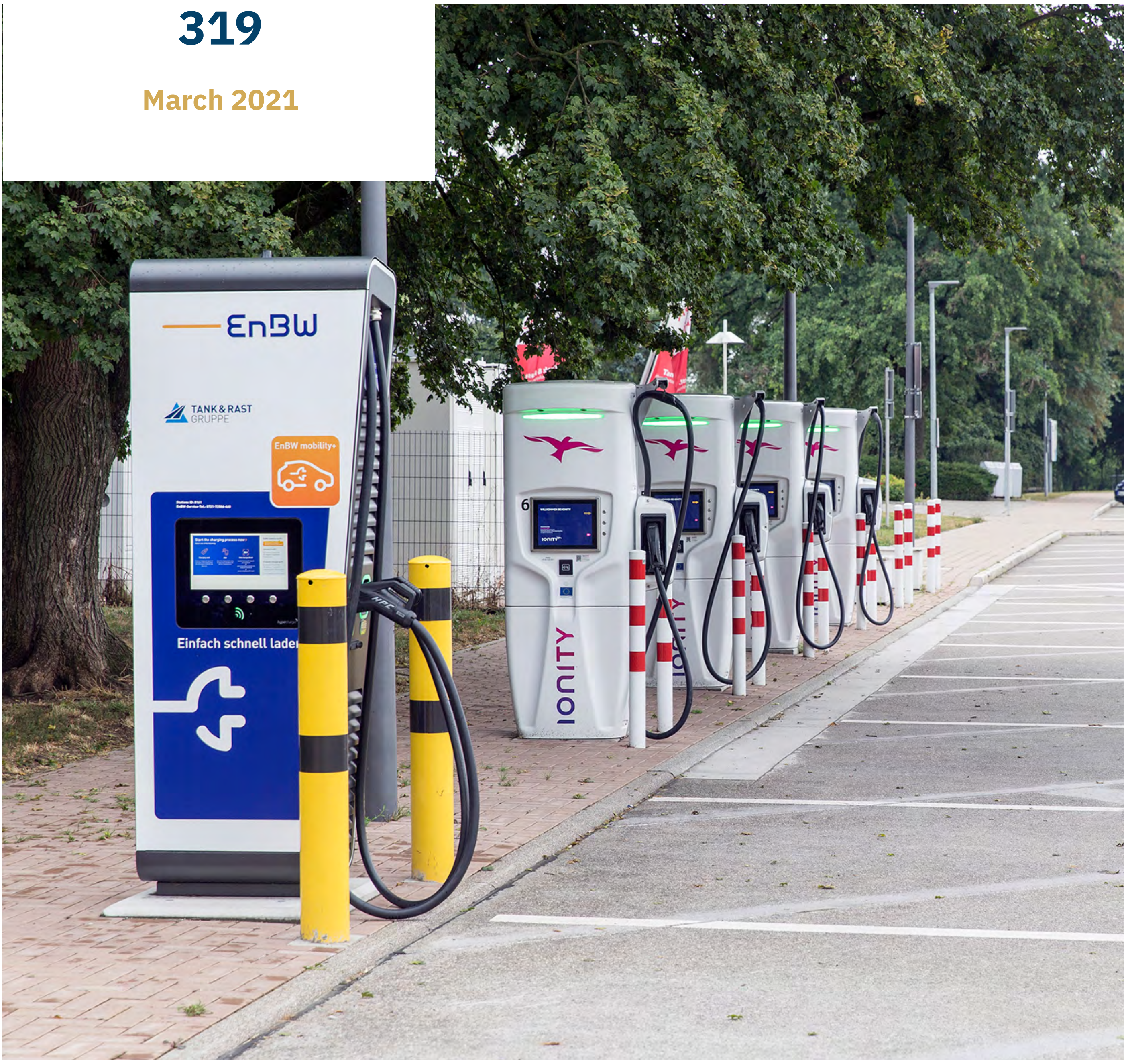
Occasional Paper

319

March 2021



SADC e-Mobility Outlook: Accelerating Low Carbon Transport Futures

FADIEL AHJUM

African perspectives
Global insights

SOUTH AFRICAN INSTITUTE OF INTERNATIONAL AFFAIRS

Abstract

Transport in Southern Africa is acknowledged as a foundation to regional economic development and integration and which attests to SADC's Regional Indicative Strategic Development Plan (RISDP) emphasising transport infrastructure investment. Of the estimated 567 Mt of carbon dioxide (CO_2) attributed to fuel combustion by SADC member states in 2014, the transport sector was responsible for 17%, or 94 Mt of CO_2, for which road transport was the primary contributor. The SADC population, currently at 363 million, is projected to exceed 700 million by 2050. Should regional development and investment in transport infrastructure reflect South Africa's present trajectory, regional emissions and energy demand will increase dramatically and challenge the implementation of member states' climate change commitments. It is therefore imperative to decarbonise the SADC transport sector to realise the vision of the Green Economy Strategy and Action Plan for Sustainable Development and the Nationally Determined Contributions member states have pledged.

Electric vehicles confer substantial reductions in GHG emissions and energy demand compared to internal combustion engines (ICEs), with the potential for zero direct emissions from road transport at less than half the energy supply requirement when compared to ICE vehicle. In the context of a just transition, regional electrification of transport should target public transport with policy incentives to encourage public-private participation. A large electric vehicle fleet stimulates electricity demand, driving investment in the power sector: in South Africa this could translate to a 20% increase in electricity demand by 2050. The investment in power generation to support e-mobility replaces the need to upgrade existing refineries to improve fuel quality. No additional investment in new crude-oil refinery capacity would be warranted if the transport fleet is electrified.

Introduction

