemented to a variable degree. Table 13 provides a comprehensive overview of the currently implemented and planned sectoral climate policies with the potential to affect GHG emissions directly.

Table 13: Overview of implemented climate change policies in the agriculture and forestry sector in South Africa

OVERVIEW OF EXISTING, PLANNED AND POTENTIAL CLIMATE CHANGE POLICIES FOR THE AGRICULTURE AND FORESTRY SECTORS IN SOUTH AFRICA				
Changing Activity	**Energy efficiency**	**Renewables**	**Nuclear or CCS or fuel switch**	**Non-energy**
Standards and support for sustainable agricultural practices and use of agricultural products ▪ National Climate Change Response Policy (Climate Smart Agriculture) (2011)				
Incentives to reduce CO2 emissions from agriculture (none)				
Incentives to reduce CH4 emissions from agriculture ▪ Long Term Mitigation Strategy (LTMS) - Enteric Fermentation and Reduced Tillage programmes (2007, planned)				
Incentives to reduce N2O emissions from agriculture (none)				
Incentives to reduce deforestation or support for afforestation/reforestation ▪ Strategic Plan for the Department of Agriculture, Forestry and Fisheries 2013/14 to 2017/18 (2013) ▪ Long Term Mitigation Strategy (LTMS) - Afforestation programme (2007, planned) ▪ Working on Fire (2003) ▪ National Forest Act (1998)				

No policies currently exist and a similar policy gap exists in all other countries

No policies currently exist however South Africa could adopt policies from other countries

Existing and planned policies for South Africa

The amount of policies in the agricultural and forestry sector targeted at climate change mitigation in South Africa is limited. The Biennial Update Report of 2017 lists the following activities for the forestry sector (Department of Environmental Affairs, 2017b):

1) **Working on Fire – Firewise Programme**: A government funded training and employment programme under the Department of Environmental Affairs for fire awareness and education, prevention and fire suppression
2) **Long Term Mitigation Strategy (LTMS) – Afforestation Project**: Plant an additional 760,000 ha of commercial forests
3) **Working on Land**

For the agriculture sector, the Biennial Update Report of 2017 mentions two measures that are analysed in the long-term mitigation strategy, however not yet implemented policies:

1) **Long Term Mitigation Strategy (LTMS) – Enteric Fermentation**: Transfer free-ranging cattle to feedlots and adjust their nutrition (planned)
2) **Long Term Mitigation Strategy (LTMS) – Reduced Tillage** on croplands in order to reduce soil erosion (planned)

The National Climate Change Response Policy names climate smart agriculture (CSA) as a practice "that lowers agricultural emissions, is more resilient to climate changes, and boosts agricultural production" (Government of South Africa, 2011). A number of CSA activities is in place in South Africa (Nciizah & Wakindiki, 2015), however their expected or actual mitigation impacts are not reported.

The DEA, together with GIZ, has reviewed further policies related to the agriculture and forestry sector, which are potentially related but not necessarily directed at mitigation and finds that "consideration of the emissions implications of proposed actions was largely absent from most document" (DEA, 2014).

2.5.3 Comparison of recent developments and projections to benchmarks

2.5.3.1 **Actionable indicator No.8:** Reduce emissions from forestry and other land use to 95% below 2010 by 2030, stop net deforestation by the 2020s

The data uncertainty does not allow to assess whether South Africa is compatible with this benchmark. According to national data, the forestry sector has been a net sink over the period from 2000 to 2012, no official national data is available for later years (Department of Environmental Affairs, 2016a), nor are projections. South Africa's Greenhouse Gas Mitigation Potential Analysis excludes the sector and states "there is not sufficient evidence to be able to predict a change in either case so no sequestration is provided for (positive or negative)" (Department of Environmental Affairs, 2014c). In the inventory, crop- and grasslands are sources of emissions, however those are overcompensated by a sink from forest lands. Opposed to national data, FAO Statistics show a small emission source for the land use sector in total, stable over the last two decades at around 2 $MtCO_2e$ (FAOSTAT, 2017).

Given the importance of the timber industry, the area of woody crops has almost doubled since the early 1990s, and stabilised over the last decade (FAOSTAT, 2017). However, at the same time, the overall forest area has continuously decreased (Department of Environmental Affairs South Africa, 2014; FAOSTAT, 2017).The planted trees are non-domestic species, and concerns about their negative impacts on water resources have been raised in the past (Bosch & von Gadow, 1990). It is unclear whether this will be a sustainable way for a long term 1.5°C compatible development.

The reason the forests are a net sink despite decreasing forest area may be that the carbon content of the planted forests compared to the deforested area. However, with different contradicting data sources available, it is unclear whether this is the reason for this apparent mismatch, or whether there are methodological issues in the inventory.

2.5.3.2 **Actionable indicator No.9:** Keep emissions in 2020 at or below current levels, establish and disseminate regional best practice, ramp up research

South Africa meets the element of the benchmark on the overall development of emissions. National projections suggest that emissions from the sector will decrease slightly by 2% over the period from 2010–2020, and another 2% by 2030, mostly because of an expected decline of emissions from enteric fermentation (Department of Environmental Affairs, 2014c).

Over 2000–2012, total GHG emissions from livestock declined by 6%. This decline was attributed to the decline in cattle populations, which fell 5.5% from 2000 to 2010 (not data yet reported for 2012). However, the total livestock population over this period increased by 7%, due to large growth in the poultry industry (Department of Environmental Affairs, 2017b). Latest forecasts suggest that the total poultry stock will continue to increase significantly by 26% by 2030 and by 43% 2050 compared to 2016 levels (FAOSTAT, 2017). Reversing recent trends, cattle populations will also increase again over the same period, namely by 20% by 2030 and 29% by 2050 compared to 2016 levels.

The decline in cattle numbers and the growth in poultry results in a fall in total livestock emissions because poultry does not contribute to enteric fermentation emissions, which accounted for 97% of GHG from livestock in 2010 (Department of Environmental Affairs South Africa, 2014).

On the other hand, South Africa's meat calorie consumption per capita was 332 kcal/cap/day in 2013, which is substantially above the world average of 237 kcal/cap/day. The meat production

per capita is also high, at 158g/cap/day in 2012 and increasing. In contrast, the global average meat production per capita in 2013 was 117g/cap/day (Climate Action Tracker, 2018b).
The agriculture emissions intensity (GHG emissions per value added) is substantial; in 2013, this figure was 1.7 tCO_2e/thousand USD, representing a significant 37% decrease from 1990 levels. The global average agriculture intensity was 1.2 tCO_2e/thousand USD in 2010 (Climate Action Tracker, 2018b).

South Africa does not meet the remaining elements of the benchmark: There are limited activities to disseminate best practice or research in the sector: there are some activities around climate smart agriculture (Nciizah & Wakindiki, 2015), however with an unclear impact on mitigation of GHG.

2.5.4 Conclusion

The agriculture and forestry sectors hold a small share of GHG emissions in South Africa, and mitigation in those areas is outside the focus of policy making, although research identifies some mitigation potentials (Department Environmental Affairs of South Africa, 2014). Most relevant implemented actions relate to afforestation, rather due to economic interests to further strengthen the timber industry, than for mitigation of emissions. South Africa is also trying to avoid forest fires, however, a large share of emissions stems from use of fuel wood in households. In the agricultural sector, there is no implemented legislation related to mitigation. There are Climate Smart Agriculture activities, however, their impact on GHG mitigation remains unclear.

South Africa meets the global quantitative benchmark for agriculture, for the benchmark on forestry, data uncertainty is too high to conduct a final assessment. On the national level, there are additional potentials and room for actions to improve the sustainability of the sector. One example is stopping deforestation: While commercial forest plantations have increased, the forest area over all has still decreased. Negative impacts on water from commercial forest plantations have been reported in the past, increasing the pressure on agricultural production.
According to South Africa's BUR the government is already working on implementing parts of the activities identified in the LTMS for the agricultural sector (Department of Environmental Affairs, 2014b). These activities could be the basis for further actions or streamlining of mitigation in already ongoing programmes.

3 Selection of focus areas for analysis on scaling up climate action

The report prioritises three areas for in-depth analysis on scaling up climate action in South Africa: the electricity supply sector, the passenger transport sector in urban areas, and the residential buildings sector. This section explains the reasoning for looking further into these three areas, considering the South African national context and country-specific circumstances. Note that the selection to focus on these areas in no way indicates that less mitigation action is needed in all other remaining sectors. Relevant literature in the field and most recent emission scenarios clearly indicate that all sectors need to maximise their efforts for 1.5°C Paris Agreement compatibility (Kuramochi et al., 2018). The selection of focus areas for scaling up climate action is based on the following criteria combined with expert judgement by the authors.

i. **GHG emissions:** The relevance of the (sub-)sector in terms of historical and projected future GHG emissions
ii. **Existing gap**: The existing gap between currently existing and planned policies and 1.5°C compatible benchmark(s)
iii. **Potential for scaling up climate action:** The potential for enhancing climate action given local and global sectoral development (e.g. decreasing prices for RE technologies, CCS capacities, pending investment in infrastructure)
iv. **Priority in the national discourse:** Priority of the respective (sub-)sector in the national discourse or opportunities to enhance climate action due to recent social, political, or economic developments
v. **Overlaps with other sectors:** The (sub-)sector's degree of overlap with other sectors relevant for long-term decarbonisation (e.g. CO_2-neutral electricity sector in parallel to electrification trends in the transport or buildings sector)
vi. **Co-benefits potential and sustainable development goals:** Potential to realise co-benefits of scaling up climate action in a given country context (e.g. local job development through ambitious renewables deployment or reduction in urban air pollution due to modal shift away from combustion engines), especially linking to the country's sustainable development goals

The following sections provide explanation for each sector's selection, also considering the technical feasibility of the research for the sectors. For example, data availability might be a limiting factor.

3.1 Electricity supply sector

This research analyses the South African electricity sector in-depth as **all abovementioned criteria** are highly applicable to this sector. Electricity generation remains the single most important sector in South Africa for a successful transition toward a zero-emission society.

i. **GHG emissions**: The electricity supply sector remains South Africa's most emission intensive sector accounting for around 45% of total emissions in 2012 (Department of Environmental Affairs, 2016a). Emissions further increased by around 9 $MtCO_2e$/yr by 2015 (IEA, 2018) and stem from the predominantly coal-based electricity generation. Additional coal capacity is planned to come online in the nearby future.
ii. **Existing gap**: Currently implemented policies clearly fail to transform the South African electricity supply sector in line with a 1.5°C Paris Agreement compatible emission trajectory (see Section 0 for detailed explanation). Recently announced plans for updating the country's energy planning might present a transition away from coal towards renewables-based generation in the medium- to long-term, but further ambitious action until 2030 and beyond would be required to successfully decarbonise the sector by mid-century.
iii. **Potential for scaling up climate action**: The South African electricity sector shows significant potential for scaling up climate action in the short-, medium-, and long-term.

Excellent conditions for renewables instalments in South Africa (especially for solar and wind technologies), sharp cost decreases for renewable technologies globally and locally, as well as opportunities for local economic development and job creation constitute a promising basis for accelerated deployment of renewables. For instance, the REIPPP auction policy has already been very successful in driving down average tariffs provided by the South African government over the course of the four bidding rounds (Hartley et al., 2017).

iv. **Priority in the national discourse**: The long-term energy planning for South Africa is the subject of fierce public debate, especially considering the socio-economic relevance of coal mining and extraction (Sartor, 2017). The challenge of a "just transition" away from coal-based electricity generation while considering other relevant socio-economic considerations critically influences public discourse and policy making.

v. **Overlaps with other sectors**: The decarbonisation of electricity supply sector constitutes a prerequisite for any ambitious climate action in the context of low-carbon electrification efforts in other sectors of the economy. Electrification trends that are vital for successful sectoral transitions in other sectors such as an increase of electricity mobility in the transport sector, depend on future low-emission electricity supply to effectively reduce overall GHG emissions (Kuramochi et al., 2018).

vi. **Co-benefits potential and sustainable development goals:** The transition away from coal-based electricity generation towards a predominantly renewables-based electricity generation offers significant potential to generate co-benefits. The most significant potentials for co-benefits include job growth in the renewables sector and other low-carbon-oriented sectors, sustainable local industrial development and innovation, and a reduction of air pollution from coal combustion. Such co-benefits directly contribute to several of South Africa's sustainable development goals and further substantiate progress achieved over the last decades (STATS South Africa, 2017), such as promoting access to affordable, reliable, sustainable and modern energy for all (SDG 7).

3.2 Passenger transport in urban areas

The South African urban passenger transport sector has been chosen for in-depth analysis as the criteria of **potential for scaling up climate action**, **existing gap** and **co-benefits potential** are all highly applicable to this sub-sector in South Africa. As half of all transport-related emissions occur in cities, there is an urgent need for a transition towards sustainable urban transport systems worldwide (Worldbank, 2018). The need for transition further arises from sustained urban populations putting pressure on inadequate existing transport infrastructure and high levels of air pollution from fuel combustion, which affect societal health. Thus, the development of sustainable urban transport systems is mandatory, not only from a climate perspective, but also from social and economic perspectives (McKinsey Center for Business and Environment, 2017).

i. **GHG emissions:** Direct road transport contributed to a moderate share of 8% in national emissions in 2012 (Department of Environmental Affairs, 2016a) with about 50% of these emissions stemming from passenger transport. Direct emissions are projected to almost triple by 2050 under a scenario considering currently implemented and planned policies (Department of Transport, 2017b). Annual transport-related emissions from the major South African cities of Johannesburg, Cape Town and Durban add up to almost 20 $MtCO_2$ with urban population and corresponding transport-related emissions expected to significantly increase by 2050 (C40, 2017).

ii. **Existing gap:** Currently implemented policies clearly fail to transform the South African transport sector in line with a 1.5°C Paris Agreement compatible emission trajectory (see Section 2.2). Available projections for South Africa indicate that future emissions will significantly increase under policies implemented on a national and subnational level (Department of Transport, 2017b).

iii. **Potential for scaling up climate action**: Urban passenger transport in South African (and worldwide) inherently possesses a vast potential for scaling up climate action by introducing zero-carbon transportation and shifting away from private vehicle use. Several cities have proven capable of leveraging such opportunities as the examples of

Tokyo, Stockholm or Bogota illustrate (Arthur D. Little Global, 2014; Observatorio de Movilidad, 2016). City-level action on urban passenger transport oftentimes face less bureaucratic and political hurdles and can be tailored more conveniently to local needs and circumstances. Several promising policy approaches and pilots have been implemented in South Africa already in recent years, including bus rapid transit systems, integrated public transport network strategies, and intelligent transport system strategies (Department of Environmental Affairs, 2017b).

iv. **Priority in the national discourse:** Unequal access to (urban) mobility inherited from apartheid has still not been successfully overcome and constitutes a pressing policy issue for local municipalities (Department of Transport, 2017b; Prim, 2016; Thomas, 2016). Furthermore, sustained growth in urban populations and a subsequent increase in urban mobility demand cannot be met in a sustainable manner by the existing transport infrastructure heavily relying on private vehicles. Accordingly, several city authorities already strive to initiate a modal shift away from private vehicles towards public transport (City of Johannesburg, 2017; eThekwini Transport Authority, 2010; Gauteng Province Department of Roads and Transport, 2013; Transport and Urban Development Authority Cape Town, 2016).

v. **Overlap with other sectors:** Ongoing academic debate deals with the question of how electrification trends in the transport sector and the decarbonisation of the electricity supply sector might interact on national and local levels. While the sustainable electrification of transport relies on zero-carbon electricity generation to effectively reduce emissions, a large electric vehicle fleet may potentially facilitate high renewable energy penetration of the electricity supply sector by serving as a large battery storage.

vi. **Co-benefits potential and sustainable development goals**: Policy interventions in urban passenger transport have the potential to provide equitable, safe and clean mobility choices to citizens and thereby facilitate economic development and social participation. Integrated transport planning and electrified mobility might particularly reduce congestion, air pollution, and severe accidents (Day et al., 2018). Such co-benefits might considerably contribute to South Africa's sustainable development goal. For example, the reduction of air pollution can also reduce rates of cardiovascular disease, cancer, diabetes and chronic respiratory disease, thus also reducing mortality rates. This then also promotes SDG 3's provision of healthy lives and well-being for all ages.

3.3 Residential buildings sector

The South African residential buildings sector has been chosen for in-depth analysis as the criteria of **existing gap**, **priority in national discourse**, and **co-benefits potential** are all highly applicable to this sector in South Africa.

i. **GHG emissions:** While direct energy use in the residential buildings sector contributed to a moderate share of 4% of overall emissions in 2012 (Department of Environmental Affairs, 2016a), final energy consumption including electricity remains high an approximate 17% share in 2012 and is expected to further increase with an ongoing electrification trend.

ii. **Existing gap**: Current policies do not consider a transition of the South African residential buildings sector in line with a 1.5°C Paris Agreement compatible emission trajectory (see Section 2.3 for detailed explanation).

iii. **Potential for scaling up climate action**: The residential buildings sector offers significant potential for accelerated climate action up to 2030 and beyond, both on the national as well as municipal level. As outlined in the proposed Post-2015 National Energy Efficiency Strategy (Department of Energy, 2016b), further climate action could be implemented on the energy performance of newly constructed buildings, the renovation of existing residential buildings stock to improve thermal performance, and on energy efficiency improvements of appliances and lighting.

iv. **Priority in the national discourse:** Some recent policy developments in the residential buildings sector suggest opportunities for promising developments. This relates particularly to the introduction of energy efficiency requirements for newly constructed buildings (Sustainable Energy Africa, 2017) and the proposed sector efficiency targets in Post-2015 National Energy Efficiency Strategy introduced in 2016 (Department of Energy, 2016b). The latter aims for an overall 20% improvement in the average energy performance of the residential building stock by 2030 relative to a 2015 baseline value measured by the energy consumption (excl. plug loads) per m² of habitable space per year. The need for resource efficiency in housing due to South Africa's energy and water crisis will continue to provide a significant driver of accelerated climate action.

v. **Co-benefits potential and sustainable development goals:**

- **Social housing:** Social housing and the transition to low-emission buildings initiatives offer great synergies to achieve several social, health and economic benefits while initiating the transition towards a low-emission residential buildings sector. Several promising pilots for green and low-emission social housing have taken place in South Africa recently, even as implementation and enforcement of wider policies remain uncertain (Ampofo-anti, 2017; Didiza, 2014; PAGE, 2017). These co-benefits directly contribute to a range of sustainable development goals, particularly to make cities and human settlements inclusive, safe, resilient and sustainable (SDG 11).
- **Economic savings and job creation:** In the context of South Africa's economic stagnation, accelerated climate action in the residential buildings sector offers opportunities for job creation and local economic development linked to retrofitting and new construction of green and low-emission residential buildings (AIDC, 2016; World Green Building Council, 2016b). Such positive effects on both low and high-skilled employment, as well as local economic development support South Africa's development agenda in terms of employment (SDG 8), as well as improving the quality of education, skills development and innovation (SGD 9).

4 Scenario analysis of scaling up climate action in South Africa

This section presents detailed analysis of emission reduction potentials and selected co-benefits for three focus areas: **electricity supply, urban passenger transport in Gauteng, Cape Town, and Durban**, and the **residential buildings sector.** The quantification of emission reduction potentials of enhanced climate action and the respective co-benefits covers three different scenario categories presented in the following section. This approach allows comparison of sectoral emission trajectories and potentials for achieving mitigation co-benefits with different sets of indicator values, informed by recent research in the field. The comparison further allows the identification of overlaps or gaps between South Africa's sectoral emission trajectories and the sectoral transformations required for alignment with Paris Agreement targets on mitigation, other sector transformation case studies from international frontrunners, and alternate scenarios considering the specific national context. Where different analyses are available, some scenario categories present a range of indicator values, thus accounting for an upper and lower bound.

1.5°C Paris Agreement compatible benchmarks

The **scenario category of '1.5°C Paris Agreement compatible benchmarks'** comprises of sectoral indicator values, which are in line with a 1.5°C compatible sectoral emission trajectory. Where available, these indicator values are country-specific benchmarks (e.g. country-specific RES indictor values for different points in time until 2050). Otherwise, this scenario category relies on indicator values representing global average levels or levels from countries/regions/cities with similar characteristics as default indicator values. The analysis in this scenario category enhances the general understanding about required sectoral transitions in the national context to be in line with the most ambitious end of the Paris Agreement's temperature target.

Applying best-in-class level(s)

The **scenario category 'Applying sectoral best-in-class level(s)'** identifies indicator values from international and regional frontrunner(s) on national climate action in the respective (sub-)sector. The absolute indicator level(s) or growth rate(s) from such reference cases are applied to historical national developments in the respective sector. These scenarios illustrate what impact the replication of sectoral transitions achieved by international frontrunners would imply in the respective national context. This approach might only partially account for potential differences in economic, political, and geographical circumstances between the international or regional front-runners and the countries under analysis.

National scenarios

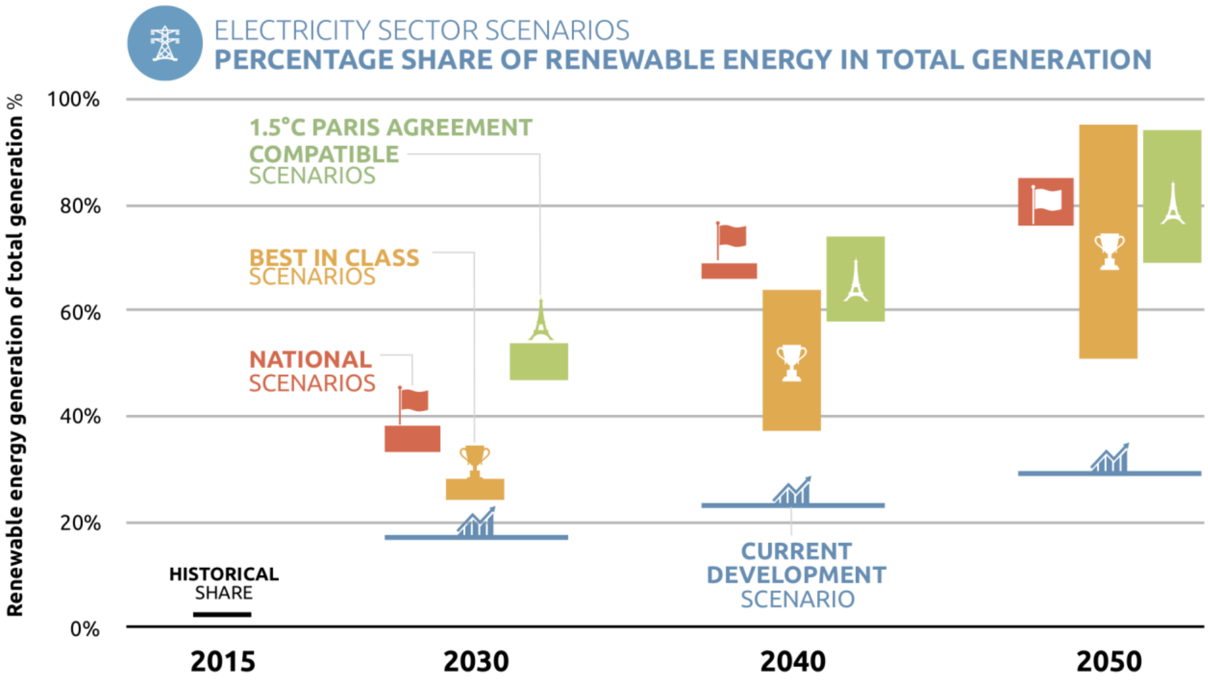
The **scenario category 'National scenarios'** applies sectoral indicator levels obtained from research conducted by national research institutions or governmental agencies of the respective country under analysis. Such analysis might include least-cost scenarios, analysis on the general potentials for (sub-)sectoral transformation or long-term strategies/sectoral plans proposed by national governments or national non-state actors. This scenario category aims to illustrate the sectoral emissions abatement potentials suggested by national studies that consider the country-specific circumstances.