The landmark 2015 Paris Agreement includes a long-term temperature goal of 'holding the increase in the global average temperature to well below 2˚C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5˚C above pre-industrial levels.'[1] In the same decision, countries requested the Intergovernmental Panel on Climate Change (IPCC) to produce a special report on the impacts of global warming and in 2018 the IPCC Special Report on Global Warming of 1.5˚C (SR15) was released. The report makes it very clear that: a) we are already facing climate impacts; b) that these will be significantly worse at 2˚C than at 1.5˚C; and that a global CO_2 emissions pathways consistent with keeping global

1 UN, Paris Agreement to the UN Framework Convention on Climate Change (UNFCCC), Article 2.1 (a) (Dec. 12, 2015), https://unfccc.int/files/meetings/paris_nov_2015/application/pdf/paris_agreement_english_.pdf.

temperature within the 1.5˚C limit require rapid global emissions reductions – 45% by 2030 (in relation to 2010 levels) and global CO_2 emissions should reach net zero[2] by 2050.[3]

The findings of the report formed the basis of the call by the UN-Secretary General to countries, to take urgent additional climate action at the UN Climate Action Summit, held ahead of COP 25 in 2019. Existing NDCs under the Paris Agreement will result in global warming of 2.9–3.4˚C.[4] Countries will need to significantly increase their mitigation ambition in their NDCs updated in 2020, and in subsequent NDCs communicated in 2025, to keep the global effort to address the climate crisis on track.

Previous analyses, based on mitigation potential (in turn based on available technologies and their costs) aimed at limiting emissions to 2050.[5] In the longer term, the Paris Agreement requires countries to achieve peak GHG emissions (hereafter referred to as 'emissions') as soon as possible and 'to undertake rapid reductions thereafter in accordance with best available science, so as to achieve a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of this century, on the basis of equity and in the context of sustainable development. This provides all countries with a framework for not only limiting emissions but reducing emissions to net-zero before 2100. The IPCC's SR15 requires this to occur globally around 2050 for CO_2, and for there to be 'deep reductions' in other gases.[6]

Long-term planning therefore should consider how to reduce emissions to zero in each sector of the economy where this is feasible and also identify sectors and/or subsectors in which this is currently not possible and to explore future technology options, in the context of sustainable development challenges in the overall economy.

How then does this affect southern African countries? This paper takes a closer look at land transport in SADC with emphasis on South Africa, as the largest contributor to emissions in the region, to explore the role of transport and the synergies that exist with the power sector in decarbonising the region. Comparative examples from Angola, the Democratic Republic of Congo (DRC), Mozambique and Zambia are used to highlight key transitional risks and opportunities.

2 'Net-zero' means that, globally, we reach a point at which CO_2 sources equal CO_2 sinks.

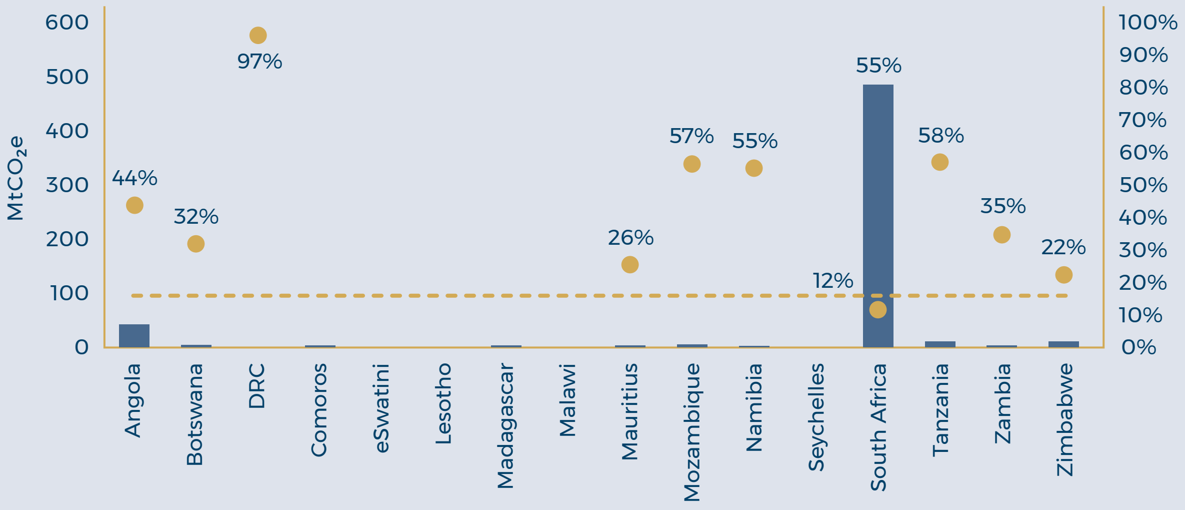
3 Intergovernmental Panel on Climate Change (IPCC), Global warming of 1.5˚C. An IPCC Special Report on the impacts of global warming of 1.5˚C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty (In Press, 2018), https://www.ipcc.ch/sr15/.

4 J Christiansen and A Olhoff, *Lessons from a decade of emissions gap assessments*, Emissions Gap Report, 10th Edition (Nairobi: UN Environment Programme, 2019), https://wedocs.unep.org/bitstream/handle/20.500.11822/30022/EGR10.pdf.

5 For instance, the Long-Term Mitigation Scenarios (LTMS-2007) and the Mitigation Potential Analysis (MPA-2014) both explored options to limit South Africa's emissions to 2050. While the LTMS did underpin South Africa's 'Peak, Plateau and Decline' emissions benchmark range, which proposes emissions peaking between 2025 and 2035, neither analysis addresses the question of sectoral decarbonisation or of net-zero emissions.

6 IPPC, "Global warming of 1.5˚C", 95.

Figure 1 Fossil fuel combustion: CO_2 emissions for SADC member states (2014)



Source: World Bank, 'World Development Indicators,' https://databank.worldbank.org/

SADC is estimated to account for 2–3% of global GHG emissions from fossil fuel combustion, totalling 594 Mt CO_2 in 2014.[7] South Africa contributes the majority share of 82%, with Angola (the second largest African GHG emitter) accounting for 8% of the total (see Figure 1). Within the limitations of available data for the region, all member states tend to exhibit large shares of GHG emissions from fuel combustion for transport services, for which South Africa's transport sector has the lowest contribution at 12% in 2014.