4.1 Electricity supply sector

Scaling up climate action in the South African electricity supply sector can trigger significant emissions reductions for all scenario categories below a current development scenario by 2050. Our findings for South Africa highlight that under scenarios proposed by South African research organisations, greenhouse gas emissions for electricity generation in South Africa could be reduced by up to 83% below the current development scenario by 2050. Further action would be required to fully decarbonise the South African electricity supply sector by mid-century or shortly thereafter, while most ambitious scenarios applying best-in-class levels of international frontrunners ramping up renewable-based electricity generation would come close to a Paris Agreement compatible trajectory. These findings highlight the vast opportunities to initiate a transition toward a zero-carbon electricity supply sector in South Africa.

Table 14 provides an overview of the analysis results for scaling up climate action in the South African electricity supply sector. The table's upper graph presents the value ranges for the RES indicators for each of the three scenario categories. Figure 11 displays emission trajectories after quantification with the PROSPECTS South Africa scenario evaluation tool.

Table 14: Outcome overview of analysis on scaling up climate action in South Africa's electricity sector



Current Development Scenario (CDS)	National scenarios	Best-in-class scenarios	1.5°C Paris Agreement Compatible scenario
3% by 2015	-	-	-
17% by 2030	33–38% by 2030	24–28% by 2030	47%–54% by 2030
23% by 2040	66–69% by 2040	37–64% by 2040	58%–74% by 2040
29% by 2050	76–85% by 2050	51–95% by 2050	69%–94% by 2050
Based on PROSPECTS South Africa tool developed by Climate Action Tracker (2018)	*Based on 'Moderate Demand Scenario' analysis by Steyn et al. (2017) and 'Least Cost Scenario' by Wright et al. (2017)*	*Based on s-curve vRES update approach by Cornet at al. (2018) and values identified in the literature (Fekete et al., 2015)*	*Based on* 'Decarbonised Scenario' *by Wright et al.* (2017) and IPCC Special report (IPCC, 2018)

Required policy measures for sectoral transformation	Remaining challenges threatening implementation
⇨ Substantial grid infrastructure investments and grid management upgrade ⇨ Politically and socially negotiated solution for "just transition" out of coal mining and coal-based electricity generation ⇨ Sustainable support by government for policy measures promoting the large-scale uptake of renewables	⇨ Lack of willingness by political leadership to initiate ambitious sectoral transformation ⇨ High influence and political leverage of several stakeholders representing narrow interests ⇨ Unsolved problems of chronical mismanagement and financial solvency with state-owned utility Eskom

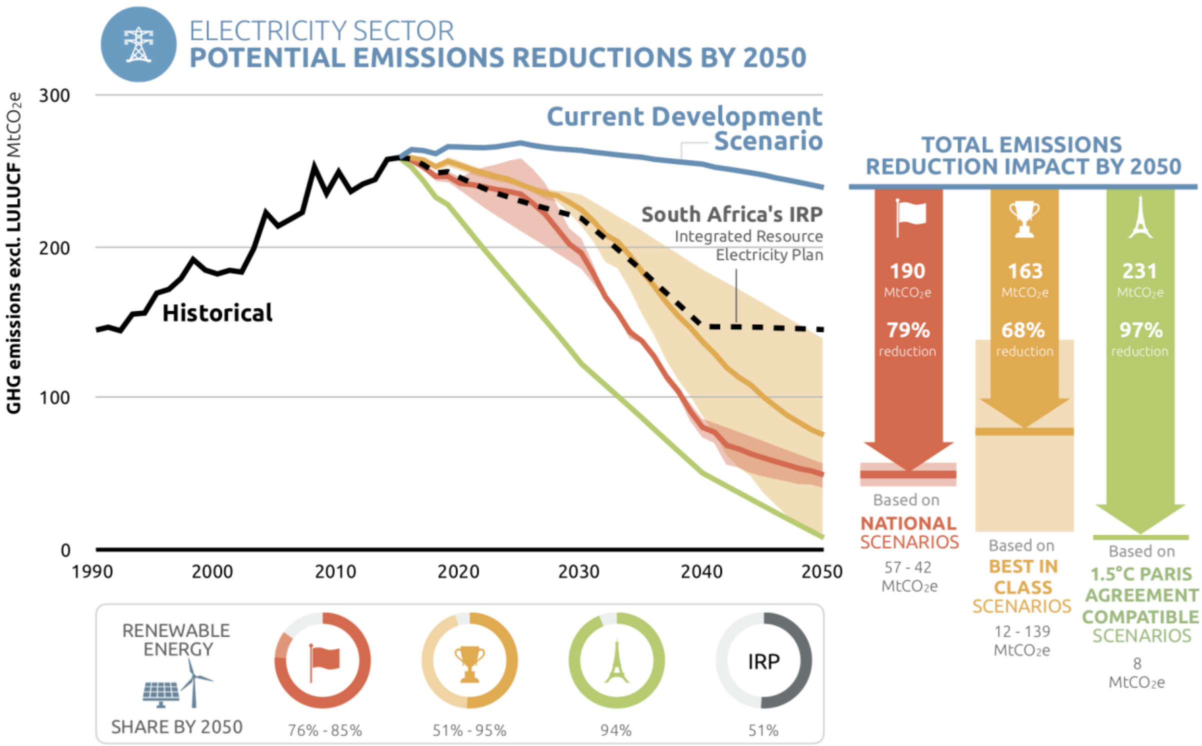


Figure 11: Overview of sectoral emission pathways under current policies and different levels of accelerated climate action in the South African electricity supply. The forecasted electricity demand considers accelerated climate action in the South African residential buildings and urban transport sector in Gauteng, Cape Town, and Durban. All sectoral projections towards 2050 done in the CAT PROSPECTS South Africa scenario evaluation tool.

4.1.1 South African context for scaling up climate action in the electricity sector

Sector transformation towards renewables is financially feasible

National and international price developments for renewable technologies and advanced storage technologies make a transition of South Africa's electricity supply sector away from coal-based electricity generation by mid-century or shortly thereafter financially feasible. Most recent analysis by national research organisations show that solar, wind, and flexible power technologies such as gas power plants are the least-cost electricity generation options for newly built capacity in South Africa (Hartley et al., 2017; Wright et al., 2017). The proposed IRP update of 2018 by the Department of Energy confirms these findings, although the submitted policy adjusted scenario accounts for other generation technologies due to political considerations (Department of Energy, 2018). Even with a conservative modelling approach — including pessimistic assumptions for new technologies and optimistic assumptions for established technologies — the least-cost pathway for all new capacity investments is to build solar PV, wind or flexible power plants (Wright et al., 2017). In-depth analysis considering comprehensive data on South African coal plants obtains similar results (Steyn et al., 2017). The transition to least-cost electricity generation in the future substantiates South Africa's ambition to promote country-wide access to affordable, reliable, sustainable and modern energy (SDG 7).

Tariffs for renewable technology auctions in South Africa and around the world have sharply decreased (IRENA, 2017; Wright et al., 2017). Government planning by the Ministry of Energy until recently has inadequately addressed these general developments of renewables and conventional technologies, e.g. overestimating renewables and underestimating the cost of conventional technologies. Another example, the newly proposed IRP update of 2018 still includes annual build-constraints for renewable energy deployment of 1 GW in solar PV and 1.6 GW in wind respectively (Department of Energy, 2018). The plan emphasises that such build limits do not affect the total installed capacity and energy mix for the period up to 2030.

However, further cost reductions of renewables forecasted in the nearby future are not properly reflected in choosing the energy mix up to 2030 and 2050.

South Africa has a high renewable energy resource potential for solar PV and wind with vast areas of South Africa suitable for generating electricity at low-cost from renewable energy (Hartley et al., 2017; Knorr et al., 2016). Both stable and abundant solar radiation and onshore wind resource would allow South Africa to further expand renewables-based electricity generation at comparatively low costs, also including decentralised electricity generation.

Growing costs of conventional coal technologies, including those currently under construction, are increasingly become a financial burden for South Africa. The outdated and inefficient coal plant fleet imposes a financial burden on Eskom due to increasing fuel costs, required maintenance and refurbishment, and necessary investments to comply with legislative environmental standards (Steyn et al., 2017). Recent analysis suggests that new coal capacity awarded under South Africa's coal baseload independent power producer (IPP) procurement programme will substantially raise the overall cost of electricity supply and is not necessary to meet future demand (Ireland & Burton, 2018). Recent research forecasts further increases in coal prices in South Africa due to more-costly exploration operations and switch in contract-structures (Hartley et al., 2017; Steyn et al., 2017).

Long-term planning and investments in transmission and grid infrastructure indispensable

The transition toward a predominantly renewables-based electricity supply requires advanced long-term planning of transmission, grid connection, and grid management infrastructure. Such forward-looking planning comprises adjustments during the early stage, the medium stage planning on introducing market design concepts and enhancing the system infrastructure's flexibility and stability, as well as the advanced stage (or stabilisation) planning such as storage and sector coupling. Recent analysis suggests that the South African power system already has sufficient flexibility amongst existing and planned power plants to handle short and medium term renewable capacity additions of 4.2 GW of wind and 12.8 GW of solar PV by 2020, rising to 11 GW of wind and 27.5 GW of solar PV by 2030 with only moderate additional costs (Obert & Pöller, 2017).

Long-term planning for the energy sector's transition enable the South African government to better understand required improvements in grid infrastructure, respective investment needs, and the need to mobilise international financial and technical assistance. For example, Eskom and KfW, the German development bank, signed a $100 million loan facility to connect renewable-power projects run by independent producers to the grid (Burkhardt, 2018), mainly expanding the transmission network in the Northern Cape province. With an increasing share of (variable) renewable generation capacity and storage connected to the grid, investments in modernising, expanding and updating the South African electricity grid will become significantly more important to successfully realise the sector's transition towards a zero-carbon society.

Job benefits, local economic development, and "just transition"

An ambitious transition towards a predominantly renewables-based electricity supply fosters significant employment generation in low-carbon-oriented sectors, local economic development opportunities, and the reduction of air pollution from coal combustion. National analysis on the previously proposed but never adopted IRP update of 2016, for example, suggested that a fully decarbonised electricity supply sector by mid-century could create as much as 112,000-144,000 direct and indirect jobs annually (Wright et al., 2017). The South African Photovoltaic Industry Association (SAPVIA) estimates job creation of 55,000 local jobs by 2025 in the solar photovoltaic industry alone assuming an installation of 1.5 GW annually (Beetz, 2017). South African policy makers acknowledge the positive employment effects of accelerated climate action. Most prominently, Energy Minister Jeff Radebe explicitly mentioned that renewable independent power producer projects could create over 114,000 'job years' (Omarjee, 2018), where a job year is equivalent to a full-time employment opportunity for one person, for one year.

These opportunities for employment impacts and local development of an accelerated energy transition go hand-in-hand with early planning for a 'just transition' away from coal-based electricity generation. Eskom employs around 8,000 employees in 15 coal power plants in South Africa (Steyn et al., 2017). The South African coal mining industry directly employed around 77,000 people in 2016 (Chamber of Mines in South Africa, 2018), representing about 17% of the total mining workforce. Coal mining in South Africa further creates about 170,000 indirect employment opportunities, mainly in transportation and storage of coal products according to coal mine associations. The political task of reconciling the needs (1) to eradicate (energy) poverty, (2) to provide reliable employment opportunities during the recent economic crisis, (3) to manage a "just transition" for all communities affected by a potential coal phase-out, and (4) to protect the South African eco-system services and natural resources, remains a crucial challenge that needs to be considered in any discussion about phasing-out coal (Sartor, 2017).

Employment generation and local industrial development in sectors that are more likely to form the core of electricity supply in the future, both in South Africa and globally, directly enable South Africa to promote sustainable economic growth and employment as provisioned in SDG 8 and SDG 9. Evidence from other developing and developed countries worldwide emphasises that energy transitions towards a predominately renewables-based electricity generation by mid-century and beyond entail (IRENA, 2018b).

4.1.2 Scenario analysis for scaling up climate action in the electricity sector

4.1.2.1 Identification of indicator levels

Table 15 provides a complete overview of indicator levels identified for the three scenario categories. The indicator levels have been directly input into the PROSPECTS South Africa scenario evaluation tool alongside the current development scenario to conduct the emission pathway analysis for the South African electricity supply sector.

Table 15: Identification of indicator levels for scaling up climate action in the electricity supply sector

	Current Development Scenario (CDS)	National scenarios	Best-in-class scenarios	1.5°C Paris Agreement Compatible scenario
Share of renewables in total electricity	3% by 2015	-	-	-
	17% by 2030	33–38% by 2030	24–28% by 2030	47%–54% by 2030
	23% by 2040	66–69% by 2040	37–64% by 2040	58%[1]–74% by 2040
	29% by 2050	76–85% by 2050	51–95% by 2050	69%–94% by 2050
References	*Based on PROSPECTS South Africa tool developed by Climate Action Tracker (2018)*	*Based on 'Moderate Demand Scenario' analysis by Steyn et al.* (2017) *and 'Least Cost Scenario' by Wright et al. (2017)*	*Based on s-curve vRES update approach by Cornet at al.* (2018) *and values identified in the literature (Fekete et al., 2015)*	*Based on* 'Decarbonised Scenario' *by Wright et al.* (2017) and IPCC Special report (IPCC, 2018)

[1] *Value obtained through linear interpolation of IPCC special report RES benchmarks for 2030 and 2050* (IPCC, 2018).

1.5°C Paris Agreement compatible benchmarks

The 1.5°C Paris Agreement compatible benchmarks represent sectoral indicator values for the renewable energy share (RES) in total electricity generation, which are in line with a 1.5°C Paris Agreement compatible emission trajectory for the South African electricity supply sector. The review of relevant literature in the field identifies a RES indicator range of **47% to 54% by 2030**, **58% to 74% by 2040**, and **69% to 94% by 2050**. The benchmark values have been derived from the following literature:

- **Upper bound of the RES indicator range**: The upper bound indicator values are based on the 'Decarbonised Scenario' analysis by the CSIR Energy Centre as part of their *Formal comments on the Integrated Resource Plan (IRP)* (Wright et al., 2017). The 'Decarbonised Scenario' analysis models a least-cost energy sector development under the constraint of 95% sectoral emission reductions by 2050, including an early coal fleet decommissioning. The modelling yields a RES of **54% by 2030**, **74% by 2040**, and **94% by 2050** required to achieve a 95% emission reduction.
- **Lower bound of the RES indicator range**: The lower bound indicator values are based on the world average benchmarks for RES (%) in generated electricity defined in the IPCC Special Report on the impacts of global warming of 1.5 °C (IPCC, 2018). Table 16 summarises these findings according to Figure 3B of the IPCC special report. For the South Africa analysis at hand, the benchmarks applied use the lower range of the interquartile range for no or low overshoot: **47% by 2030** and **69% by 2050**. It is important to note that this benchmark for RES alone is insufficient to reduce sector emissions in line with the Paris Agreement temperature target if the remaining electricity generation stays GHG emission intensive (i.e. other than low-/zero-carbon).

Table 16: Identification of indicator levels for renewables share in electricity generation (in %) in Figure 3B of the IPCC Special Report on the impacts of global warming of 1.5 °C (IPCC, 2018). *P4 scenarios have been excluded in this table as these scenarios assume a high overshoot.*

Renewables share in electricity generation (in %)	P1 - No or low overshoot	P2 - No or low overshoot	P3 - No or low overshoot	Interquartile range - No or low overshoot
by 2030	60%	58%	48%	(47%,65%)
by 2050	70%	81%	63%	(69%,87%)

Applying best-in-class levels

Applying best-in-class levels of international frontrunners in raising the renewable energy share in total electricity generation suggests a model on how the South African electricity sector might also transform under similar developments. The application results in a RES indicator ranges of **24–28% by 2030**, **37–64% by 2040**, and **51–95% by 2050**. The range of RES indicator values have been derived as follows:

- **Upper bound of the RES indicator range**: The upper bound indicator values have been obtained by applying an s-curve shaped good practice trajectory for the uptake of variable renewable-based electricity generation (i.e. solar and wind) to South Africa's recent sector developments as of 2015. The s-curve has been fitted to Denmark's historical growth in share of renewables generation between 2009 and 2015 (19.2% to 39.2%) and an upper ceiling as defined by Denmark's long-term target of 100% renewable electricity generation by 2050. The summary report by Cornet at al. (2018) explains the methodological approach in more detail. The results for South Africa with a share of variable renewable-based electricity generation of 2% in 2015 are 22% by 2030, 59% by 2040, and 88% by 2050. The RES including non-variable forms of electricity generation are **28% by 2030**, **64% by 2040**, and **95% by 2050**. This share only includes variable renewable energy sources. The s-curve based approach to apply best-in-class levels narrowly focuses on variable renewables while not modelling the uptake of other low-carbon electricity generation technologies. The approach allows the user to set values by 2050 for biomass, nuclear, and hydro generation informed by the lifetime of currently existing capacity and/or external projections until 2050. No such additional assumptions have been applied for South Africa.

- **Lower bound of the RES indicator range**: The lower bound values represent a linear increase of 1.35 %-points per year in South Africa's share of renewable-based electricity generation. The annual increase in %-points is informed by the average growth of renewable energy in the United Kingdom and in Germany after the implementation of ambitious renewables support policies (Fekete et al., 2015). The results for South Africa starting with a share of renewable-based electricity generation of 3% in 2015 (incl. hydro) are **24% by 2030**, **37% by 2040**, and **51% by 2050**. This linear approach faces the limitation that no dynamic uptake in the renewable energy can be incorporated, especially when reaching the natural threshold of 100% in total generation.

National scenarios

Recently published modelling results by South African research institutions inform the selection of RES ranges for national scenarios in the South African electricity sector. The RES indicator ranges are **33–38% by 2030, 66–69% by 2040**, and **76–85% by 2050**. The range of indicator values have been informed by the following modelling results:

- **Upper bound of RES indicator range**: The upper bound values are informed by the 'Moderate Demand Scenario' analysis conducted by the CSIR Energy Centre using updated data on all South African coal plants by Steyn et al. (2017). The analysis models a least-cost electricity sector development for South Africa until 2050 under moderate electricity demand projections and detailed levelised cost data for all South African coal plants such as plant-specific generation costs. The RES indicator value ranges are **33% by 2030**, **69% by 2040**, and **85% by 2050**.
- **Lower bound of RES indicator range**: The lower bound indicator values are based on the 'Least Cost Scenario' analysis by the CSIR Energy Centre as part of their *Formal comments on the Integrated Resource Plan (IRP)* (Wright et al., 2017). The 'Least Cost Scenario' analysis models a least-cost energy sector development until 2050 under no constraints in renewable capacity additions. The estimates for cost reductions for renewables are aligned with the latest auctioning results under the REPPPP. The modelling results indicate a RES share of **38% by 2030**, **66% by 2040**, and **76% by 2050**. The alternative 'Least Cost Scenario - Expected costs' results in slightly higher RES shares of 36% by 2030, 67% by 2040, and 76% by 2050, while assuming additional cost reductions for solar PV, wind, CSP, and battery technologies applied in comparison to the 'Least Cost Scenario' scenario.

4.1.2.2 Quantification of emission levels with PROSPECTS South Africa

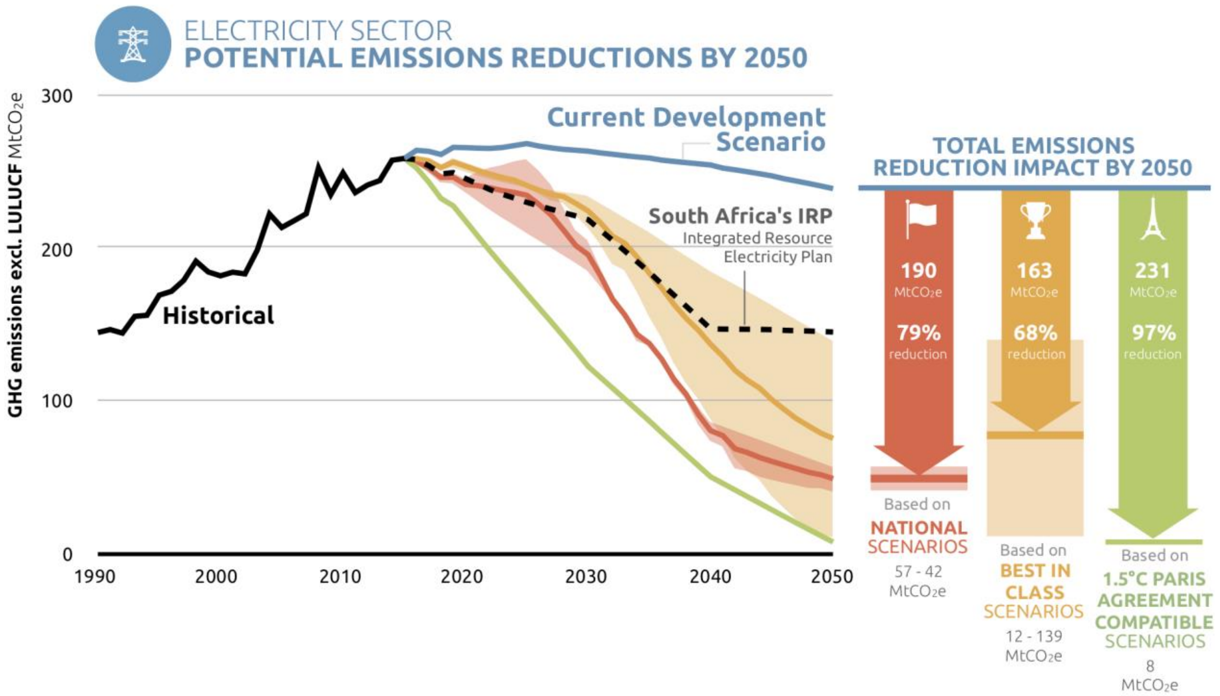


Figure 12: Overview of sectoral emission pathways under current policies and different levels of accelerated climate action in the South African electricity supply. The forecasted electricity demand considers accelerated climate action in the South African residential buildings and urban transport sector in Gauteng, Cape Town, and Durban. All sectoral projections towards 2050 done in the CAT PROSPECTS South Africa scenario evaluation tool.