All member states have registered NDCs, except for Angola, signalling a commitment to transformational development that integrates climate change mitigation.[8] As the second largest economy on the continent, South Africa's economy accounts for half of the SADC GDP.[9] Owing to its coal intensive economy, South Africa's emissions represent almost half the region's emissions and therefore has a preeminent role in the SADC decarbonisation agenda.

Decarbonised transport: The imperative of a sustainable transport transition

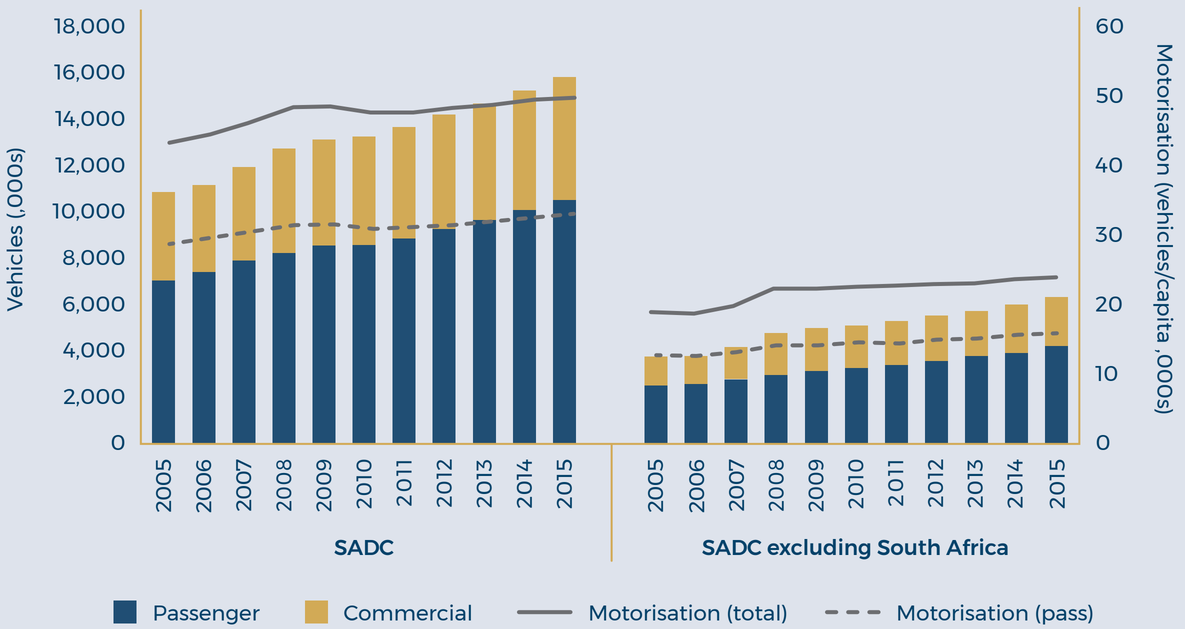
The transport sector is responsible for roughly a quarter of energy-related CO_2 emissions globally and despite improvements in efficiency, continue to increase.[10] Road vehicles

7 Author calculated from indicators sourced from: World Bank, 'World Development Indicators,' https://databank.worldbank.org/.
8 UNFCCC, 'NDC Registry (Interim)', https://www4.unfccc.int/sites/ndcstaging/Pages/Home.aspx.
9 'SADC – Southern African Development Community,' https://countryeconomy.com/countries/groups/southern-african-development-community.
10 International Energy Agency (IEA), *Tracking Transport 2020* (Paris: IEA, 2020), https://www.iea.org/reports/tracking-transport-2020.

account for three quarters of global transport emissions. In South Africa, this figure is even higher, with more than 90% of transport emissions arising from road transport.[11] Globally, despite advances in vehicle efficiency, alternative fuels and alternative mobility technologies, road transport emissions continue to increase, offsetting mitigation savings.[12] Thus, while switching to less carbon intensive fuels and less energy intensive technologies is critical, politically ambitious policy responses which address institutional, infrastructural, and behavioural inertia will determine the pace of the transport transition.