Figure 12 illustrates the emission ranges for emissions from electricity generation up to 2050 under the different scenario definitions. Under the *current development scenario*, emissions continue increasing up to 2025 and slightly decrease afterwards. The emission levels in 2050 are around 19 $MtCO_2e$ below 2015 levels. The scenario reflecting the electricity generation split of the draft IRP update of 2018 up to 2050 released in August 2018 represents a variation of the current development scenario (Department of Energy, 2018). Although the proposed *policy adjusted scenario* only covers a period until 2030, other modelled scenario runs in the proposed report update such as the IRP3 cover the entire period until 2050.[7] The IRP3 scenario leads to directly bending the electricity sector's emissions curve downwards, followed by a steady decrease of emissions up to 2040. After 2040, the IRP3 only foresees a slight decrease in the share of coal in electricity generation. Thus, overall emission levels remain constant even with increasing electricity demand.

All pathways under accelerated climate action in the South African electricity sector lead to emissions substantially lower than the current development scenario by 2050. The pathways vary in the level of emissions reached by 2050 and the distinct pathway trajectories:

- The '**1.5°C Paris Agreement compatible' pathway** starts decreasing emissions immediately, driven by a quick ramp-up of renewable electricity generation and decreasing coal-fired generation. The rates of reduction are almost constant over time. The sector fully decarbonises by mid-century implying a complete electricity supply from renewables and other low/zero-carbon technologies. Note that we have excluded the less ambitious end of renewable energy shares from the emissions estimates, as the benchmark itself allows the remaining electricity generation to remain carbon-intensive, and thus results in emission levels that are incompatible with the Paris Agreement's temperature limit.
- The '**Applying best-in-class levels' pathway** continues to keep emissions at about today's level and starts decreasing emission levels from 2020 onwards. The long-term

[7] The IRP3 scenario assumes median electricity demand forecast and an annual renewable built limit of 1 GW of solar PV and 1.6 GW of wind (Department of Energy, 2018).

reductions of the upper end of the range are moderate, while the lower end starts decreasing emissions at a high rate around 2030, and almost leads to a complete decarbonisation of the South African electricity supply sector by 2050 with only 12 $MtCO_2e$ emitted in that year.

- The '**National scenarios' pathway** reveals a significant range in the first two decades: the upper end of the range increases emissions, driven by an increase in electricity generation in parallel to sustaining a high share of coal-based generation. The lower end of the range starts reducing emissions quickly with the share of renewables rapidly increasing early on. In the medium-run, the scenario range converges towards 2035. The scenario with early adoption of a higher share of renewables becomes the scenario with higher emission level in the long term (higher bound of emission range by 2050). The scenario with the strong emissions increase in the 2020s partially compensates for this and goes to lower levels by 2050 (lower bound of emission range by 2050). Under both scenarios, the pace of reduction is extremely high in the 2030s, and then slows down in the 2040s.

Table 17: Key indicators describing the scenarios for GHG emissions from the electricity supply sector in South Africa for the period between 2015–2050.

Scenario	Year of peaking	Maximum rate of reduction [absolute reductions in MtCO2e/yr]	Remaining emissions in 2050 [MtCO2e/yr]
Current Development Scenario (CDS)	2025	2.0	239
IRP3 of Draft IRP 2018 update	Immediate	7.5	145
1.5°C Paris Agreement compatible	Immediate	10.3	8
Applying best-in-class levels	Immediate to 2020	5.3–16.4	12–139
National scenarios	Immediate to 2025	10.2–21.3	42–57

The total electricity generation varies between different scenario categories due to changes in climate action in other sectors, e.g. increased electrification of urban passenger transport and electricity savings in households (see Figure 13). In ambitious climate action scenarios with lower electricity demand, less renewable capacity is required to achieve the same relative share of renewable electricity supply. The forecasted electricity generation continues to increase substantially until 2050 under all scenarios.

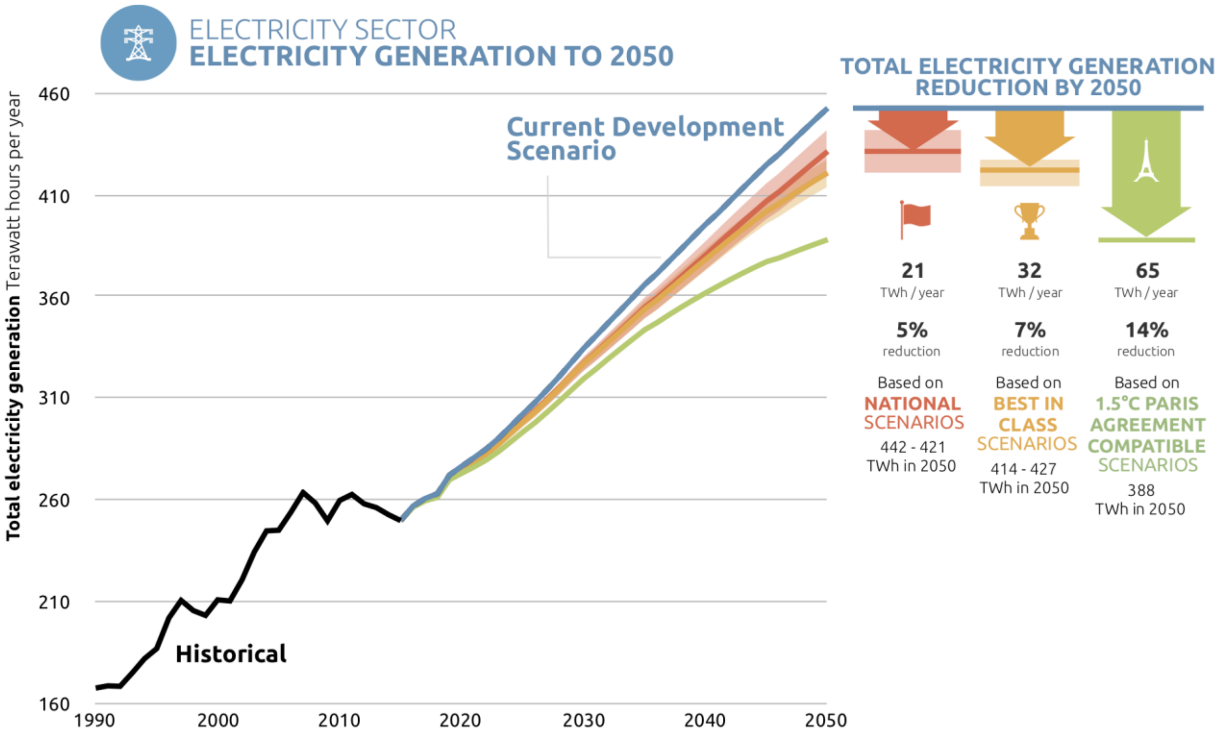


Figure 13: Total annual electricity generation (in TWh/yr) in South Africa under different scenario categories, considering the demand side effects from accelerated climate action from urban passenger transport and residential building sector in the respective scenario categories. All sectoral projections towards 2050 done in the CAT PROSPECTS South Africa scenario evaluation tool.

4.1.2.3 Quantification of employment impacts for different scenarios

Overall direct and indirect employment impacts

The quantification of employment impacts for different electricity supply sector scenarios between 2016 and 2030 reveals that job generation is broadly similar across all scenarios. Under a current development scenario, approximately 106 thousand people per year are directly employed in the development of new capacity and the operation and maintenance of both existing and new capacity on average per year over the period between 2016 and 2030. We estimate that the investments would stimulate a further 180 thousand indirect and induced jobs on average per year.

The estimated employment impact across all other scenarios is of a similar order of magnitude. They range between approximately 100–129 thousand direct jobs per year and 275–350 thousand jobs when considering the wider indirect and induced impacts of the investments. Direct employment estimates are relatively broad in scope reflecting investments linked to planning, construction, the manufacturing of component parts, operation (including fuel supply, where relevant) and maintenance of power plants. Total employment further considers the indirect impact of electricity supply investments through the supply chain –for example the production of cement for concrete foundation of wind turbines – as well as induced economic impacts driven by the spending of wages throughout the economy.

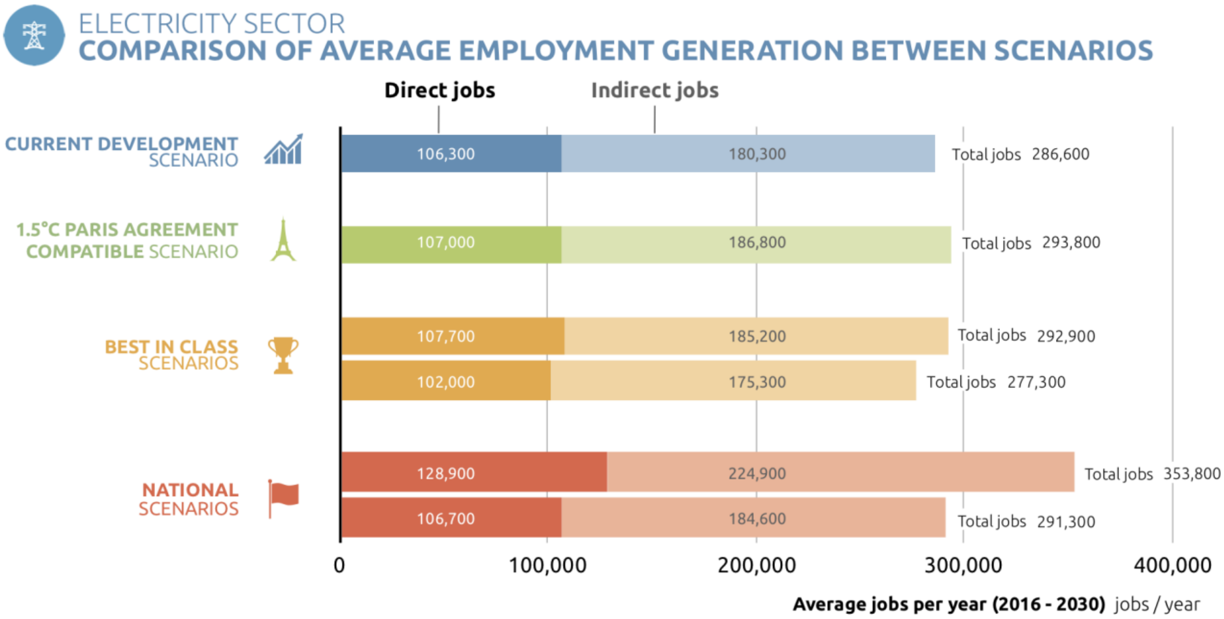


Figure 14: Average direct employment generation per year between 2016–2030 (orange) and average total employment generation per year between 2016–2030 (grey) in South Africa for different electricity generation scenarios.

Low-carbon-oriented employment opportunities and a "just transition" away from coal

Electricity supply sector scenarios with accelerated renewables deployment gradually substitute coal mining jobs with jobs in manufacturing, and construction of renewables, combined cycle gas and peaking generation capacity. These findings emphasise the employment potential of accelerated climate action in the electricity generation sector while at the same time highlight the need for a "just transition" for those communities affected by diminishing mining jobs.

Coal-fired generation is the main incumbent technology in South Africa's electricity supply sector today. A current development scenario with high coal dependencies continues to support significant local employment, particularly in the mining of the fuel throughout the period to 2030 (see Figure 15). These jobs in coal mining and fossil fuel-based electricity generation are at risk if South Africa commits to decarbonise its electricity sector in line with the Paris Agreement temperature target and are therefore less sustainable in the medium to long-run.

Estimates of direct job creation under different electricity generation scenarios in Figure 15 do not consider overall productivity improvements in the South African (coal) mining sector. Our findings remain conservative in nature as they do not account for "natural" job loss in the coal mining related to such productivity improvements in a current development scenario.

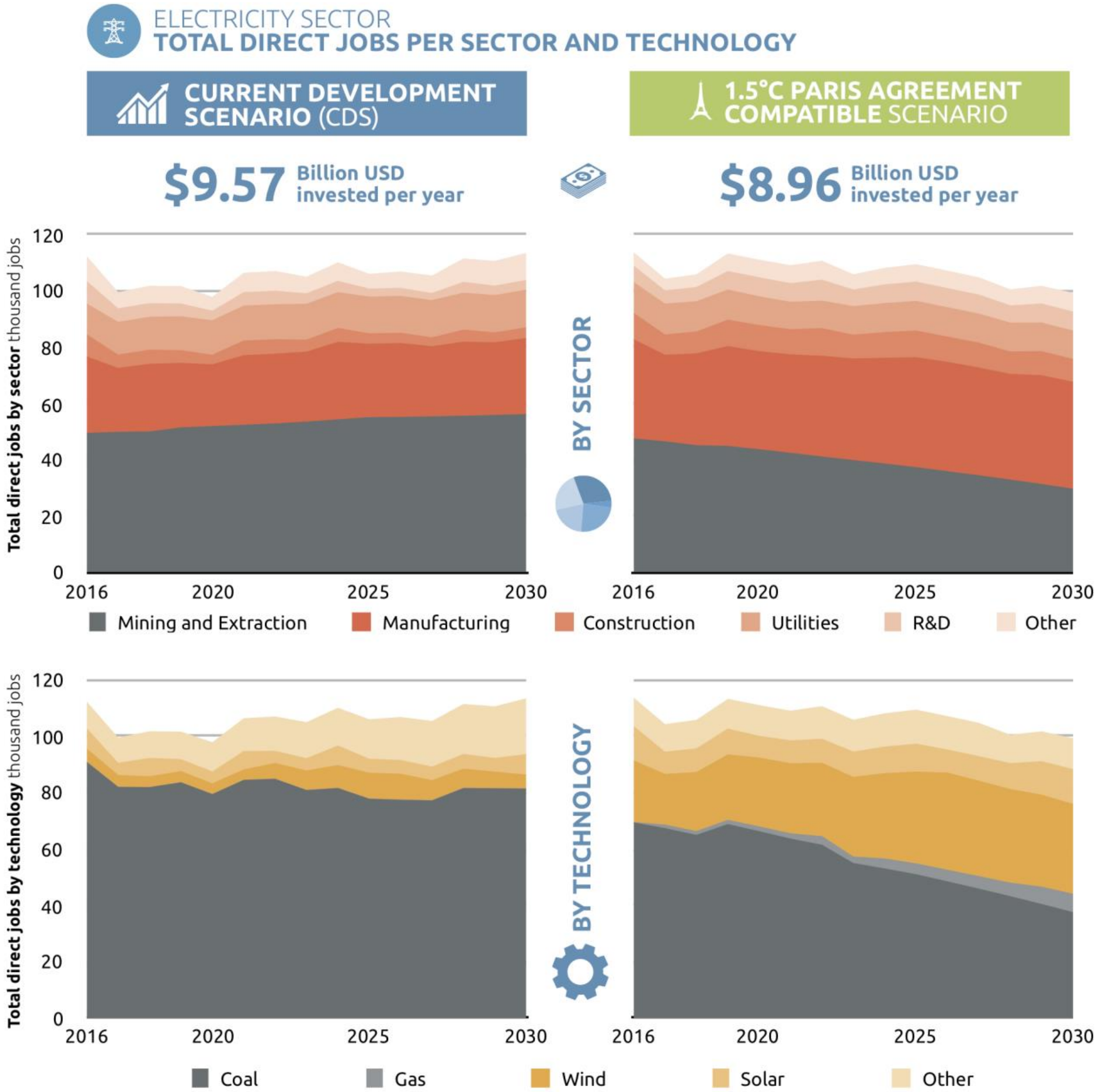


Figure 15: 'Total direct jobs per employment sector' and 'Total direct jobs per generation technology' between 2016-2030 for the Current Development Scenario (CDS) (graphs on left) and the 1.5°C Paris Agreement compatible scenario for the South African electricity supply sector (graphs on right). Direct employment estimates reflect energy supply sector investments linked to planning, construction, the manufacturing of component parts, operation (including fuel supply such as coal mining, where relevant) and maintenance of power plants.

Alternative scenarios in which renewable capacity is expanded to meet the increase in electricity demand generate equivalent levels of more sustainable employment. These jobs are in technologies and sectors that are more likely to form the core of electricity supply in the future, both in South Africa and globally.

Investing today in growing the supply chain of low carbon electricity supply technologies will allow South Africa to manage a gradual, just transition away from coal sector employment. The pathways for a Paris Agreement compatible scenario in Figure 15 show a steady decline in coal-based jobs over time, particularly in the mining sector, which are largely replaced by manufacturing and construction jobs. A well-managed transition could be delivered via the usual turnover of the workforce in combination with fewer opportunities to join the sector. The investment savings in the lower carbon scenarios could also be channelled to supporting re-training opportunities for existing coal sector employees. A coordinated just transition can therefore avoid the risk of sudden large-scale unemployment in the coal sector and the costly social and political problems that would likely emerge from this outcome.

Total investment under different electricity generation scenarios

The projection under the upper bound of the national scenario range requires the largest investment of all the scenarios. This drives slightly higher absolute employment impacts than lower cost pathways such as the Paris Agreement compatible scenario. The vertical axis of Figure 16 shows that the number of direct jobs created per unit of investment is highly similar across scenarios (between 11-12 job years per million USD) with the most jobs per unit of investment in the Paris Agreement compatible scenario and the upper bound of the national scenario range. However, the scenarios differ in terms of their total investment requirements over the period to 2030.

Investment requirements per unit of electricity generation is lowest in scenarios with high shares of wind and solar PV through the entire period between 2016 and 2030 at approximately 31 USD of investment required on average to deliver each unit of output. Heavily coal-based scenarios such as the current development scenario or the upper bound of the national scenario range are more expensive per unit of output. The latter requires an average investment of approximately 38 USD per MWh. This difference stems from the higher levelised costs of electricity (LCOE) for coal-based generation compared to solar PV and wind and the increased investment requirements drive the higher absolute estimates of job creation. These differences in investment required on average to deliver each unit of output further substantiate when considering the period up to 2050.

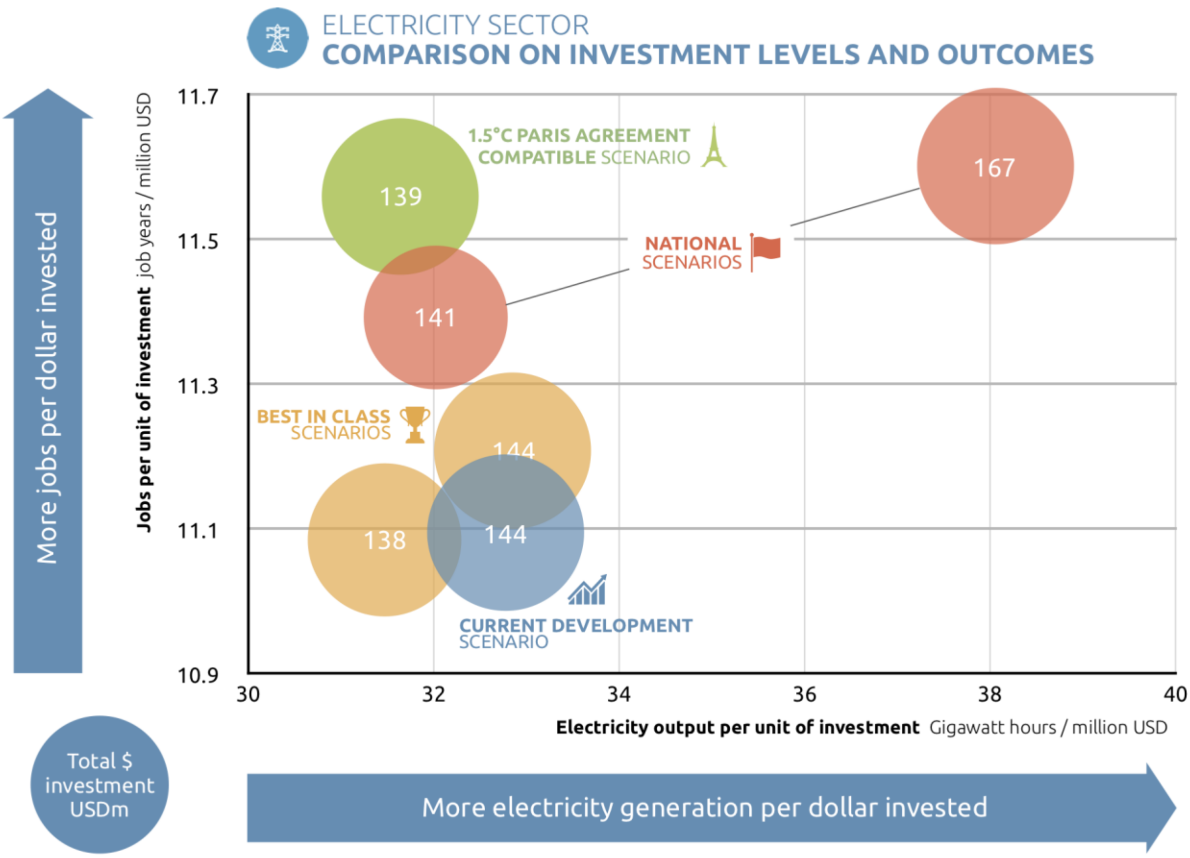


Figure 16: Average job generation per investment (in job years per USDm) and average investment per unit of electricity generation (in GWUSD per MWh) in the South African electricity supply sector for different electricity generation scenarios between 2016–2030.

4.2 Passenger transport in urban areas of Gauteng, Cape Town and Durban

This section analyses the mitigation impact that a transition toward higher deployment of public and electrified modes of transport can have in the three South African metropolitan areas: Gauteng as the central urban agglomeration of South Africa with Johannesburg and Pretoria at its centre, as well as the cities of Cape Town and Durban.