In 2015, the SADC vehicle population was estimated at 16 million vehicles with passenger vehicles accounting for approximately 65% of the fleet (see Figure 2). The SADC motorisation rate[13], excluding South Africa, is well below the continental average of approximately 40 vehicles per 1000 persons compared to the global average of 180 vehicles per 1000 persons.[14] South Africa, Mauritius and Botswana are exceptions, having similar motorisation rates to the global average. South Africa's vehicle population represents 60% of the SADC fleet and when combined, results in a higher SADC motorisation rate of 50 vehicles per 1000 persons.

Figure 2 Estimated vehicle population in SADC and motorisation rates



Source: UN Department of Economic and Social Affairs (UNDESA), 'World Population Prospects 2019: Data Booklet,' https://population.un.org/wpp/Publications/Files/WPP2019_DataBooklet.pdf

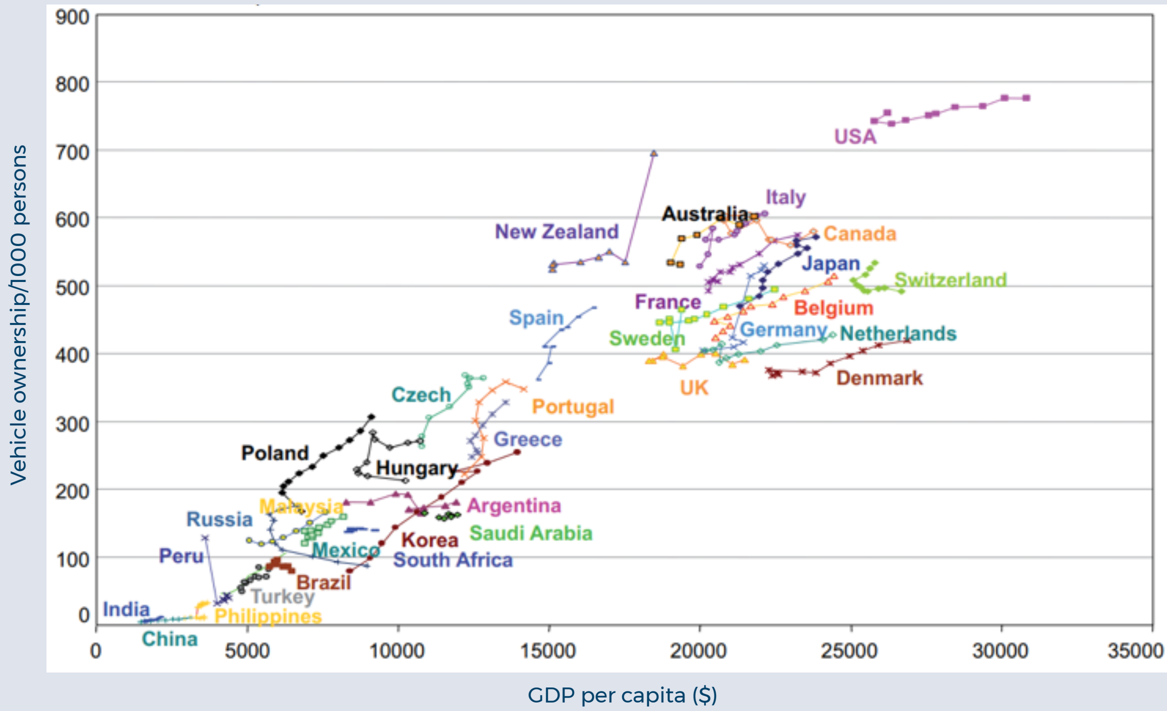
11 World Wildlife Fund (WWF), "Low Carbon Frameworks: Transport" (Brief, WWF, Cape Town, 2016), http://awsassets.wwf.org.za/downloads/wwf_2016_transport_emissions_in_south_africa.pdf.