In the most ambitious scenario compatible with the Paris Agreement temperature goal, the urban passenger transport in three urban areas of Cape Town, Durban, and the Gauteng province including Johannesburg and Pretoria fully decarbonises by 2050 through shifting towards public modes of zero-carbon transport and increased electric mobility.

Achieving this critically hinges on the electricity supply sector decarbonising in line with the Paris Agreement temperature goal. Such ambitious policies in three major urban areas alone can stabilise the total emission levels of the South African ground transportation sector—including freight transport—at around today's emission levels by 2050.

Table 18 provides an overview of the analysis results for scaling up climate action in the South African urban passenger transport sector. The table's upper rows present the value ranges for the sector-specific indicator values for each of the three scenario categories. Figure 17 displays the resulting emission pathways after quantification with the PROSPECTS South Africa scenario evaluation tool.

Table 18: Outcome overview of analysis on scaling up climate action in urban passenger transport sector

Indicator		Indicator values for scenario categories		
		1.5°C compatible benchmarks	**Applying best-in-class level(s)**	**National scenarios**
Share of public transport (bus, train and MBT) in urban passenger transport		**55%–61% by 2030 61%–71% by 2040 70%–80% by 2050**	**55%–61% by 2030 61%–71% by 2040 70%–80% by 2050**	*[No ambitious and comprehensive national scenario available, see further explanation in Section 5.2.2.1]*
		Based on international frontrunners of Bogota (67% share of public transport) and Hong Kong (80%) (LSE Cities, 2018; Observatorio de Movilidad, 2016)	*Based on international frontrunners of Bogota (67% share of public transport) and Hong Kong (80%) (LSE Cities, 2018; Observatorio de Movilidad, 2016)*	
Electric vehicle shares in urban vehicle fleet	**Personal Vehicle**	**44% by 2030 93% by 2040 100% by 2050**	**10%–14% by 2030 44%–46% by 2040 84%–85% by 2050**	
	Buses	**60% by 2030 97% by 2040 100% by 2050**	**10%–100% by 2030 54%–100% by 2040 90%–100% by 2050**	
	Minibus-Taxis	**62% by 2030 98% by 2040 100% by 2050**	**10%–14% by 2030 58% by 2040 92% by 2050**	
	Sources	*Based on benchmark for last fossil fuel vehicle sold in 2035 and EV shares in new sales of 100% in 2035* (Kuramochi et al., 2018)	*Based EV sales rate of San Jose for personal vehicles* (Lutsey, 2018) *and Shenzhen for buses and minibus taxis* (WRI, 2018)	

Required policy measures for sectoral transformation	Remaining challenges threatening implementation
⇨ Initiation of an ambitious modal shift towards public mass transport ⇨ Discourage use of private vehicles, while simultaneously promoting private electric vehicle purchase and invest in charging infrastructure ⇨ Expand public transport capacity while replacing the old public vehicle fleet with electric vehicles	⇨ Financial funding available in short- and medium term for required investments ⇨ Geographical circumstances in South African urban agglomerations such as Urban sprawl and low density ⇨ High private and public investment cost for electric vehicles and charging infrastructure

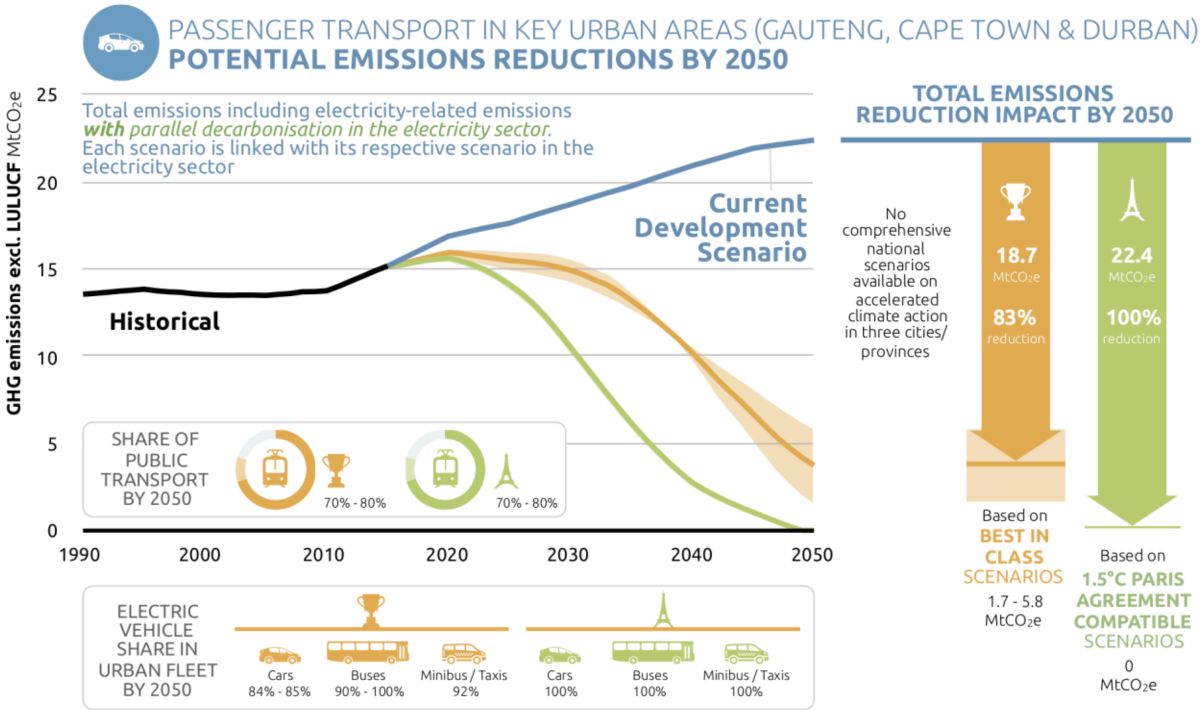


Figure 17: GHG emissions in the South African urban passenger transport sector in Cape Town, Durban, and the Gauteng province including Johannesburg and Pretoria, including electricity-related emissions and parallel climate action according to the respective scenario categories in the South African electricity supply sector. Historical emission levels for urban passenger transport in three urban areas under a Current Development Scenario (CDS) estimated using historical transport-related emission levels (C40 2018) as well as additional assumptions for the future increase in urban population and per capita transport demand (UN DESA, 2018).

4.2.1 Context for scaling up climate action in the urban passenger transport sector in South Africa

The historical heritage of apartheid city planning

The geographical structure of South African cities has significantly been shaped by spatial planning under apartheid that divided the city along race and class (Prim, 2016; Thomas, 2016). Transport systems were designed to enforce segregation and discrimination of citizens instead of facilitating their mobility, with investment being directed in favour of private cars predominantly in white areas (City of Johannesburg, 2017; Weakley & Bickford, 2015). As a result, apartheid has created sprawled and inefficient cities orientated towards privately owned cars (Bubeck, Tomaschek, & Fahl, 2014; City of Johannesburg, 2017; Weakley & Bickford, 2015).

Policy makers in today's post-apartheid South Africa still struggles to successfully address the social, economic and environmental deficits of this heritage (Thomas, 2016). Former townships located at the periphery of cities suffer from a severe undersupply of public transport. Correspondingly, its habitants that commonly have low income, are exposed to high travel cost, long travel patterns and limited access to mobility services, a phenomenon known as 'mobility-related exclusion' (Prim, 2016; Thomas, 2016; Weakley & Bickford, 2015). The end of apartheid was followed by a period of private sector oriented transport planning (Thomas, 2016). The long lasting lack of institutional public transport favoured the uptake of the privately owned minibus-taxis (MBT) that nowadays dominate public transport (Bubeck et al., 2014; City of Johannesburg, 2017; Gauteng City Region Observatory, 2014). The FIFA World Cup in 2010 boosted public investment in transport infrastructure such as bus rapid transit (BRT) systems in Johannesburg and Cape Town as well as the Gautrain (Gauteng City Region Observatory, 2014; Thomas, 2016; Weakley & Bickford, 2015). However, these interventions are controversially debated with regard to their impact to overcome inequalities in mobility (Jennings, 2015; Prim, 2016; Thomas, 2016; Weakley & Bickford, 2015).

South African authorities have fallen short on their promises of providing save and affordable mobility for all citizens. While urgent need for further action remains, South African authorities expect urban centres to grow in population with increasing rates of car ownership (Department of Transport, 2017b; Department of Transport South Africa, 2017; Gauteng Province Department of Roads and Transport, 2013). While some population groups still suffer from an undersupply of mobility, increasing use of personal vehicles enhances the threat of a grid-lock in South Africa's major cities (Department of Transport South Africa, 2017).

Emissions reduction options in the South African urban passenger transport sector

According to the emissions reporting under the C40 initiative, annual transport-related emissions from South Africa's three major cities (Johannesburg, Cape Town and Durban) sum up to almost 20 $MtCO_2$ (C40 Initiative, 2018), roughly 80% of which related to urban passenger transport. Under currently implemented policies, emissions from urban passenger transport will further increase by around 40% by 2050. **Among different option for emissions abatement in the urban passenger transport sector, this study considers modal shift away from private vehicles and transport sector electrification for in-depth analysis:**

- **Modal shift:** Shifting transport activity from modes with carbon-intensive emissions to modes with lower specific emissions can significantly reduce energy demand and average emissions per passenger kilometre. South African cities are governed by privately owned cars with vast potential for substantial modal shifts to urban passenger transport systems.
- **Electrification:** Replacing vehicles with internal combustion engines with electric or plug-in hybrid vehicles reduces tailpipe emissions to virtually zero. Absolute emissions from electricity generation in turn increases due to higher power demand, unless electricity generation is fully decarbonised.

Other options such as the reduction of transport activity through densification and decentralised infrastructure for mobility services, the introduction of emissions standards, or measures to increase load factors have not been considered in the scope of this study.

The role of modal shift for urban passenger transport systems

South African public authorities in several regions and cities already focus on expanding public transport networks in their integrated urban transport planning. Most prominently, Cape Town strives for public transport supplying 80% of all passenger trips (Transport and Urban Development Authority Cape Town, 2016). Without indication of clear target shares, the Gauteng Province Roads and Transport Department and the City of Johannesburg emphasise the importance of higher shares of public transport use in the future (City of Johannesburg, 2017; Gauteng Province Department of Roads and Transport, 2013). In Durban, a first phase of the "Go!Durban" integrated rapid public transport network is supposed to start operation before the end of 2018 (Go!Durban, 2018). With the implementation of BRT systems in seven major cities, South Africa has moved towards a phase of partial implementation (Zhang, 2017). Nevertheless, public authorities have been criticised for a lack of funding allocated to public transport infrastructure (Gauteng City Region Observatory, 2014; Sustainable Energy Africa, 2015).

Personal vehicles remain the predominant mode of transport in South African cities, followed by mini-bus taxis. Given the high specific emissions of personal vehicles, a modal shift to public modes of transport offers large mitigation potential. The benefits of a modal shift towards high shares of public mass transport go well beyond emissions abatement. South African urban areas face a shortage of equitable public modes of transport in many underprivileged urban areas. In view of mobility being a key enabler of economic activity and social connectedness (Lah, Shrestha, & Hüging, 2015), South African authorities face the need improve public transport infrastructure to facilitate social participation of all citizens and thereby increase access to services, culture, and job opportunities (Thomas, 2016). Public transport network expansions tackle existing undersupply for mobility for low-income groups and encourages commuters to switch from MBTs or private vehicles to buses, BRT or rail (WWF, 2016).

As for many cities worldwide, South African cities face severe challenges to avoid a collapse of urban transport system. With sustained population growth and increasing car ownership, road traffic in urban areas will further increase under projected developments (Department of Transport, 2017b; Department of Transport South Africa, 2017). For example, the Gauteng Province Department for Roads and Transport predicts a 'congestion nightmare' and severe consequences for the local economy and environment without policy intervention (Gauteng Province Department of Roads and Transport, 2013). Congestions cause tremendous economic cost, reduce the quality of life for citizens and hamper the development of cities (Gouldson et al., 2015). Further benefits of modal shifts include improved air quality and road safety (Huizenga, Peet, & Gota, 2016).

A lack of available financial resources is usually an important issue that hinders successful implementation of modal shifts. Examples from developing countries as Bogota or Medellin show that public transport can be successfully developed even under budget constraints (ICLEI, 2017; Observatorio de Movilidad, 2016). BRT systems constitute a valuable option and are estimated half as expensive as light rail systems and only a tenth of metro rail (Gouldson et al., 2015).

The role of electrified transport for urban passenger transport systems

As of 2018, the number of electric vehicles being sold in South Africa remains negligible (BusinessTech, 2018), but cities in both developed and developing countries have proven that local policies can substantially foster EV deployment. Qingdao, Oslo or San Jose all show EV market shares of above 10% for electric vehicles (Hall, Moultak, & Lutsey, 2017). Despite electrification being the only option to achieve a decarbonisation of urban transport, electric vehicles are not yet a high priority for transport planning of South African major cities. Besides the obvious advantage of zero tailpipe emissions, electric vehicles could reduce the exposure of urban transport systems to the global fuel price shocks that concern authorities (City of Johannesburg, 2017; Gauteng Province Department of Roads and Transport, 2013). In addition, improved air quality has been a key driver for cities to implement EV support schemes worldwide (Hall, Moultak, et al., 2017). Electric vehicles also obtain the potential to facilitate the connection of high shares of renewables to the grid by serving as a battery storage.

There are several policies that can be applied on a local level and have proven successful in promoting electric vehicles. Among them are the provision of financial and behavioural incentives such as parking fee exemptions or access to bus lanes and the development of charging infrastructure (Hall, Moultak, et al., 2017; International Energy Agency, 2018). Furthermore, public procurement can increase the visibility of EVs and initiate a local market (Aber, 2016).

4.2.2 Scenario analysis for scaling up climate action in urban passenger transport sector in Gauteng, Cape Town, and Durban

4.2.2.1 Identification of indicator levels

Table 19: Identification of indicator levels for scaling up climate action in urban passenger transport sector

<table>
<tr><th></th><th colspan="2">1.5°C compatible benchmarks</th><th>Applying best-in-class level(s)</th><th>National scenarios</th></tr>
<tr><td>Share of public transport (bus, train and MBT) in urban passenger transport</td><td colspan="2">No distinct benchmark(s) for Paris Agreement compatibility on share of public transport available, but research on Paris Agreement compatible sector pathways explicitly highlights the importance of 'shift policies' (Gota, Huizenga, Peet, Medimorec, & Bakker, 2018).
Modal shifts defined in 'Applying best-in-class level(s)' scenarios used in this report to reflect ambitious modal shifts.</td><td>International frontrunners' share of public transport in urban transportation
• Bogota: 67% of public transport (Observatorio de Movilidad, 2016)
• Hong Kong: 80% of public transport (LSE Cities, 2018)</td><td rowspan="2">[No ambitious and comprehensive national scenario available, see further explanation in Section 5.2.2.1]</td></tr>
<tr><td>Electric vehicle share in urban vehicle fleet</td><td colspan="2">Last fossil fuel car sold by 2035 and respectively 100% of EV share in new cars sold as of 2036 (Kuramochi et al., 2018)</td><td>International frontrunners' share of public transport in urban transportation
• Shenzhen: 100% electric buses and 63% electric taxis (WRI, 2018)
• 13% share of EV in new car sales in 2017 in San Jose, California (Lutsey, 2018)</td></tr>
<tr><td colspan="5">Indicator levels for scenario analysis in the PROSPECTS South Africa scenario evaluation tool</td></tr>
<tr><td rowspan="2">Modal Split</td><td>Low ambition</td><td>Linear increase to 67% share of public transport in total urban transportation by 2050 (moderate modal shift as in Bogota)</td><td>Linear increase to 67% share of public transport in total urban transportation by 2050 (moderate modal shift as in Bogota)</td><td rowspan="4">[-]</td></tr>
<tr><td>High ambition</td><td>Linear increase to 80% share of public transport in total urban transportation by 2050 (substantial modal shift as in Hong Kong)</td><td>Linear increase to 80% share of public transport in total urban transportation by 2050 (substantial modal shift as in Hong Kong)</td></tr>
<tr><td rowspan="2">Electric vehicle share</td><td>Low ambition</td><td rowspan="2">S-curve uptake of EV share with 100% EV market share for newly sold vehicles from 2036 onwards</td><td>EV share of all vehicle types according to San Jose's share of EV in new car sales development extrapolated with s-curve fit</td></tr>
<tr><td>High ambition</td><td>• Replacement of conventional buses with electric buses within 5-year period following the example of Shenzhen
• EV share of personal vehicles and MBTs according to San Jose's share of EV in new car sales development extrapolated with s-curve fit</td></tr>
</table>

1.5°C Paris Agreement compatible scenarios

To be in line with a 1.5°C compatible pathway, passenger transport-related emissions must decrease to almost zero around mid-century (Kuramochi et al., 2018). Accordingly, all personal vehicles on the road must be electric by that time, requiring the last fossil fuel car to be sold by 2035 (Kuramochi et al., 2018). Recent research also highlights the importance of modal shifts in transport to achieve the GHG emissions reductions required to meet the Paris Agreement temperature target (Gota et al., 2018). Modal shift and electrification of transport ought to be complementary measures and not alternatives, as high shares of public transport facilitate the electrification of the entire sector. Combined, these measures lead to cleaner and less energy intensive urban transport.

- **1.5°C Paris Agreement compatible benchmarks – High ambition:**
  - **Modal shift**: Recent research highlights the importance of modal shift in (urban) passenger transport (Gota et al., 2018). As the nature of modal shift does not allow the derivation of distinct 1.5°C Paris Agreement compatible benchmarks, this scenario uses the higher ambitious end of the benchmark defined in 'Applying best-in-class level(s)' scenario: Hong Kong's share of **80% of public transport** is used as a target share for the South African urban public transport **by 2050**. The increase is interpolated linearly, with no growth in total MBT activity.
  - **Electrification**: For all road transport modes (personal vehicles, MBT, Bus, BRT), the **share of EVs in new sales is modelled with an s-curve that reaches 100% in 2036**. With a lifetime for personal vehicles assumed to be 15-years, the new sales translate into shares of the total fleet via a stock turnover model. For buses, lifetime is assumed to be 12 years, while it is set to 10 years for MBTs.

- **1.5°C Paris Agreement compatible benchmarks – Low ambition:**
  - **Modal shift:** Similar to the higher ambitious scenario above, this scenario uses the lower ambitious end of the benchmark defined in 'Applying best-in-class level(s)' scenario: Bogota's share of **67% of public transport** is applied as a target share for the entire South African urban transport sector **by 2050**. The increase is interpolated linearly, with no growth in total MBT activity.
  - **Electrification**: For all road transport modes (personal vehicles, MBTs, Bus, BRT), the **share of EVs in new sales is modelled with an s-curve that reaches 100% in 2036**. With a lifetime for personal vehicles assumed to be 15-years, the new sales translate into shares of the total fleet via a stock turnover model. For buses, lifetime is assumed to be 12 years, while it is set to 10 years for MBT's.

Applying best-in-class levels scenarios

For both indicators, modal split and use of electric vehicles, there are numerous illustrative examples of cities forging ahead and striving for a sustainable urban transport system. While Hong Kong's metro system entered into operation in 1979 and is worldwide acknowledged as one of the best of its kind, Bogota has successfully taken measures to expand public transport and to mitigate against increasing car ridership only recently (Eco Mobility, 2018; The Straits Times, 2015). With regard to personal electric vehicles, Oslo and San Jose, among others, are viewed as front runners with EV shares in new sales above 10% (Hall, Cui, & Lutsey, 2017). Shenzhen has electrified its entire bus fleet of more than 16,000 vehicles within only five years and is currently doing the same with its taxi fleet (WRI, 2018). This study applies the indicators from best-in-class examples to the South African urban transport sector to estimate the impacts if South African authorities were to follow these examples:

- **Applying best-in-class level(s) – High ambition:**
  - **Modal shift**: Significant modal shift combined with accelerated electric vehicle uptake: Hong Kong's share of **80% of public transport** is used as a target share for the South African urban public transport **in 2050**. The increase is interpolated linearly, with no growth in total MBT activity.

    - **Electrification**: Additionally, **electrification of the entire bus fleet** (BRT and usual buses) is assumed to happen **during the first five years** according to the example of Shenzhen. **Electrification of private vehicles and MBT's is modelled according to the EV uptake of San Jose** as described in the higher ambition 1.5°C Paris Agreement compatible benchmark.

- **Applying best-in-class level(s) – Low ambition:**
    - **Modal shift**: As Bogota is an example from a developing country it can more realistically be compared with Johannesburg, Durban or Cape Town, leaving aside geographical structures of these cities. The share **of 67% of public transport** in the modal split of Bogota is applied as a target share for the entire South African urban transport sector **for the year 2050**, where growth of this indicator is assumed to happen linearly. All expansion of public transport activity is allocated to bus, rail and BRT, because MBTs are considered the least sustainable mode of public transport.
    - **Electrification:** Regarding electric vehicle application, San Jose can be considered a front runner amongst metropolitan areas with a market share of 13% in 2017. For this scenario, historical market shares from San Jose were fitted with an s-curve that converges to 100% in the future. In turn, this curve was shifted in time and then used to model future South African shares of EV's in new sales in metropolitan areas. There is no differentiation between the type of vehicles. Electrification of buses, MBTs and personal vehicles all follow the s-curve derived from San Jose for passenger vehicles.

National scenarios

There is a lack of detailed national analyses about possible developments of the urban transport systems in South Africa. Bubeck et al. provide one of the few available studies quantifying the effects of public transport interventions for the Gauteng Province with a 2040 time horizon (Bubeck et al., 2014). The authors consider a modal shift induced by the expansion of the Rea Vaya (BRT) and the Gautrain network according to official planning and compared to the reference scenario, which assumes no addition to BRT and Gautrain capacities.

Some cities also vaguely define their own targets, such as Cape Town striving for public transport supplying 80% of all passenger trips (Transport and Urban Development Authority Cape Town, 2016). However, no comprehensive and ambitious national scenario assessments exist for both increased electrification and substantial modal shift for the three urban areas under analysis. Due to this lack of comprehensive and ambitious national scenarios, this report does not include any such scenario.

4.2.2.2 Quantification of emission levels with PROSPECTS South Africa

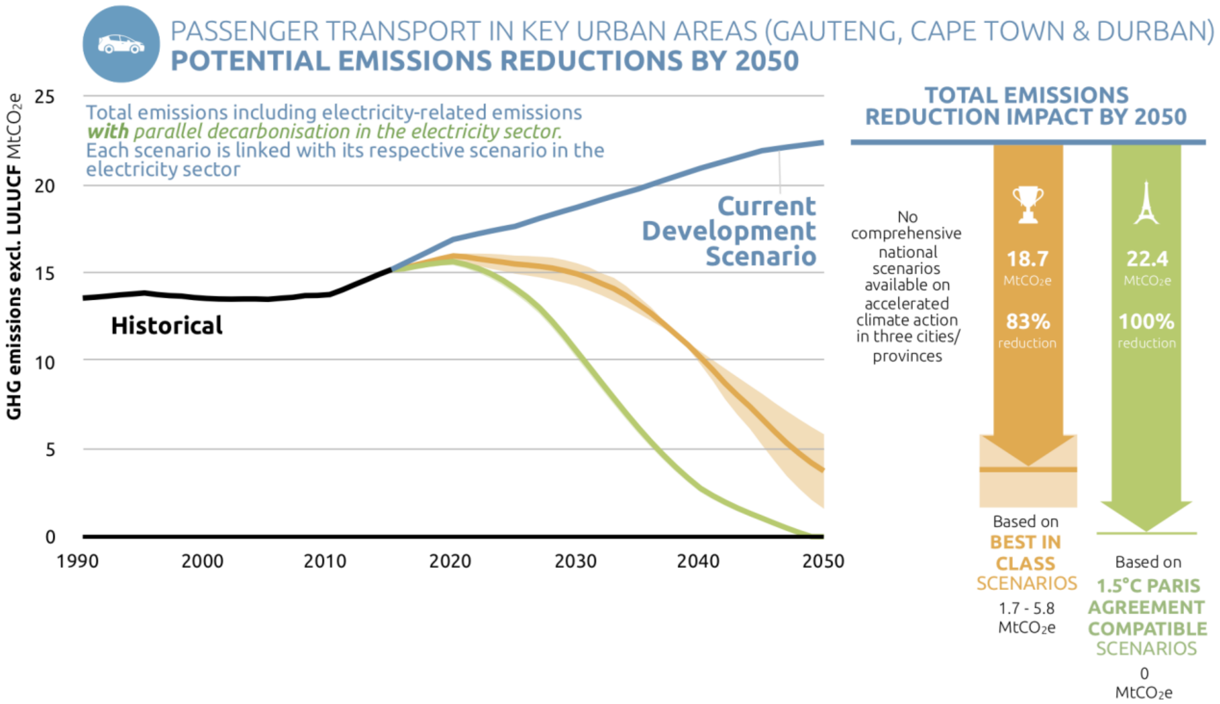


Figure 18: GHG emissions in the South African urban passenger transport sector in Cape Town, Durban, and the Gauteng province including Johannesburg and Pretoria, including electricity-related emissions and parallel climate action according to the respective scenario categories in the South African electricity supply sector. Historical emission levels for urban passenger transport in three urban areas under Current Development Scenario (CDS) estimated using historical transport-related emission levels (C40 2018) as well as additional assumptions for increase in urban population and per capita transport demand (UN DESA, 2018).

Figure 18 illustrates the ranges of GHG emissions of urban passenger transport in Cape Town, Durban, and the Gauteng province including Johannesburg and Pretoria up to 2050 under the different scenario definitions. Emissions continue increasing up to 2050 under a current development scenario to around 22 $MtCO_2e/yr$.

Accelerated acclimate action by these three urban areas in the passenger transport sector alone can significantly reduce GHG emissions levels by 2050 through initiating a substantial modal shift and introducing electric vehicles, buses, and MBTs. The mitigation impact of accelerating rates to electrify urban passenger transport critically depends on the decarbonisation of South African electricity generation.

- The '**1.5°C Paris Agreement compatible' pathway** peaks emissions (incl. electricity-related emissions) around 2020. Thereafter, emissions significantly decrease between 2020–2040, resulting from a modal shift away from passenger cars and the progressing electrification of the remaining personal vehicles, buses and MBTs. The urban passenger transport sector in all three urban areas fully decarbonise by 2050.
- The '**Applying best-in-class levels' pathway** stabilises emissions (incl. electricity-related emissions) from urban passenger transport around 2030, after which emissions significantly decrease. Emissions in 2050 are slightly above the Paris-compatible scenario, relating both to less ambitious modal shift and transport electrification as well as a reduce speed in decarbonisation of the electricity supply.
- Due to a lack of ambitious and comprehensive national scenarios, no '**National scenarios' pathway** could be included in this report (see Section 4.2.2.1 for further explanations).

Accelerated climate action in the urban passenger transport sector changes the sector's electricity demand, given the increased share of electric vehicles under the different scenarios considered. Figure 19 illustrates the same scenario pathways as above without electricity-related emissions. It shows a lower decline of emissions in both scenario category pathway ranges, as a result from decreasing direct fuel use due to the shift to electricity.

This means that the difference in emissions between both graphs stem from decarbonisation efforts in the South African electricity generation sector. This comparison emphasises the critical importance of comprehensive action across sectors. Electrifying transport without increasing the share of zero-carbon technologies in electricity generation will limit potential positive mitigation impacts of accelerated climate action in this sub-sector.

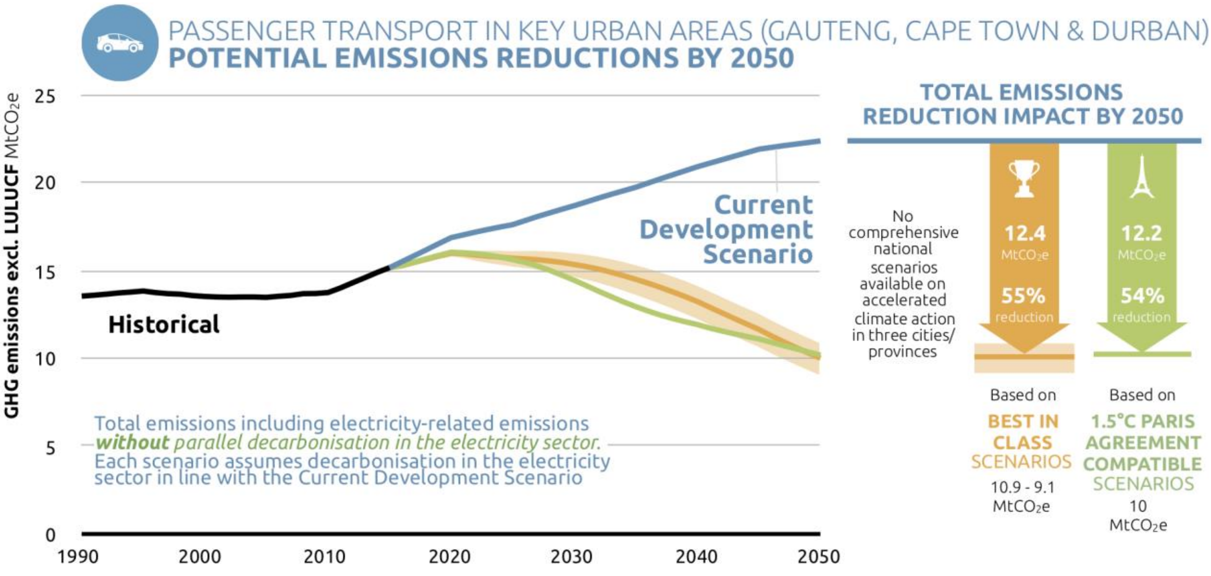


Figure 19: GHG emissions in the South African urban passenger transport sector in Cape Town, Durban, and the Gauteng province including Johannesburg and Pretoria, incl. electricity-related emissions and no additional actions in other sectors beyond current policies. Historical emission levels for urban passenger transport in three urban areas under Current Development Scenario (CDS) estimated using historical transport-related emission levels (C40 2018) as well as additional assumptions for increase in urban population and per capita transport demand (UN DESA, 2018).

4.3 Residential buildings sector

Energy efficiency gains through tighter building codes for new residential buildings, increased rates of thermal retrofits, and more efficient appliances can fully decarbonise the residential buildings sector by mid-century if the electricity supply sector were to decarbonise in line with the Paris Agreement temperature goal.

Even without any further climate action in the electricity supply sector beyond levels, such sector policies in South Africa's residential buildings sector could still reduce emissions by up to 37% below today's levels by 2050.

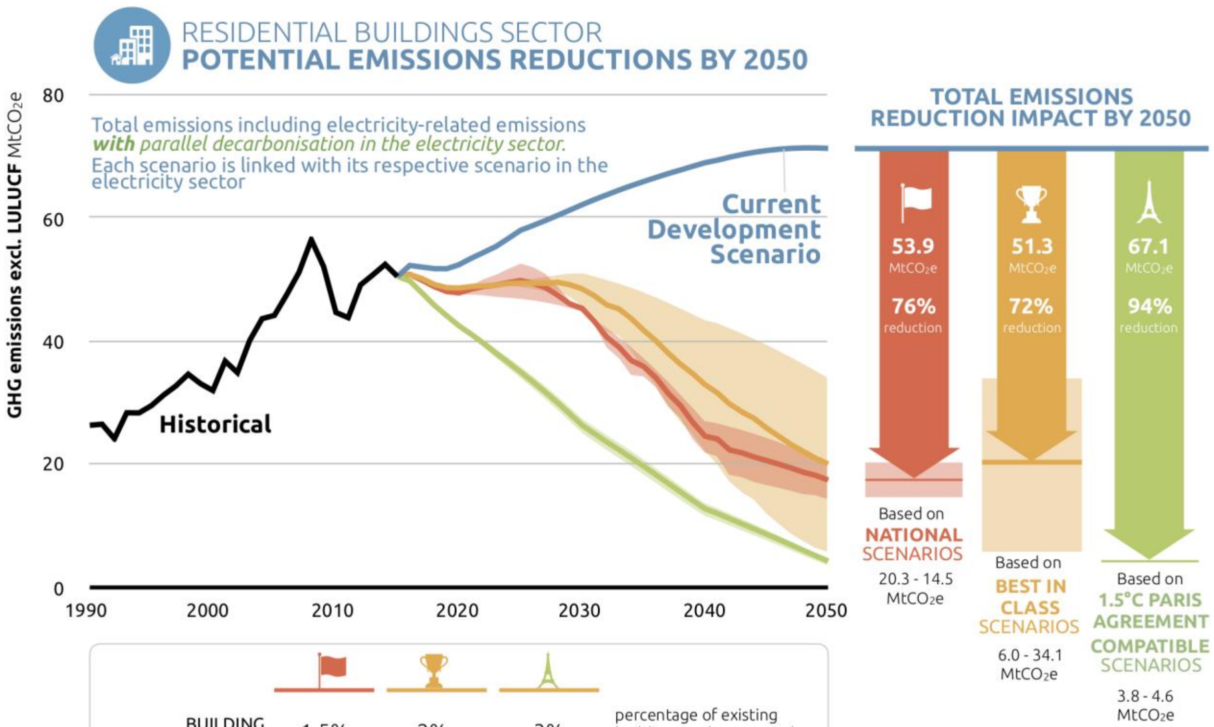
This residential building sector transition entails key opportunities to advance socially-just housing, while generating local employment opportunities and attenuating the adverse health effects of conventional forms of inappropriate housing.

Table 20 provides an overview of the analysis results for scaling up climate action in the residential buildings sector. The table's upper rows present the value ranges for three indicators considered relevant for the scenario modelling in the South African residential buildings sector. Figure 20 displays the resulting emission trajectories for each of the three scenario categories.

Table 20: Outcome overview of the scaling up climate action analysis in the residential buildings sector

Indicator	Indicator values for scenario categories		
	National scenarios	Applying best-in-class level(s)	1.5°C compatible benchmarks
Renovation rate	• *Not specified in Post-2015 NEES, thus arbitrary dummy rate of 1.5% assumed*	• 2% renovation rate from 2030–2050 • Rate under current policies from 2016–2030	• 3% renovation rate from 2020–2050 • Rate under current policies from 2016–2020
	n/a	*Based on best-in-class practice identified in Kriegler et al.* (2018)	*Based on benchmark for non-OECD regions specified in Kuramochi et al. (2018)*
Relative improvement of energy efficiency in renovated/new buildings	**38–74%** improvement compared to 2015	**45–73%** improvement compared to 2015	**75–100%** improvement compared to 2015
	Based on quantified targets for retrofits and new buildings specified in Post-2015 National Energy Efficiency Strategy (Department of Energy, 2016b)	*Based on best-in-class benchmarks for retrofits and new buildings identified in Kriegler et al.* (2018)	*Based on benchmarks for retrofits and new buildings identified in Kuramochi et al. (2018)*
Energy intensity improvement of cooking/ lighting/ appliances (electricity + direct energy)	Average efficiency improvement of **0.9%** per year until 2030 and **0.6%** per year from 2030–2050	Average efficiency improvement of **1.8%** per year applied from 2016–2050	Average efficiency improvement of **2%** per year applied from 2016–2050
	Based on targets specified in Post-2015 National Energy Efficiency Strategy for (Department of Energy, 2016b)	*Based on best-in-class practice identified in Fekete et al.* (2015)	*Based on benchmarks identified in Kriegler et al.* (2018)

Required policy measures for sectoral transformation	Remaining challenges threatening implementation
⇨ Promotion and robust enforcement of building standards for new and retrofitted buildings ⇨ Reliable and accessible financial support for project developers and house owners via adequate policy instruments ⇨ Consequent inclusion of green and low-carbon urban planning and construction in social housing	⇨ Lack of willingness by political leadership to initiate ambitious sectoral transformation ⇨ Tight fiscal national budget situation and lack of international funding pursed for social housing ⇨ Required improvement in cooperation between national and sub-national action to implement efficient and effective strategy



BUILDING RENOVATION RATE	1.5%	2%	3%	percentage of existing building stock renovated per year to 2050
ENERGY EFFICIENCY IMPROVEMENTS OF BUILDINGS	38 - 74%	45 - 73%	75 - 100%	improvement of energy efficiency of any renovated and/or new buildings relative to 2015
ENERGY EFFICIENCY IMPROVEMENTS OF APPLIANCES	0.6-0.9%	1.8%	2%	improvement per year of energy efficiency of cooking, lighting and appliances

Figure 20: GHG emissions in the South African residential building sector under different scenarios, including the sector's electricity-related emissions and additional climate action in the electricity supply sector beyond current policies. All emission pathways in the residential buildings sector assume the forecasted electricity supply mix as specified for the respective scenario categories.

4.3.1 South African context for scaling up climate action in the residential buildings sector

Low-emission social housing provides multiple social, health and economic benefits

Social housing and the transition to low-emission buildings offer great synergies to achieve several social, health and economic benefits while initiating the sectoral transformation towards a low-carbon residential buildings sector. These social, economic and health-related benefits of social housing enable South Africa to promote its sustainable development agenda, particularly on inclusive, resilient and sustainable human settlements and cities (SDG 11) as well as on increasing well-being and general health (SDG 3). The South African government built almost three million low-cost homes between 1994 and 2012 and a further three million are targeted by 2025 (GBCSA, 2012). Social Housing Regulatory Authority aims for social housing development of 27,000 units in the current Medium Term Strategic Framework (MTSF) period between 2014 and 2019 (SHRA, 2017). These ongoing developments present an opportunity to implement green building design principles as specified in environmental guidelines for low-income housing (PAGE, 2017).

Several promising pilots and policy developments for a green and low-emission social housing have taken place in South Africa recently, even as implementation and enforcement remain uncertain. The Presidential Infrastructure Coordinating Commission (PICC) resolution in 2013 requires that 60% of the government's social infrastructure building to be constructed from innovative building technologies (IBTs) by 2017 (Ampofo-anti, 2017). In addition, the National Norms and Standards for the Construction of Stand Alone Residential Dwellings and Engineering Services (Norms and Standards) in social housing sector were directed to be in line with SANS 10400-XA regulations in 2013 (Didiza, 2014).

Recent pilots of implemented low-emission social housing initiatives in South Africa provide first indications of improvements in quality and affordability of living. 15 projects of low-emission and green social housing demonstrate financial self-sustainability and other benefits such as poverty alleviation, skills development, capacity building, and emission reductions (PAGE, 2017). A first 'green street' upgrade in a low-income area in Cato Manor Green Street resulted in significant improvements in life quality through hot water access, better insulation, rainwater harvesting, and better air circulation as well as energy saving and greater affordability of utility services (GBCSA, 2012).

Shift to green and low-emission residential buildings financially feasible

The proportion of green buildings in South Africa and worldwide continues to increase while higher construction costs are oftentimes offset by cheaper operations costs and higher returns on investments compared to conventional buildings. Recent estimates suggest that the share of 'green buildings' might climb from 41% in 2017 to 61% in 2018 of all South African buildings, which is in line with the trend of increasing demand for voluntary green certified new buildings (World Green Building Council, 2016a). In addition, the first four net zero buildings projects in South Africa have been announced in October 2017 (GBCSA, 2017).

New green buildings in South Africa increasingly demonstrated cheaper operations costs and higher returns on investments compared to conventional buildings (GBCSA, 2017)**.** For example, the average financial return for the top quartile of energy efficient buildings stood at 12.5% against 11.5% for conventional buildings in 2015 (GBCSA, 2017). Cost premia for green buildings also tend to decrease rapidly (GBCSA, 2017). The need for resource efficiency due to South Africa's energy and water crisis might continue to provide the business case for green building.

Low-emission residential buildings are furthermore mandated to meet tighter regulatory standards, which would be in line with tentative sector targets postulated in the Post-2015 National Energy Efficiency Strategy introduced in 2016 (Department of Energy, 2016b). The proposed target would increase the average energy performance of new residential buildings by 38%. Thermal retrofits shall further achieve a 15% thermal performance improvement by 2030 in dwellings built before 2015 (relative to a 2015 baseline).

Main barriers persist for building retrofit such as high upfront costs, high borrowing rates, and long payback periods as well as a lack of capacity and technical expertise (World Green Building Council, 2016b). Split incentives between investors and tenants persist in the residential buildings sector, although further facilitating ESCO activities and placing more stringent energy savings requirements could help overcome these challenges, as planned under the draft post-2015 National Energy Efficiency Strategy.

Significant benefits for job creation and local economic development

Energy efficiency improvements though building retrofits and low-emission housing offer significant opportunities for local economic development and job creation (Day et al., 2018)**.** There is high potential for further gains in employment for all skill and qualification levels within the labour force. Job creation is primarily linked to the retrofitting and new construction of green and low-emission residential buildings in South Africa (AIDC, 2016), especially at the municipality level. Green retrofitting of existing buildings is expected to be the largest activity for the green building industry in South Africa within the next three years (World Green Building Council, 2016b).

Recent pilots in the South African municipalities of KwaDukuza and Steve Tshwete showcase positive effects on employment (Day et al., 2018). Aesthetic changes and building system upgrades can generate local employment opportunities. These employment opportunities lead to the development of skills and knowledge across the local labour market, specifically on building construction, retrofits, operations, maintenance, higher safety, as well as potential jobs, to the local economy. Such positive effects on low- and high-skilled employment and local economic development support South Africa's development agenda in terms of employment (SDG 8) as well as improving the quality of education, skills development and innovation (SGD 9).

4.3.2 Scenario analysis for scaling up climate action in the residential buildings sector

4.3.2.1 Identification of indicator levels

Table 21 provides a complete overview of indicator levels identified for the three different scenario categories. The upper part presents the respective benchmarks specified in relevant literature. The lower part explains how these benchmark levels have been translated into indicator levels for input in the PROSPECTS South Africa scenario evaluation tool.

Table 21: Identification of indicator levels for scaling up climate action in the residential buildings sector

		National scenarios	Applying best-in-class level(s)	1.5°C compatible benchmarks
Renovation rate		15% improvement in the thermal performance of dwellings (cooling and heating) built before 2015 as stipulated in the Post-2015 NEES *Based on quantified targets for retrofits specified in Post-2015 National Energy Efficiency Strategy (Department of Energy, 2016b)*	• **2%** renovation rate from **2030** onward with **45%** energy efficiency improvement per retrofit *Based on best-in-class practice identified in Kriegler et al.* (2018)	• **3%** renovation rate from **2020** onward with **75%–80%** energy efficiency improvement per retrofit *Based on benchmark for non-OECD regions specified in Kuramochi et al. (2018)*
New buildings stock		• 38% average improvement in the energy performance of new buildings by 2030 as stipulated in the Post-2015 NEES *Based on quantified targets for new buildings specified in Post-2015 National Energy Efficiency Strategy (Department of Energy, 2016b)*	• **22 kWh/m²/year** of new buildings stock from **2030** onward *Based on best-in-class benchmarks for new buildings identified in Kriegler et al.* (2018)	• **0 kWh/m²/year** of new buildings stock from **2025** onward *Based on benchmarks for new buildings identified in Kuramochi et al. (2018)*
Appliances		• 33% reduction in the average specific energy consumption of new household appliances purchased in South Africa by 2030 relative to a 2015 baseline *Based on targets specified in Post-2015 National Energy Efficiency Strategy for (Department of Energy, 2016b)*	• Average efficiency improvement of **1.8%** per year (all appliances) *Based on best-in-class practice identified in Fekete et al.* (2015)	• Average efficiency improvement of **2%** per year (all appliances) *Based on benchmarks identified in Kriegler et al.* (2018)
Indicator levels for scenario analysis in the PROSPECTS South Africa scenario evaluation tool				
Renovation rate	High ambition / Low ambition	*Not specified in Post-2015 NEES, thus dummy renovation rate of 1.5% assumed*	• **2%** renovation rate from **2030** • Rate under current policies before 2030	• **3%** renovation rate from **2020** • Rate under current policies before 2020
Relative improvement of energy efficiency in renovated/ new buildings	High ambition	**74%** as derived from Post-2015 NEES for thermal retrofit of pre-2015 buildings stock using default renovation rate of 1.5%	**73%** calculated compared to average historical energy intensity per m² in 2015 from benchmark for new buildings stock	**100%** as derived from benchmark for new buildings stock of **0 kWh/m²/year**
	Low ambition	**38%** as stipulated in the Post-2015 NEES for new buildings from 2030	**45%** as derived from benchmark for renovated buildings stock	**75%** as derived from lower range of benchmark for renovated buildings stock
Energy intensity improvement of cooking/ lighting/ appliances (electricity + direct energy)	High ambition / Low ambition	• Average efficiency improvement of **0.70%** per year (until 2030) • Average efficiency improvement of **0.68%** per year (2030–2050)	Average efficiency improvement of **1.8%** per year (all appliances)	Average efficiency improvement of **2%** per year (all appliances)

1.5°C Paris Agreement compatible benchmarks

The 1.5°C Paris Agreement compatible benchmarks represent sectoral indicator values for the three selected indicators, which are in line with a 1.5°C Paris Agreement compatible sectoral emission trajectory for the South African residential buildings sector. A review of relevant literature and studies in the field identifies the following:

- For new buildings stock being constructed, **all new buildings shall be fossil fuel free and near net-zero energy by 2025** (Kuramochi et al., 2018), constituting the average benchmark for non-OECD regions.
- For the renovation of existing residential buildings stock, the renovation rate ought to **increase to 3% by 2020** (constituting the average benchmark for non-OECD regions) with an achieved **average reduction of 75–80% in final energy use per retrofit** (Boermans, Bettgenhäuser, Offermann, & Schimschar, 2012; Kuramochi et al., 2018).
- As for energy efficiency improvements of appliances and lighting, an **average efficiency improvement of 2.0% per year** constitutes the Paris Agreement compatible value for efficiency improvements of appliances and lighting toward 2030 (Kriegler et al., 2018).

These Paris Agreement compatible benchmarks translate into indicator levels for the PROSPECTS-based emission trajectory quantification for South Africa as follows:

- **Renovation rate**: 3% renovation rate from 2020 onwards with a renovation rate under currently implemented policies used before 2020.
- **Relative improvement of energy efficiency in renovated/new buildings**: Range of 75% (deep retrofit of existing buildings) to 100% (near-zero emission new buildings).
- **Relative improvement of total energy intensity of cooking/lighting/appliances (electricity + direct energy)**: Average efficiency improvement of 2% per year for all appliances.

Applying best-in-class levels

Applying best-in-class levels of international frontrunners in increasing energy efficiency of new building stock and retrofitting of existing building stock suggest a path for how the South African residential buildings sector might transform under similar developments. A review of relevant literature and international good practices identifies the following benchmarks:

- For new buildings stock being constructed, the European Union's Energy Performance of Buildings Directive (EPBD) requires that all new buildings in EU Member States shall be nearly net-zero energy by the end of 2020 (Climate Action Tracker, 2016b). In general, the EPBD's requirements can be considered international best practice, although EU Member States interpreted the directive's objective of 'near zero energy' differently in terms of final energy consumption allowed (BPIE, 2015). A common interpretation of "nearly net-zero energy" is an energy consumption of **22 kWh/m^2/year,** which constitutes an improvement of 73% compared to the average energy efficiency of the existing building stock in South Africa (Kriegler et al., 2018).
- For the renovation of existing residential buildings stock, a **renovation rate of 2% with efficiency improvements of 45% through renovation (% of "efficiency levels of new building") from 2030 onwards** (Kriegler et al., 2018) can be considered as a best-in-class approach, based on the following indicator components identified in the literature and other policies:
    - ***Renovation rate (% per year)***: 2% renovation rate as stipulated by the '2 Degree Scenario' in IEA's Energy Technology Perspective 2016 report (IEA, 2016a). The European Union's Energy Performance of Buildings Directive (EPBD) even obliges a 3% deep renovation rate for centrally owned government buildings (Climate Action Tracker, 2016b), however, this targeted renovation rate has not yet been further extended to the residential buildings sector.
    - ***Efficiency improvement through renovation (% of "efficiency levels of new building")***: Government subsidies in Germany by state-owned KfW bank subsidise renovations of existing buildings. The maximum subsidy (equals to best conditions)

are granted to buildings that are at least 45% better than the reference house in the respective category.
    - ***Target year policies***: The target year of the renovation rate specified above is 2020 for developed countries as informed by the European Union's Energy Performance of Buildings Directive (EPBD) and 2030 for developing countries.
- As for energy efficiency improvements of appliances and lighting, an **average efficiency improvement of 1.8% per year** across all appliances is considered international best practice (Fekete et al., 2015).

These identified best-in-class benchmarks translate into indicator levels for the PROSPECTS-based emission trajectory quantification for South Africa as follows:

- **Renovation rate**: 2% renovation rate from 2020 onwards with a renovation rate (identified by IEA ETP 2016) applied under currently implemented policies before 2020.
- **Relative improvement of energy efficiency in renovated/new buildings**: Range of 45% adopted from best-in-class efficiency improvement for renovations (deep retrofit of existing buildings) to 73% adopted from best-in-class efficiency improvement for new buildings (applying best-in-class levels to South Africa's average historical energy intensity per m^2 in 2015).
- **Relative improvement of total energy intensity of cooking/lighting/appliances (electricity + direct energy)**: Average efficiency improvement of 1.8% per year for all appliances.

National scenarios

The **Post-2015 National Energy Efficiency Strategy** introduced in 2016 (Department of Energy, 2016b) specifies energy efficiency targets for the residential as well as public and commercial buildings sectors. Overall, the Post-2015 NEES aims for a 20% improvement in the average energy performance of the residential building stock by 2030 relative to a 2015 baseline value measured by the energy consumption per m^2 of habitable space per year, excluding plug loads. This overarching efficiency improvement in the residential buildings sector breaks down into energy efficiency improvements for new buildings stock and the renovation of existing building stock. A separate target specifies intended energy efficiency improvements of appliances and lighting.

- For new buildings stock being constructed, the Post-2015 NEES aims for a **38% average improvement in the energy performance of new buildings by 2030** relative to a 2015 baseline through tightening of building standards.
- For the renovation of existing residential buildings stock, thermal retrofits shall achieve a **15% improvement in the thermal performance of dwellings built before 2015 by 2030** relative to a 2015 baseline. It is worth highlighting that this is a very ambitious target. An assumed renovation rate of 1.5% per year, would require efficiency improvements of 73% per renovation. Even with a renovation rate of 3%, an efficiency improvement of 40% would be the minimum to achieve the envisaged average energy intensity.
- As for energy efficiency improvements of appliances and lighting, the Post-2015 NEES aims for a **33% reduction in the average specific energy consumption of new household appliances purchased in South Africa by 2030** relative to a 2015 baseline.

These benchmarks translate into indicator levels for the PROSPECTS-based emission trajectory quantification for South Africa as follows:

- **Renovation rate**: The Post-2015 NEES does not specify a targeted renovation rate for thermal retrofits to achieve a 15% improvement in the thermal performance of dwellings built before 2015. For this reason, the analysis assumes an arbitrary dummy renovation rate of 1.5% per year.
- **Relative improvement of energy efficiency in renovated/new buildings**: Range of 38% (as stipulated in the Post-2015 NEES for new buildings from 2030 onwards) to 74% (as stipulated in the Post-2015 NEES for dwellings built before 2015, based on a default

renovation rate of 1.5%). For a higher ambitious scenario, the efficiency improvement of 73% resulting from the 2030 target for the existing building stock was applied to all new and renovated buildings. For the lower ambitious scenario, the efficiency improvement target for new buildings as stipulated in the Post-2015 NNES was applied to new and renovated buildings in the PROSPECTS South Africa scenario evaluation tool.

- **Relative improvement of total energy intensity of cooking/lighting/appliances (electricity + direct energy)**: Average efficiency improvement of 0.70% per year until 2030 and 0.68% per year between 2030 and 2050.

Some other national studies, such as analysis on energy efficiency improvements of retrofitted municipal buildings (South African Cities Network, 2014) or The South Africa 2050 Calculator, provide further insights on potentials to enhance climate action in the South African residential buildings sector (Department of Environmental Affairs, 2015). For reasons of consistency, only the targeted energy efficiency improvements stated in the Post-2015 National Energy Efficiency Strategy have been considered in this analysis under the 'National Scenario's category.

4.3.2.2 Quantification of emission levels with PROSPECTS South Africa

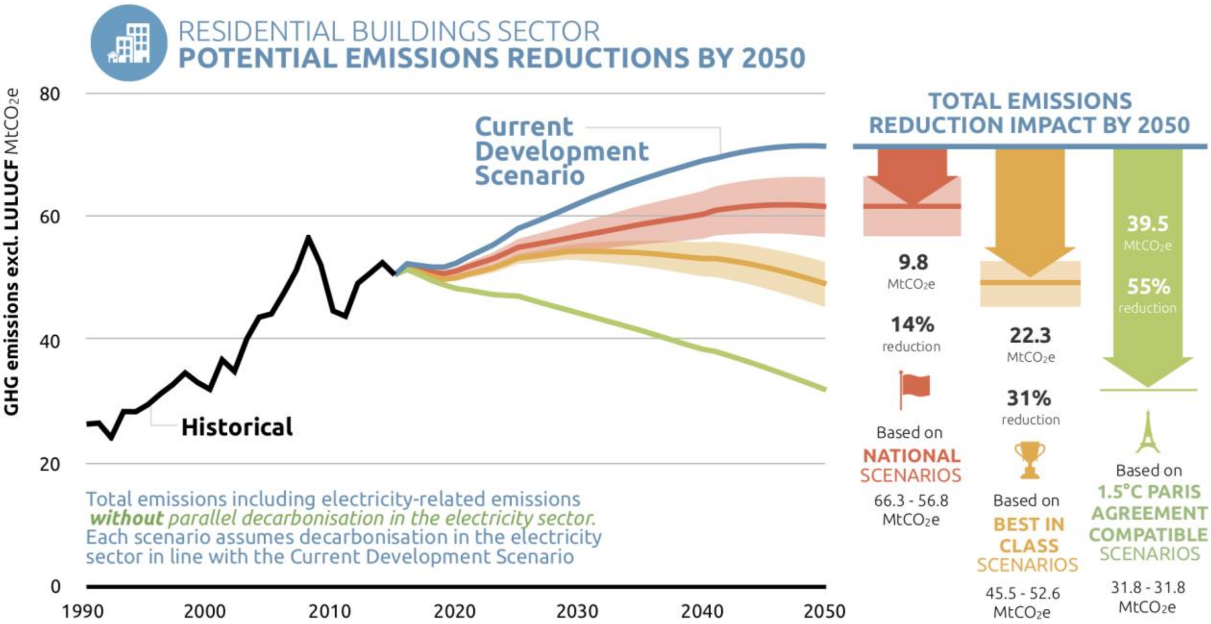


Figure 21: GHG emissions in the South African residential building sector under different scenarios, including the sector's electricity-related emissions but without any additional climate action in the electricity supply sector beyond current policies. All emission pathways in the residential buildings sector assume the forecasted electricity supply mix as specified under the Current Development Scenario (CDS).

Figure 21 illustrates the range of emission trajectories in the residential buildings sector up to 2050 under the different scenario categories. The graph includes electricity-related emissions, which contribute to the sector's total emissions by about 70% and increase over time. Under the current development scenario, emissions from residential buildings continue to increase until 2050 up to about 72 MtCO2e/yr. Pathways under accelerated climate action imply strong reductions of GHG emissions beyond the current development scenario below today's level:

- The '**1.5°C Paris Agreement compatible' pathway range** immediately reduces emissions levels from around 50 MtCO_2e/yr today to up to 30–40 MtCO_2e/yr in 2050 under the most ambitious scenario.
- The '**Applying best-in-class levels' pathway range** allows emissions to increase slightly and peak around 2030 2035. The sector's emission levels then decrease to around 45–55 MtCO_2e/yr by 2050, in the same range as today's emissions level.
- The '**National scenarios' pathway range** show a continuous increase of emissions reaching around 56–66 MtCO_2e/yr by 2050. While emission levels remain below the current development scenario (CDS), pathways under this scenario category range do reflect stronger action in the residential buildings sector.

Emission pathways under the different scenario categories fundamentally change when considering accelerated climate action in the electricity supply sector (see Section 4.1 for detailed information). Figure 22 illustrates emission trajectories for South Africa's residential buildings sector, accounting for the decarbonisation of South Africa's electricity generation up to 2050. Under the most ambitious scenario, the residential buildings sector almost fully decarbonises by mid-century, combining energy efficiency on the end-user side and decarbonising South Africa's electricity generation. Under all scenario categories, emission levels including electricity-related emissions considerably decrease below today's emission levels of about 50 $MtCO_2e$/yr by mid-century.

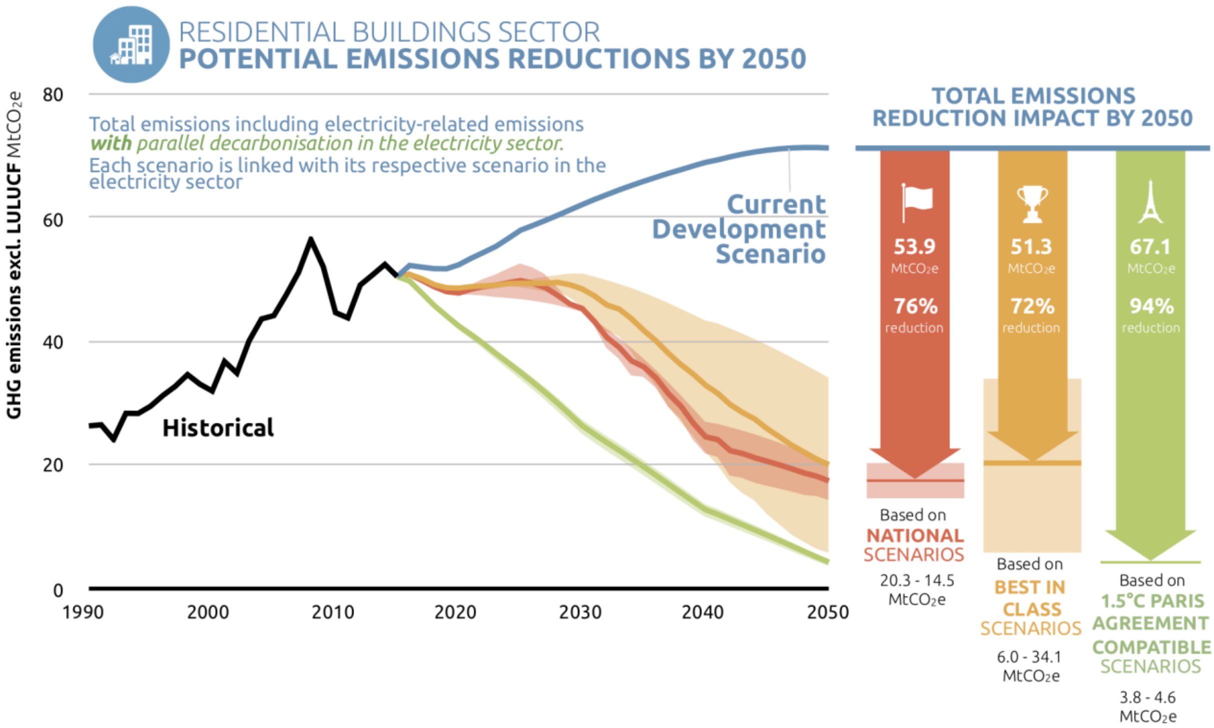


Figure 22: GHG emissions in the South African residential building sector under different scenarios, including the sector's electricity-related emissions and additional climate action in the electricity supply sector beyond current policies. All emission pathways in the residential buildings sector assume the forecasted electricity supply mix as specified for the respective scenario categories.

These results emphasise the critical importance of comprehensive and coordinated climate action across demand and supply sectors. Accelerated climate action in the residential buildings demand sector depends on ambitious decarbonisation of South African electricity generation to successfully transition towards zero-carbon by mid-century or shortly thereafter. Without increasing the share of zero-carbon technologies in South African electricity supply, the mitigation impact of accelerated climate action will be considerably limited in the residential buildings sector.

4.4 Combined cross-sectoral analysis

South Africa's Nationally Determined Contribution (NDC), 2020 pledge and long-term target pledge are consistent with their long-term goal to constrain emissions to follow a peak-plateau-decline (PPD) trajectory. Based on this, South Africa's emissions should peak between 2020 and 2025 (as targeted by the Copenhagen and NDC pledge), plateau for approximately a decade and then decline in absolute terms towards 2050.[8]

South Africa's NDC targets an absolute emissions level in the range of 398–614 $MtCO_2e$ incl. LULUCF over the period 2025–2030 (Government of South Africa, 2016a). Assuming LULUCF remains at the sector average level over the 2000–2012 period (-17 MtCO2e), this NDC translates to an emissions level of between 415–631 $MtCO_2e$/yr excl. LULUCF by 2030. For 2050, the long-term emissions target range defined by the PPD trajectory is 229–445 $MtCO_2e$/yr excl. LULUCF. Scaling up climate action in South Africa's electricity supply sector, residential buildings sector and urban passenger transport (in Gauteng, Cape Town and Durban) alone can reduce South Africa's total greenhouse gas emissions by up to 22% below the current development scenario by 2030 (see upper graph in Figure 23). This would mean peaking emissions before 2030 and being within the peak-plateau-decline (PPD) target range by 2030 as specified in South Africa's Nationally Determined Contribution (NDC) (Government of South Africa, 2016a).

South Africa would also come close to achieving the upper bound of their emissions target range by 2050 (see lower graph in Figure 23). Upscaled actions in the three (sub-)sectors under analysis lead to significant overall reductions, and a Paris Agreement compatible scenario would require complete decarbonisation in these three (sub-)sectors by 2050.

These findings emphasise that reaching South Africa's 2050 targets requires more ambitious climate action in other sectors apart from those three (sub-)sectors analysed in this study, even more so for achieving an economy-wide decarbonisation by mid-century (or shortly thereafter) to be in line with the Paris Agreement temperature target.

8 A detailed explanation of South Africa's pledges can be found under: www.climateactiontracker.org/countries/south-africa/pledges-and-targets/

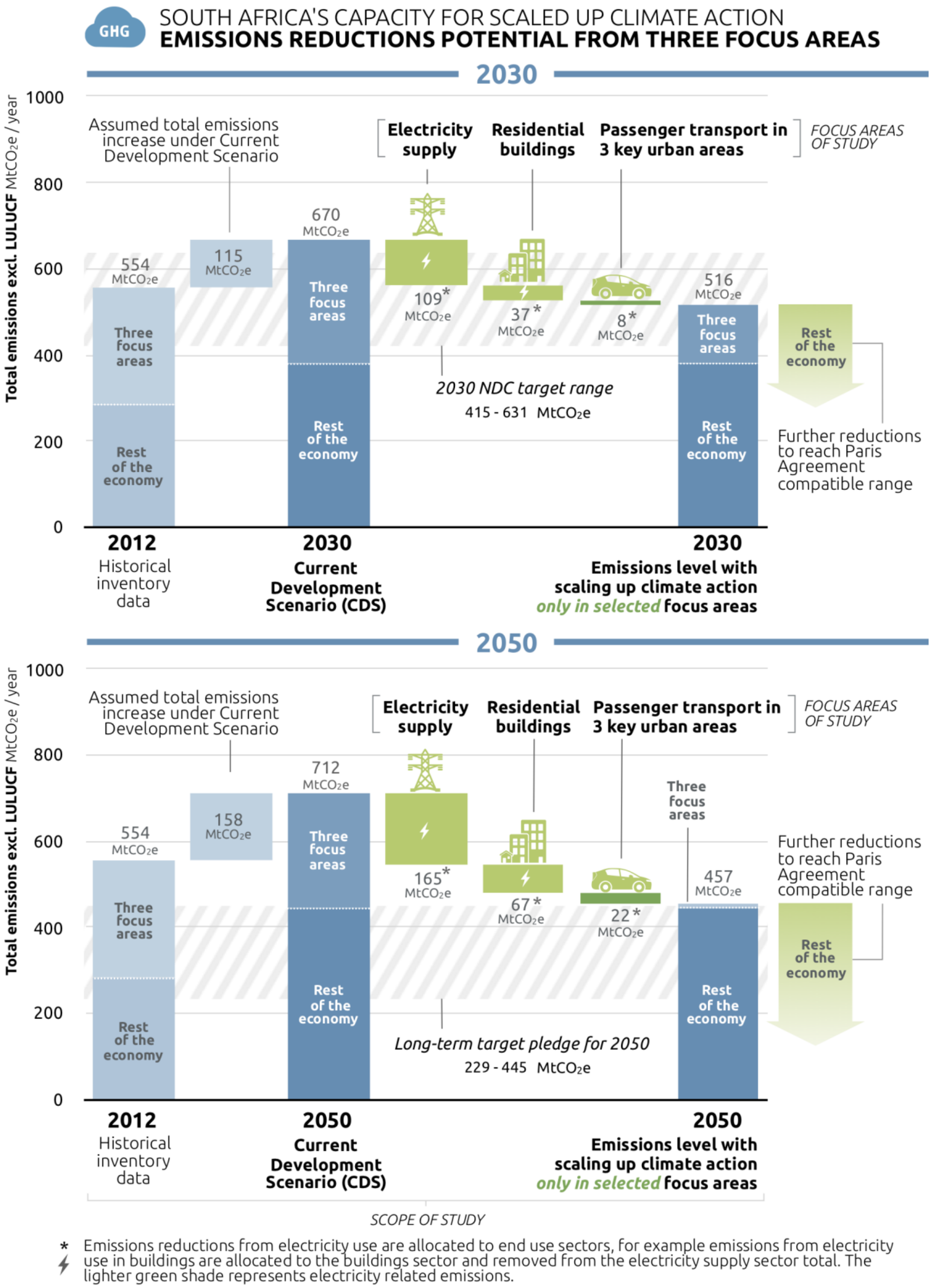


Figure 23: Overview of total emission levels (excl. LULUCF) under historical inventory data in 2012 (left bar), under a current development scenario in 2030/2050 (middle bar), and most ambitious levels of accelerated climate action by 2030/2050 in the electricity supply, the residential buildings sector, and the urban passenger transport in Gauteng, Cape Town and Durban (right bar). All electricity-related emission reductions from the residential buildings and urban transport sectors are allocated as emissions reductions under these two end-use sectors.

5 Conclusion

The analysis shows that upscaled mitigation action in electricity generation, urban passenger transport (Gauteng, Cape Town, and Durban) and residential buildings in South Africa can decrease projected national emissions from today and decarbonise the three focus areas of this analysis by mid-century, in line with a global Paris Agreement-compatible pathway. Further actions in all other sectors will be required to ensure economy-wide Paris Agreement-compatible development.

The upscaled mitigation actions come with important co-benefits, such as improved air quality and modernized housing. The research of this report also indicates that renewable energy can increasingly replace coal to enable a nearly fossil fuel-free electricity sector in 2050. While job opportunities in the mining and extraction industry would phase out along with the generation capacities, renewable energy development would create jobs in a similar order of magnitude, and result in a significantly more cost-efficient energy supply.

Ambitious policy making is required to enable a Paris Agreement-compatible and "just" development scenario in the focus areas considered in this report. For the electricity sector, a clear commitment to renewable energy is needed in parallel to a clear phase-out plan for coal-fired power plants. The proposed update of the Integrated Resource Plan (IRP) in 2018 is a first step in the right direction. It could be furthered strengthened to avoid fossil fuel power plants becoming stranded assets under a Paris Agreement-compatible pathway.

In the urban passenger transport sub-sector, comprehensive policy packages can support reducing transport demand, instigating a modal shift towards less carbon-intensive transport sources, moving towards zero-carbon solutions, and increasing the penetration of electric vehicles above all. In the residentials buildings sub-sector, a transition to zero-energy buildings for new buildings and increased renovation are fundamental for Paris-compatibility for the sector. Promoting efficient appliances avoids unnecessary electricity demand. However, full decarbonisation of the buildings and transport sector is only possible if the electricity sector also decarbonises by mid-century of shortly thereafter.

KEY FINDINGS

- ⇨ Scaling up climate action in South Africa's electricity supply, urban passenger transport, and residential buildings sectors which cover about half of South Africa's 2012 emissions can reduce the country's total greenhouse gas emissions by up to 96% below 2012 emissions in these focus areas by 2050.
- ⇨ Actions in these areas alone would reduce economy-wide emissions by 17 % below 2012 levels, and bring South Africa close to meeting its 2050 emissions reduction target. While the three focus areas will almost fully decarbonise under our most ambitious scenario, additional action in other sectors and sub-sectors will be needed to decrease economy-wide emissions in line with the Paris Agreement's temperature limit.
- ⇨ Research from South African institutes indicates that under least-cost scenarios, GHG emissions from electricity generation in South Africa could decrease by up to 83% below 2012 emissions levels by 2050.
- ⇨ A fully decarbonised electricity sectors is critical for enabling low-carbon electrification trends in urban passenger transport and residential buildings in line with the Paris Agreement temperature limit.
- ⇨ There is huge potential for (sub-)national actors to accelerate climate action by successfully decarbonising key areas such as urban passenger transport and residential housing, for example by shifting towards public modes of transport and increase electric mobility in Cape Town, Durban, and Gauteng.
- ⇨ Changing from a high to a low-carbon electricity supply by 2030 is likely to create as many employment opportunities in South Africa as it would make obsolete and provides jobs in technologies and sectors that are more likely to form the core of future electricity supply, both in South Africa and globally.

Authors

Ecofys
Thibaud Lemercier
Tom Berg
Yvonne Deng
Kornelis Blok

NewClimate Institute
Frederic Hans
Hanna Fekete
Keno Riechers
Takeshi Kuramochi
Niklas Höhne
Nicolas Fux
Harry Fearnehough

Climate Analytics
Bill Hare
Michiel Schaeffer
Ursula Fuentes Hutfilter
Tina Aboumahboub
Jasmin Cantzler
Andrzej Ancygier
Matt Beer

The Climate Action Tracker is made possible due to generous support from the ClimateWorks Foundation and the German Ministry for Environment, Nature Conservation and Nuclear Safety (BMU) via the International Climate Initiative. The content of this report is the responsibility of the authors only.

Climate Action Tracker

The Climate Action Tracker (CAT) is an independent scientific analysis produced by three research organisations tracking climate action since 2009. We track progress towards the globally agreed aim of holding warming well below 2°C, and pursuing efforts to limit warming to 1.5°C.

climateactiontracker.org

The Consortium

Ecofys, a Navigant company, is a leading international energy and climate consultancy focused on sustainable energy for everyone. Founded in 1984, the company is a trusted advisor to governments, corporations, NGOs, and energy providers worldwide. The team delivers powerful results in the energy and climate transition sectors. Working across the entire energy value chain, Ecofys develops innovative solutions and strategies to support its clients in enabling the energy transition and working through the challenges of climate change.

ecofys.com

NewClimate Institute is a non-profit institute established in 2014. NewClimate Institute supports research and implementation of action against climate change around the globe, covering the topics international climate negotiations, tracking climate action, climate and development, climate finance and carbon market mechanisms. NewClimate Institute aims at connecting up-to-date research with the real world decision making processes.

newclimate.org

Climate Analytics is a non-profit climate science and policy institute based in Berlin, Germany with offices in New York, USA, Lomé, Togo and Perth, Australia, which brings together interdisciplinary expertise in the scientific and policy aspects of climate change. Climate Analytics aims to synthesise and advance scientific knowledge in the area of climate, and by linking scientific and policy analysis provide state-of-the-art solutions to global and national climate change policy challenges.

climateanalytics.org

Bibliography

Aber, J. (2016). Electric Bus Analysis for New York City Transit, (May), 37. https://doi.org/http://www.columbia.edu/~ja3041/Electric%20Bus%20Analysis%20for%20NYC%20Transit%20by%20J%20Aber%20Columbia%20University%20-%20May%202016.pdf

AIDC. (2016). *One Million Climate Jobs: Moving South Africa forward on a low-carbon, wage-led, and sustainable path*. Retrieved from http://aidc.org.za/download/climate-change/OMCJ-booklet-AIDC-electronic-version.pdf [accessed on 4 April 2018]

Altieri, K., Trollip, H., & Caetano, T. (2015). *Pathways to deep decarbonisation in South Africa*. Retrieved from http://deepdecarbonisation.org/wp-content/uploads/2015/09/DDPP_ZAF.pdf [accessed on 21 December 2017]

Ampofo-anti, N. L. (2017). Delivering construction projects using innovative building technologies. *Proceedings 11th Built Environment Conference*, (ASOCSA2017/Paper 038). Retrieved from https://researchspace.csir.co.za/dspace/bitstream/handle/10204/9662/Ampofo_19480_2017.pdf?sequence=1&isAllowed=y

Arthur D. Little Global. (2014). *The Future of Urban Mobility 2.0: Imperatives to Shape Extended Mobility Ecosystems of Tomorrow*. Retrieved from http://www.uitp.org/sites/default/files/members/140124 Arthur D. Little %26 UITP_Future of Urban Mobility 2 0_Full study.pdf

Beetz, B. (2017). South Africa: Calls for 1.5 GW of annual PV, 55,000 new jobs – comment. *Pv Magazine*. Retrieved from https://www.pv-magazine.com/2017/12/12/south-africa-calls-for-1-5-gw-of-annual-pv-55000-new-jobs-comment/ [accessed on 2 July 2017]

BNEF. (2017). *Electric vehicle outlook 2017. Executive Summary*. Retrieved from https://data.bloomberglp.com/bnef/sites/14/2017/07/BNEF_EVO_2017_ExecutiveSummary.pdf [accessed on 14 December 2017]

Boermans, T., Bettgenhäuser, K., Offermann, M., & Schimschar, S. (2012). *Renovation Tracks for Europe up to 2050. Report commissioned by Eurima - European Insulation Manufacturers Association*. Cologne, Germany: Ecofys Germany. Retrieved from http://www.eurima.org/uploads/ModuleXtender/Publications/90/Renovation_tracks_for_Europe_08_06_2012_FINAL.pdf

Bosch, J. M., & von Gadow, K. (1990). Regulating Afforestation for Water Conservation in South Africa. *South African Forestry Journal*, *153*(1), 41–54. https://doi.org/10.1080/00382167.1990.9629032

BPIE. (2015). *Nearly Zero Energy Buildings Definitions Across Europe*. Retrieved from http://bpie.eu/uploads/lib/document/attachment/128/BPIE_factsheet_nZEB_definitions_across_Europe.pdf

Bubeck, S., Tomaschek, J., & Fahl, U. (2014). Potential for mitigating greenhouse gases through expanding public transport services: A case study for Gauteng Province, South Africa. *Transportation Research Part D: Transport and Environment*, *32*, 57–69. https://doi.org/10.1016/j.trd.2014.07.002

Burkhardt, P. (2018). South Africa's Eskom Signs $100 Million Loan From German Bank KfW. Retrieved from https://www.bloomberg.com/news/articles/2018-06-29/s-africa-s-eskom-signs-100-million-loan-from-german-bank-kfw [accessed on 20 September 2018]

BusinessTech. (2018). Here's how many electric cars have been sold in South Africa. Retrieved July 2, 2018, from https://businesstech.co.za/news/motoring/219585/heres-how-many-electric-cars-have-been-sold-in-south-africa/

C40. (2017). *C40 Greenhouse Gas Emissions Dashboard Data*. Retrieved from http://www.c40.org/other/gpc-dashboard

C40 Initiative. (2018). C40 cities. Retrieved February 15, 2018, from http://www.c40.org/cities

Chamber of Mines in South Africa. (2017). Key facts and firgures. Retrieved from http://www.chamberofmines.org.za/sa-mining/coal [accessed on 21 December 2017]

Chamber of Mines in South Africa. (2018). *Coal Strategy 2018*. Retrieved from http://www.mineralscouncil.org.za/component/jdownloads/send/25-downloads/535-coal-strategy-2018 [accessed on 2 July 2018]

City of Johannesburg. (2017). *Joburg 2040: Growth and Development Strategy "A promising future."* Retrieved from http://www.jhbproperty.co.za/index.php/why-invest/why-invest-in-joburg-2

Climate Action Tracker. (2016a). *CAT Factsheet South Africa*. https://doi.org/10.1787/eco_outlook-v2016-1-42-en

Climate Action Tracker. (2016b). *Constructing the future: Will the building sector use its decarbonisation tools? CAT Decarbonisation Series*. Climate Action Tracker (Climate Analytics, Ecofys, NewClimate Institute). Retrieved from http://climateactiontracker.org/assets/publications/briefing_papers/CAT_Decarb_Buildings_Final_2016.pdf

Climate Action Tracker. (2016c). *The ten most important short-term steps to limit warming to 1.5°C*. Climate Action Tracker (Climate Analytics, Ecofys, NewClimate Institute). Retrieved from http://climateactiontracker.org/assets/publications/publications/CAT_10_Steps_for_1o5.pdf

Climate Action Tracker. (2017a). Decarbonisation indicators. Retrieved from http://climateactiontracker.org/decarbonisation/macro/countries/cn+us/indicators/gdp_per_capita+primary_energy_demand_per_capita/variables/all

Climate Action Tracker. (2017b). *Foot off the gas: increased reliance on natural gas in the power sector risks an emissions lock-in*. Climate Action Tracker (Climate Analytics, Ecofys, NewClimate Institute). Retrieved from https://newclimateinstitute.files.wordpress.com/2017/06/cat-2017-06-16-decarbonisationseries-naturalgas2.pdf

Climate Action Tracker. (2017c). *Improvement in warming outlook as India and China move ahead , but Paris Agreement gap still looms large*. Retrieved from http://climateactiontracker.org/assets/publications/briefing_papers/CAT_2017-11-15_Improvement-in-warming-outlook.pdf

Climate Action Tracker. (2018a). Climate Action Tracker - Country Assessments. Retrieved from www.climateactiontracker.org

Climate Action Tracker. (2018b). Climate Action Tracker Data Portal. Retrieved from http://climateactiontracker.org/decarbonisation/intro

Climate Action Tracker. (2018c). *For the Talanoa dialogue : Steps towards global decarbonisation in key emitting sectors*. Retrieved from https://climateactiontracker.org/documents/394/2018-Oct_TalanoaSubmission_ClimateActionTracker_FINAL.pdf

Climate Action Tracker. (2018d). South Africa country assessment (Sept 2018). Retrieved September 19, 2018, from http://climateactiontracker.org/countries/southafrica.html

Climate Action Tracker. (2018e). *The Highway to Paris: Safeguarding the Climate by Decarbonising Freight Transport*. Retrieved from https://climateactiontracker.org/documents/353/CAT_20180522_DecarbSeries_FreightTransport.pdf

CoalSwarm. (2018). *Global Coal Plant Tracker*. Retrieved from https://endcoal.org/global-coal-plant-tracker/summary-statistics/ [accessed on 19 September 2018]

Cornet, M., Jossen, Q., Pestiaux, J., Vermeulen, P., Hagemann, M., Kuramochi, T., & Niklas, H. (2018). *The EU Can Increase Its Climate Targets To Be in Line With a Global 1.5°C Target*. Retrieved from https://europeanclimate.org/wp-content/uploads/2018/04/180401-EU-CTI-2030-Summary-for-Policy-Makers-vFinal.pdf [accessed on 9 May 2018]

Creamer, T. (2018, April 4). Radebe says signing of 27 IPP agreements a 'new dawn' for renewables in South Africa. *Engineering News*. Retrieved from http://m.engineeringnews.co.za/article/radebe-says-signing-of-27-ipp-agreements-a-new-dawn-for-renewables-2018-04-04/rep_id:4433

Davis-Reddy, C., & Vincent, K. (2017). *Climate Risk and Vulnerability: A Handbook for Southern Africa (2nd Ed.)*. Pretoria. https://doi.org/10.1016/B978-0-12-801477-6.00003-4

Day, T., Gonzales-Zuñiga, S., Höhne, N., Fekete, H., Sterl, S., Hans, F., … Van Breevoort, P. (2018). OPPORTUNITY 2030: BENEFITS OF CLIMATE ACTION IN CITIES Quantifying the benefits of city-level measures in buildings, transport and energy supply. NewClimate Institute. Retrieved from https://newclimate.org/wp-content/uploads/2018/03/C40_Opportunities_2030_report.pdf

DEA. (2014). *Climate Change Mitigation Policy Mainstreaming*.

Deign, J. (2018, February 9). Despite Eskom's Troubles, a Surprise Change in Fortune for South African Renewables. *GTM*. Retrieved from https://www.greentechmedia.com/articles/read/surprise-change-in-fortune-for-south-african-renewables#gs.qWzWTnY

Department Environmental Affairs of South Africa. (2014). *South Africa's Greenhouse Gas Mitigation Potential Analysis*. https://doi.org/10.4159/harvard.9780674864092.c26

Department of Economic Developement. (2011). *The New Growth Path (NGP)*. Retrieved from https://www.google.co.za/webhp?sourceid=chrome-instant&ion=1&espv=2&ie=UTF-8#

Department of Energy. (2007). *Biofuels Industrial Strategy of South Africa*. Retrieved from http://www.un-page.org/file/1521/download?token=bV7klp1w [accessed on 17 November 2017]

Department of Energy. (2011). *Integrated Resource Plan for Electricity 2010-2030*. Retrieved from http://www.energy.gov.za/IRP/irp files/IRP2010_2030_Final_Report_20110325.pdf

Department of Energy. (2012). *Regulations Regarding the Mandatory Blending of Biofuels with Petrol and Diesel. Government Gazette*. https://doi.org/http://dx.doi.org/9771682584003-32963

Department of Energy. (2016a). *CoGeneration IPP Procurement Programme*. Retrieved from https://www.ipp-projects.co.za/PressCentre/GetPressRelease?fileid=2e60fc5c-68d5-e511-943c-2c59e59ac9cd&fileName=CoGen_IPP_Procurement Programme_Window 1A Announcement Jan 2016.pdf [accessed on 16 November 2017]

Department of Energy. (2016b). *Draft Post-2015 National Energy Efficiency Strategy. Government Gazette*. Retrieved from https://www.gov.za/sites/www.gov.za/files/40515_gen948.pdf [accessed on 30 August 2017]

Department of Energy. (2018). *Draft Integrated Resource Plan 2018*. Retrieved from http://www.energy.gov.za/IRP/irp-update-draft-report2018/IRP-Update-2018-Draft-for-Comments.pdf [accessed on 30 August 2018]

Department of Energy of South Africa. (2015). *National Energy Act (34/2008): Published for public comments: Draft Regulations regarding Registration, Reporting on Energy Management and Submission of Energy Management Plans . Government Gazette*. Retrieved from http://www.energy.gov.za/files/policies/Draft-Regulations-Registration-Reporting-on-Energy-Management-and-Submission-of-Energy-Management-Plans.pdf

Department of Environmental Affairs. (2011). *National Strategy for Sustainable Development and Action Plan*. Retrieved from https://www.environment.gov.za/sites/default/files/docs/sustainabledevelopment_actionplan_strategy.pdf [accessed on 20 December 2017]

Department of Environmental Affairs. (2013). *GHG Inventory for South Africa*. Retrieved from https://www.environment.gov.za/sites/default/files/docs/greenhousegas_invetorysouthafrica.pdf

Department of Environmental Affairs. (2014a). *South Africa's 1st Biennial Update Report*. Retrieved from http://unfccc.int/resource/docs/natc/zafbur1.pdf [accessed on 25 October 2017]

Department of Environmental Affairs. (2014b). South Africa's 1st Biennial Update Report, (November), 63–65. Retrieved from http://unfccc.int/resource/docs/natc/zafbur1.pdf [accessed on 25 October 2017]

Department of Environmental Affairs. (2014c). *South Africa's Greenhouse Gas Mitigation Potential Analysis - Annex G: AFOLU sector*. Pretoria, South Africa.

Department of Environmental Affairs. (2015). South Africa 2050 Calculator. Retrieved September 27, 2018, from http://sa2050pathways.environment.gov.za/pathways/1111111111111111111111111111111111111111/primary_energy_chart/comparator/111111111111111111111111111111111111111

Department of Environmental Affairs. (2016a). *Draft GHG National Inventory Report - South Africa: 2000-2012*. Retrieved from https://cer.org.za/wp-content/uploads/2014/02/Draft-GHG-Inventory-Report-SA.pdf [accessed on 21 February 2018]

Department of Environmental Affairs. (2016b). National Pollution Prevention Plans Regulations. *Government Gazette*. Retrieved from https://www.environment.gov.za/sites/default/files/gazetted_notices/nemaqa_39of2004_nationalpoll ution_preventionplansregulations_gn39578.pdf

Department of Environmental Affairs. (2017a). National Greenhouse Gas Emission Reporting Regulations. *Government Gazette*, *622*(40762), 4–24. Retrieved from https://www.gov.za/sites/www.gov.za/files/40762_gen275.pdf

Department of Environmental Affairs. (2017b). *South Africa's 2nd Biennial Update Report*. Retrieved from http://unfccc.int/files/national_reports/non-annex_i_parties/biennial_update_reports/application/pdf/south_africa_2nd_bur.pdf [accessed on 21 February 2018]

Department of Environmental Affairs. (2018). *Climate Change Bill, 2018: For public comment. Government Gazette*. https://doi.org/http://dx.doi.org/9771682584003-32963

Department of Environmental Affairs and Tourism - Republic of South Africa. (2008). People - Planet - Prosperity : A National Framework for Sustainable Development in South Africa, (July), 1–94.

Department of Environmental Affairs South Africa. (2014). *GHG Inventory for South Africa*. Retrieved from https://www.environment.gov.za/sites/default/files/docs/greenhousegas_invetorysouthafrica.pdf

Department of Minerals and Energy. (2005). *Energy efficiency strategy of the Republic of South Africa*. Pretoria. Retrieved from http://www.energy.gov.za/files/esources/electricity/ee_strategy_05.pdf

Department of Trade and Industry of South Africa. (2017a). *Industrial Policy Action Plan 2017/18-2019/20 Part II*. Retrieved from http://www.thedti.gov.za/DownloadFileAction?id=1171

Department of Trade and Industry of South Africa. (2017b). *Industrial policy Action Plan 2017 Part I*. Retrieved from http://www.thedti.gov.za/DownloadFileAction?id=1170

Department of Transport. (2015). *National Rail Policy Green Paper*. Retrieved from http://www.transport.gov.za/documents/11623/21629/NationalRailPolicyGreenPaper.pdf/ea72ecab-2990-41cd-a0dd-f5e7a2c3e82a [accessed on 15 December 2017]

Department of Transport. (2016). *South African State Action Plan: 2016*. Retrieved from http://www.caa.co.za/Aviation Environmental Protection Documents/South African State Action Plan 1st Edition Sept 2016.pdf [accessed on 24 November 2017]

Department of Transport. (2017a). Bus Rapid Transit System (BRT). Retrieved from https://www.gov.za/about-government/government-programmes/bus-rapid-transit-system-brt [accessed on 23 November 2017]

Department of Transport. (2017b). *Green Transport Strategy 2017-2050 - Draft*. Retrieved from https://roadtransportnews.co.za/wp-content/uploads/2017/08/Draft-Green-Transport-Strategy.pdf [accessed on 23 November 2017]

Department of Transport South Africa. (2017). *Draft White Paper on National Rail Policy*. Retrieved from http://www.transport.gov.za/documents/11623/21629/DraftWhitePaperNationalRailPolicy2017.pdf/a1ce7cfd-e45a-46e2-8f8d-76eb488cc6e9

Department of Treasury. (2017). *Release of carbon tax bill for introduction in parliament and public comment*. Retrieved from http://www.treasury.gov.za/comm_media/press/2017/2017121401 MEDIA STATEMENT - CARBON TAX BILL.pdf [accessed on 18 December 2017]

Didiza, S. (2014). *Market Intelligence Report: Built Environment*. Retrieved from https://www.greencape.co.za/assets/Uploads/GreenCape-MIR-Built-Environment.pdf? [accessed on 4 April 2018]

Eco Mobility. (2018). Bogota, Colombia. Retrieved July 2, 2018, from https://ecomobility.org/alliance/alliance-cities/bogota-colombia/

ESI Africa. (2016). Thabametsi and Khanyisa take first in SA coal baseload IPP. Retrieved November 2, 2017, from https://www.esi-africa.com/news/thabametsi-khanyisa-take-firsts-sa-coal-baseload-ipp/

Eskom. (2017a). Kusile Power Station Project. Retrieved from http://www.eskom.co.za/Whatweredoing/NewBuild/Pages/Kusile_Power_Station.aspx [accessed on 17 November 2017]

Eskom. (2017b). Medupi Power Station Project. Retrieved from http://www.eskom.co.za/Whatweredoing/NewBuild/MedupiPowerStation/Pages/Medupi_Power_Station_Project.aspx [accessed on 17 November 2017]

eThekwini Transport Authority. (2010). Integrated Transport Plan Update.

FAOSTAT. (2017). FAOSTAT statistical databases. Updated 28 September, 2017. Retrieved September 28, 2017, from http://www.fao.org/faostat/en/

Fekete, H., Roelfsema, M., Höhne, N., den Elzen, M., Forsell, N., & Becerra, S. (2015). *Impacts of good practice policies on regional and global greenhouse gas emissions*. NewClimate Institute, PBL Netherlands Environmental Assessment Agency and International Institute for Applied Systems Analysis. Retrieved from https://newclimate.org/2015/07/29/the-impact-of-good-practice-policies-on-regional-and-global-greenhouse-gas-emissions/

FIRM. (2016). *Obtaining long-term forecasts of the key drivers of greenhouse gas emissions in South Africa*. Retrieved from http://www.erc.uct.ac.za/sites/default/files/image_tool/images/119/Papers-2016/16-Merven-etal-Longterm_GHG_forecasts.pdf [accessed on 2 November 2017]

Fundira, T., & Henley, G. (2017). *Biofuels in Southern Africa: Political economy, trade, and policy environment* (WIDER Working Paper). Retrieved from https://www.wider.unu.edu/sites/default/files/wp2017-48.pdf [accessed on 25 August 2017]

Gauteng City Region Observatory. (2014). *Mobility in the Gauteng City-Region* , (Vol. 4). Retrieved from http://www.gcro.ac.za/media/reports/mobility_report_july_28_2014_medium_res_2.pdf

Gauteng Province Department of Roads and Transport. (2013). *GAUTENG ' s 25-YEAR INTEGRATED TRANSPORT MASTER PLAN*.

GBCSA. (2012). *Improving lives by greening low-cost housing housing - Case study report of the Cato Manor Green Street*. Retrieved from https://www.gbcsa.org.za/wp-content/uploads/2013/06/Improving-lives-by-greening-low-income-homes-Case-Study-2012-FINAL.pdf [accessed on 4 April 2018]

GBCSA. (2017). Green Building Council South Africa. Retrieved December 5, 2017, from https://www.gbcsa.org.za

GBPN. (2014). *South Africa*.

Go!Durban. (2018). Home | GoDurban. Retrieved July 2, 2018, from http://www.godurban.co.za/ [accessed on 1 July 2018]

Gota, S., Huizenga, C., Peet, K., Medimorec, N., & Bakker, S. (2018). Decarbonising transport to achieve Paris Agreement targets. *Energy Efficiency*, 1–24. https://doi.org/10.1007/s12053-018-9671-3

Götz, T., Tholen, L., & Adisorn, T. (2016). The New South African Standards and Labelling Programme for Residential Appliances – A First-Hand Evaluation Case Study The current status of Standards and Labelling in South Africa.

Gouldson, A., Colenbrander, S., Sudmant, A., Godfrey, N., Millward-Hopkins, J., Fang, W., & Zhao, X. (2015). Accelerating Low-Carbon Development in the World's Cities, 1–34. Retrieved from http://newclimateeconomy.net/content/press-release-low-carbon-cities-are-us17-trillion-opportunity-worldwide

Government of South Africa. (2011). *National Climate Change Response White Paper*. Retrieved from https://www.sanbi.org/sites/default/files/documents/documents/national-climate-change-response-white-paper.pdf [accessed on 24 October 2017]

Government of South Africa. (2012). *National Environmental Management: Air Quality Act. Government Gazette* (Vol. GN37054). Retrieved from https://www.environment.gov.za/sites/default/files/legislations/listofactivities_atmospheric_emissions.pdf [accessed on 17 November 2017]

Government of South Africa. (2016a). *Nationally Determined Contribution (NDC)*. Retrieved from http://www4.unfccc.int/ndcregistry/PublishedDocuments/South Africa First/South Africa.pdf [accessed on 23 August 2017]

Government of South Africa. (2016b). *Press Release - Coal-based Independent Power Producer programme announcement*. Retrieved from https://www.ipp-projects.co.za/PressCentre/GetPressRelease?fileid=228bdd35-e18e-e611-9455-2c59e59ac9cd&fileName=PressRelease-Coal-based-Independent-Power-Producer-programme-announcement-10Oct2016.pdf [accessed on 10 October 2017]

Grantham Research Institute on Climate Change and the Environment. (2017). Country Profile South Africa. Retrieved December 7, 2017, from http://www.lse.ac.uk/GranthamInstitute/country-profiles/south-africa/

Green Building Council for South Africa. (2017). Green Star SA Rating System. Retrieved December 21, 2017, from https://www.gbcsa.org.za/green-star-sa-rating-system/

GreenCape. (2017). *Market Intelligence Report 2017: Utility-scale renewable energy*. Retrieved from https://www.greencape.co.za/assets/Uploads/GreenCape-Renewable-Energy-MIR-2017-electronic-FINAL-v1.pdf [accessed on 18 October 2017]

Groenewald, Y. (2017). Dilly-dallying endangering SA's renewable programme. Retrieved August 30, 2017, from http://www.fin24.com/Economy/dilly-dallying-endangering-sas-renewable-programme-20170620

Hachigonta, S., Nelson, G. C., Thomas, T. S., & Sibanda, L. M. (2013). *Southern African Agriculture and Climate Change. A Comprehensive Analysis*. https://doi.org/10.2499/9780896292086

Hall, D., Cui, H., & Lutsey, N. (2017). Electric vehicle capitals of the world: What markets are leading the transition to electric?, (November).

Hall, D., Moultak, M., & Lutsey, N. (2017). Electric vehicle capitals of the world: Demonstrating the path to electric drive, (March), 57. Retrieved from https://www.theicct.org/sites/default/files/publications/Global-EV-Capitals_White-Paper_06032017_vF.pdf

Hartley, F., Ireland, G., Merven, B., Burton, J., Ahjum, F., McCall, B., … Arndt, C. (2017). *The developing energy landscape in South Africa: Technical Report*. Retrieved from http://www.erc.uct.ac.za/sites/default/files/image_tool/images/119/Researchdocs/ERC 2017 The developing energy landscape in South Africa - Technical Report FINAL.pdf [accessed on 12 January 2017]

Huizenga, C., Peet, K., & Gota, S. (2016). Urban Transport and Climate Change. *State of the World*, (September), 195–210. https://doi.org/10.5822/978-1-61091-756-8_16

ICLEI. (2017). *City of Medellín , Colombia Improving inclusivity through connectivity and mobility*. Retrieved from https://ecomobility.org/wpdm-package/iclei-cs-203-medellin-ecomobility-pdf/?wpdmdl=30516

Idiata, D. J., Ebiogbe, M., Oriakhi, H., & Iyalekhue, O. L. (2013). Wood Fuel Usage and the Challenges on the Environment. *International Journal of Engineering Sciences*, *2*(4), 110–114.

IEA. (2013). *Transition to Sustainable Buildings*. (I. E. Agency, Ed.). Paris, France: International Energy Agency. https://doi.org/10.1787/9789264202955-en

IEA. (2016a). *Energy Technology Perspectives 2016*. Paris, France: International Energy Agency. Retrieved from http://www.iea.org/etp/etp2016/

IEA. (2016b). *Global EV Outlook 2016: Beyond One Million Electric Cars*. Paris, France: International Energy Agency. Retrieved from https://www.iea.org/publications/freepublications/publication/Global_EV_Outlook_2016.pdf

IEA. (2017a). *Energy Statistics and Balances. 2017 Edition*. Paris, France.

IEA. (2017b). *World Energy Outlook 2017*. Paris, France: International Energy Agency. Retrieved from https://www.iea.org/weo2017/

IEA. (2018). *CO2 emissions from fuel combustion (2018 edition)*. Paris, France.

IMO. (2017). Low carbon shipping and air pollution control. Retrieved December 4, 2017, from http://www.imo.org/en/MediaCentre/HotTopics/GHG/Pages/default.aspx

Independent Power Producers Office. (2017). Independent Power Producer Procurement Programme. Retrieved August 30, 2017, from https://www.ipp-renewables.co.za/

International Energy Agency. (2018). *Global EV Outlook 2018*. Retrieved from https://webstore.iea.org/download/direct/1045?filename=globalevoutlook2018.pdf

IPCC. (2018). *IPCC special report on the impacts of global warming of 1.5°C - Summary for policy makers*. Retrieved from http://www.ipcc.ch/report/sr15/

Ireland, G., & Burton, J. (2018). *An assessment of new coal plants in South Africa's electricity future: The cost, emissions, and supply security implications of the coal IPP programme*. Retrieved from http://thegreentimes.co.za/wp-content/uploads/2018/06/Assessment-of-South-Africa-coal-plants.pdf [accessed on 2 July 2018]

IRENA. (2017). *Renewable Energy Auctions: Analysing 2016*. Retrieved from http://www.irena.org/DocumentDownloads/Publications/IRENA_REAuctions_summary_2017.pdf [accessed on 12 January 2017]

IRENA. (2018a). *Renewable Capacity Statistics 2018*. Retrieved from http://resourceirena.irena.org/gateway/dashboard/ [accessed on 19 September 2018]

IRENA. (2018b). Renewable Energy and Jobs. Annual Review 2018. Retrieved from http://irena.org/publications/2018/May/Renewable-Energy-and-Jobs-Annual-Review-2018

Jennings, G. (2015). Public Transport Interventions and Transport Justice in South Africa : a Literature and Policy Review. *Satc 2015*, (Satc 2015), 764–775.

Knorr, K., Zimmermann, B., Bofinger, S., Gerlach, A.-K., Bischof-Niemz, T., & Mushwana, C. (2016). *Wind and Solar PV Resource Aggregation Study for South Africa*. https://doi.org/RFP No. 542-23-02-2015

Kriegler, E., Bertram, C., Kuramochi, T., Jakob, M., Pehl, M., Stevanović, M., … Edenhofer, O. (2018). Short term policies to keep the door open for Paris climate goals. *Environmental Research Letters*. https://doi.org/https://doi.org/10.1088/1748-9326/aac4f1

Krog, P. J. (2015). *The potential carbon dioxide emissions reduction when energy service interventions are applied to the current subsidised housing demand*. Univeristy of Cape Town. Retrieved from https://open.uct.ac.za/bitstream/item/27692/thesis_ebe_2016_krog_petrus_jacobus.pdf?sequence=1

Kuramochi, T., Fekete, H., Hans, F., Luna, L., Gonzales-Zuñiga, S., Sterl, S., … Turkovska, O. (2017). *Greenhouse gas mitigation scenarios for major emitting countries. Analysis of current climate policies and mitigation pledges: 2017 update*. NewClimate Institute, PBL Netherlands Environmental Assessment Agency and International Institute for Applied Systems Analysis (IIASA). Retrieved from https://newclimateinstitute.files.wordpress.com/2017/11/ec-pbl_fact-sheet_currentpolicies_2017_final3b.pdf

Kuramochi, T., Höhne, N., Schaeffer, M., Cantzler, J., Hare, B., Deng, Y., … Blok, K. (2018). Ten key short-term sectoral benchmarks to limit warming to 1.5°C. *Climate Policy*, *18*(3), 287–305. https://doi.org/10.1080/14693062.2017.1397495

Lah, O., Shrestha, S., & Hüging, H. (2015). Transferring sustainable transport and ecomobility solutions, (September), 16.

LSE Cities. (2018). Urban Age Cities Compared. Retrieved March 20, 2018, from https://lsecities.net/media/objects/articles/urban-age-cities-compared/en-gb/

Lutsey, N. (2018). California's Continued Electric Vehicle Market Development, *2018*(July 2, 2018). Retrieved from https://www.theicct.org/sites/default/files/publications/CA-cityEV-Briefing-20180507.pdf

McKinsey Center for Business and Environment. (2017). Focused acceleration: A strategic approach to climate action in cities to 2030. Retrieved from https://c40-production-images.s3.amazonaws.com/researches/images/66_MCBE_C40_Focused_Acceleration_report.original.pdf?1510424835

National Assembly of South Africa. (2017). *Proceedings to the national assembly*. Retrieved from https://www.parliament.gov.za/storage/app/media/Docs/hansard/c857f54a-6c5e-4eb6-8092-c88134c4fb44.pdf [accessed on 22 November 2017]

National Cleaner Production Centre South Africa. (2015). Industrial Symbiosis Programme. Retrieved January 11, 2018, from http://ncpc.co.za/files/NCPC Brochures/ISP_FINAL_REPRO_180X180mm_final_low-res_singles.pdf

National Planning Commission. (2012). *National Development Plan*. https://doi.org/ISBN: 978-0-621-41180-5

Nciizah, A. D., & Wakindiki, I. I. C. (2015). Climate Smart Agriculture: Achievements and Prospects in Africa. *Journal of Geoscience and Environment Protection*, *03*(06), 99–105. https://doi.org/10.4236/gep.2015.36016

NCPC-SA. (2017). *Annual Report*. Retrieved from http://ncpc.co.za/files/NCPC ANNUAL REVIEW 20167_FINAL low res.pdf

Njobeni, S. (2018). New renewable energy round may rake in R50bn in investment. *BusinessReport*. Retrieved from https://www.iol.co.za/business-report/energy/new-renewable-energy-round-may-rake-in-r50bn-in-investment-15297984 [accessed on 2 July 2018]

Obert, M., & Pöller, M. (2017). Assessing the impact of increasing shares of variable generation on system operations in South Africa. Retrieved from http://www.ee.co.za/wp-content/uploads/2017/09/GIZ_M_P_E_2017_Flexibility_Study_Report.pdf [accessed on 26 October 2017]

Observatorio de Movilidad. (2016). *Reporte Anual de Movilidad 2015* (Vol. 9). Retrieved from http://bibliotecadigital.ccb.org.co/handle/11520/18119

Omarjee, L. (2018). Radebe: Renewable IPPs to create over 114 000 "job years." *Fin24*. Retrieved from https://www.fin24.com/Economy/radebe-renewable-ipps-to-create-over-114-000-job-years-20180705 [accessed on 20 September 2018]

PAGE. (2017). *Greem Economy Inventory for South Africa: An Overview*. Pretoria, South Africa. Retrieved from http://www.un-page.org/files/public/green_economy_inventory_for_south_africa.pdf [accessed on 3 April 2018]

Paton, C. (2018, September 4). Two new coal plants will have minimal effect on electricity cost, says energy department. *BusinessDay*. Retrieved from https://www.businesslive.co.za/bd/national/2018-09-04-two-new-coal-plants-will-have-minimal-effect-on-electricity-cost-says-energy-department/

Prim, L. B. (2016). *The Responsiveness of Public Transport Systems to the Development of Urban and Economic Nodes in Johannesburg*. University of the Witwatersrand. Retrieved from http://wiredspace.wits.ac.za/handle/10539/22359

Rayner, S. (2012). *International Experience and Trends: Vehicle fuel economy, taxation and fuel quality*. Retrieved from http://staging.unep.org/transport/pcfv/PDF/GFEI_AfricaLaunch/InternationalExperience.pdf [accessed on 24 November 2017]

Reuters. (2018). South Africa to open bidding round for green energy contracts in November. *Reuters*. Retrieved from https://www.reuters.com/article/safrica-power-ipp/s-africa-to-open-bidding-round-for-green-energy-contracts-in-november-idUSL5N1T31NM [accessed on 5 July 2018]

Roelfsema, M., Fekete, H., Höhne, N., den Elzen, M., Forsell, N., Kuramochi, T., … van Vuuren, D. P. (2018). Reducing global greenhouse gas emissions by replicating successful sector examples: the "good practice policies" scenario. *Climate Policy*. https://doi.org/10.1080/14693062.2018.1481356

SABS. (2014). What does "SANS 941: Energy Efficiency SANS 941: Energy Efficiency for Electrical and Electronic Apparatus for Electrical and Electronic Apparatus" require? Retrieved December 5, 2017, from https://www.sabs.co.za/docs%5CBarry_Bredenkamp_SANEDI_SABS Convention 2012.PDF

SANEDI. (2014). *The Status of Energy Efficiency in the Housing Sector - mapping energy efficiency in South Africa*.

SARS. (2017). Carbon Emissions Motor Vehicles Tax. Retrieved from http://www.sars.gov.za/ClientSegments/Customs-Excise/Excise/Environmental-Levy-Products/Pages/Motor-vehicle-CO2-emmision-levy.aspx [accessed on 23 November 2017]

Sartor, O. (2017). *Strengthening national coal transitions to raise climate ambition*.

SHRA. (2017). *Annual report 2016/17*. Retrieved from http://www.shra.org.za/images/PDFs/Annual Reports/SHRA Annual Report FA web (1).pdf [accessed on 4 April 2018]

Snyman, C. (2017). SA must embrace electric vehicles now or fall behind. *Business Day*. Retrieved from https://www.businesslive.co.za/bd/opinion/2017-03-09-sa-must-embrace-electric-vehicles-now-or-fall-behind/ [accessed on 23 November 2017]

South African Cities Network. (2014). *Modelling Energy Efficiency Potential in Municipal Operations of the SACN Member Cities*. Retrieved from http://www.sustainable.org.za/uploads/files/file39.pdf [accessed on 9 April 2018]

STATS South Africa. (2017). *Sustainable Development Goals - Indicator Baseline Report 2018 - South Africa*. Retrieved from http://www.statssa.gov.za/MDG/SDG_Baseline_Report_2017.pdf [accessed on 7 November 2018]

StatsSA. (2013). Gross Domestic Product First Quarter 2013. Retrieved from http://www.statssa.gov.za/publications/P0441/P04411stQuarter2013.pdf

StatsSA. (2017). Gross domestic product - Third quarter 2017. Retrieved December 15, 2017, from http://www.statssa.gov.za/publications/P0441/P04413rdQuarter2017.pdf

Sterl, S., Kuramochi, T., Hagemann, M., Gonzales-Zuñiga, S., Wouters, K., Deng, Y., … Beer, M. (2016). *The Road Ahead - How do we Move to Cleaner Car Fleets? CAT Decarbonisation Series*. Climate Action Tracker (Climate Analytics, Ecofys, NewClimate Institute). Retrieved from https://newclimateinstitute.files.wordpress.com/2016/09/cat_memo_decarb_transport.pdf

Steyn, G., Burton, J., & Steenkamp, M. (2017). *Eskom's financial crisis and the viability of coal-fired power in South Africa*. Retrieved from http://meridianeconomics.co.za/wp-content/uploads/2017/11/Eskoms-financial-crisis-and-the-viability-of-coalfired-power-in-SA_ME_20171115.pdf [accessed on 17 November 2017]

Strydom, M. (2017). *Environmental enforcement trends in South Africa: insights from our experience*. Retrieved from https://www.bowmanslaw.com/wp-content/uploads/2017/07/Enforcement-trends_-Melissa-Strydom-July-2017-final.pdf [accessed on 17 November 2017]

Sustainable Energy Africa. (2015). *State Of Energy in South African cities*. https://doi.org/10.1038/nj7242-1208a

Sustainable Energy Africa. (2017). *Sustainable energy solutions for South African local government A practical guide*. Cape Town; South Africa.

The Carbon Report. (2015). How will the draft carbon tax bill affect your business? Retrieved August 15, 2017, from http://www.thecarbonreport.co.za/the-proposed-south-african-carbon-tax/

The South African. (2013). SA car manufacturers applaud road map to electric vehicle industry. Retrieved from https://www.thesouthafrican.com/sa-car-manufacturers-applaud-road-map-to-establish-electric-vehicle-industry/ [accessed on 23 November 2017]

The Straits Times. (2015). Dubbed "the best in class": 6 things about Hong Kong's MTR rail system. Retrieved July 2, 2018, from https://www.straitstimes.com/asia/east-asia/dubbed-the-best-in-class-6-things-about-hong-kongs-mtr-rail-system

Thomas, D. P. (2016). Public Transportation in South Africa : Challenges and Opportunities. *World Journal of Social Science Research*, *3*(3), 352–366.

Transport and Urban Development Authority Cape Town. (2016). *Comprehensive integrated transport plan 2016 – 2020*. Retrieved from http://www.stellenbosch.gov.za/documents/municipal-policy/engineering-services/3638-comprehensive-integrated-transport-plan-2016-part-1/file

UNSCF. (2012). *The Government of South Africa - United Nations Strategic Cooperation Framerwork, 2013-17*.

Ürge-Vorsatz, D., Petrichenko, K., Antal, M., Staniec, M., Labelle, M., Ozden, E., & Labzina, E. (2012). *Best Practice Policies for Low Energy and Carbon Buildings: A Scenario Analysis*. Budapest, Hungary: Center for Climate Change and Sustainable Policy (3CSEP) for the Global Buildings Performance Network. Retrieved from http://www.gbpn.org/sites/default/files/08.CEU Technical Report copy_0.pdf

Vosper, S. J., & Mercure, J.-F. (2016). Assessing the effectiveness of South Africa's emissions based purchase tax for private passenger vehicles: a consumer choice modelling approach. *Journal of Energy in Southern Africa*, *27*(4), 25. https://doi.org/10.17159/2413-3051/2016/v27i4a1436

Weakley, D., & Bickford, G. (2015). Transport and urban Development : Two Studies from Johannesburg. *Transport and Urban Dev*. Retrieved from http://hdl.handle.net/10539/17439

World Bank. (2017). *Integration of the Carbon Tax and Carbon Budgets in South Africa*. Retrieved from https://openknowledge.worldbank.org/bitstream/handle/10986/28406/120003-25-9-2017-15-48-32-CarbonBudgetWeb.pdf?sequence=1&isAllowed=y [accessed on 16 November 2017]

World Green Building Council. (2016a). *World Green Building Trends*. Retrieved from http://www.worldgbc.org/files/8613/6295/6420/World_Green_Building_Trends_SmartMarket_Report_2013.pdf

World Green Building Council. (2016b). *World Green Building Trends*.

Worldbank. (2018). Urban Transport and Climate Change. Retrieved February 15, 2018, from http://www.worldbank.org/en/news/feature/2012/08/14/urban-transport-and-climate-change

Worldsteel. (2017). *STEEL STATISTICAL YEARBOOK 2017*. Retrieved from https://www.worldsteel.org/en/dam/jcr:3e275c73-6f11-4e7f-a5d8-23d9bc5c508f/Steel+Statistical+Yearbook+2017.pdf

Wouters, K., El-Laboudy, T., Deng, Y., Sterl, S., Kuramochi, T., Ancygier, A., … Beer, M. (2016). *Constructing the Future: Will the Building Sector use its Decarbonisation Tools?* Retrieved from https://newclimateinstitute.files.wordpress.com/20

16/11/201611-constructing-the-future-will-the-building-sector-use-its-decarbonisation-tools.pdf

WRI. (2018). How Did Shenzhen, China Build World's Largest Electric Bus Fleet? Retrieved August 14, 2018, from http://www.wri.org/blog/2018/04/how-did-shenzhen-china-build-world-s-largest-electric-bus-fleet

Wright, J., Bischof-Niemz, T., Calitz, J., Crescent, M., Robbie van, H., & Mamahloko, S. (2017). *Formal comments on the Integrated Resource Plan (IRP) Update Assumptions, Base Case and Observations 2016*. Retrieved from https://researchspace.csir.co.za/dspace/bitstream/handle/10204/9627/Wright_18803_2017.pdf?sequence=1 [accessed on 12 January 2018]

WWF. (2016). *GREENHOUSE GAS EMISSIONS FROM PASSENGER TRANSPORT IN GAUTENG - AN INVESTIGATION PER INCOME GROUP*. Retrieved from http://awsassets.wwf.org.za/downloads/wwf_ghg_emissions_from_passenger_transport_in_gauteng.pdf

Zhang, J. (2017). *Actions Towards Decarbonisation – Climate Policy Assessment and Emissions Modelling with Case Study for South Africa*. Enschede. Retrieved from http://essay.utwente.nl/73714/1/Zhang_MA_Engineering Technology.pdf