12 International Transport Forum (ITF), 'ITF Transport Outlook 2019,' https://www.oecd-ilibrary.org/sites/transp_outlook-en-2019-en/index.html?itemId=/content/publication/transp_outlook-en-2019-en.

13 Motorisation rate, unless defined otherwise, is the ratio of the total vehicle fleet to the resident population (,000s persons).

14 International Organization of Motor Vehicle Manufacturers (OICA), 'Vehicles in Use', http://www.oica.net/category/vehicles-in-use/.

Figure 3 Vehicle ownership vs income (2007)



Source: Kahn Ribeiro et al., "Transport and its Infrastructure," in *Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* (Cambridge: Cambridge University Press, 2007), https://www.ipcc.ch/site/assets/uploads/2018/02/ar4-wg3-chapter5-1.pdf

Motorisation is influenced by income and access to vehicles, with wealthier countries typically exhibiting much higher rates; the US, for example, has the highest rate of 820 vehicles per 1000 persons, relative to the European average of 470 vehicles per 1000 persons. In 2017, total vehicle demand in sub-Saharan Africa was 1.7 million[15] vehicles compared to the South African market of 557,704.[16] Although the South African market comprised a third of continental demand, income growth could see demand for 2.1 million units by 2035 in sub-Saharan Africa, with consequences for fuel demand and emissions.

Specific, ambitious and actionable transport-related policies and targets are lacking at the regional and global level, undermining climate objectives and the net-zero targets outlined in the IPCC SR15. According to the International Transport Forum (ITF), worldwide transport emissions are set to grow by 60% by 2050, even if current and announced mitigation

15 Justin Barnes, "Driving African industrialisations: Establishing a sub-Saharan African Automotive Pact" (presentation, KwaZulu-Natal Export Week, October 15, 2019), http://www.tikzn.co.za/images/exportweek/presentations/EPW2019/Day%202/Driving%20African%20industrialisation.pdf.

16 National Association of Automobile Manufacturers of South Africa (NAAMSA), 'Domestic New Vehicle Sales', https://www.naamsa.co.za/NewVehicleStatistics.aspx.

policies are implemented.[17] While the importance of decarbonising the transport sector is widely acknowledged, the path to decoupling transport activity from CO_2 emissions is far from clear. At the same time, as our analysis indicates, there are strong economic imperatives which will drive the transport sector over the next three decades towards more efficient and lower-emitting technologies, such as hybrid and EVs. This transition will not necessarily drive sustainable development outcomes, such as the universal provision of affordable mobility services, and will also not necessarily drive the transition at the speed necessary to meet overall mitigation goals. Moreover, the transition will also involve considerable disruption to both the supply of liquid fuels, vehicle manufacture and to the transport sector itself – these also need to be mitigated via policy. These three objectives will require a suite of policy responses to support a just transition in the transport sector.

Taking the imperative to policy: Driving decarbonisation in the transport sector

Policies which aim at decoupling transport from emissions are necessary to achieve climate objectives, while also enabling economic activity and meeting passenger mobility needs. Demand for transport is driven by changes in GDP, population, trade, technology and geography/urban design. Supply and demand-side interventions to shape demand trends and plan for decarbonisation therefore primarily rest on two major levers:[18]

Modal shifting

The first relates to changes in mobility that contribute to reduced energy consumption, while meeting mobility demand. For example, a private car user switching to public, electrified transport to meet the same transport needs. These changes are associated with significant gains in relation to sustainable development objectives in the transport sector. Coupled with urban design that focuses on mobility and accessibility, modal switching can contribute to the enhancement of low pollution and congestion public transport systems to the benefit of all.

Fuel switching

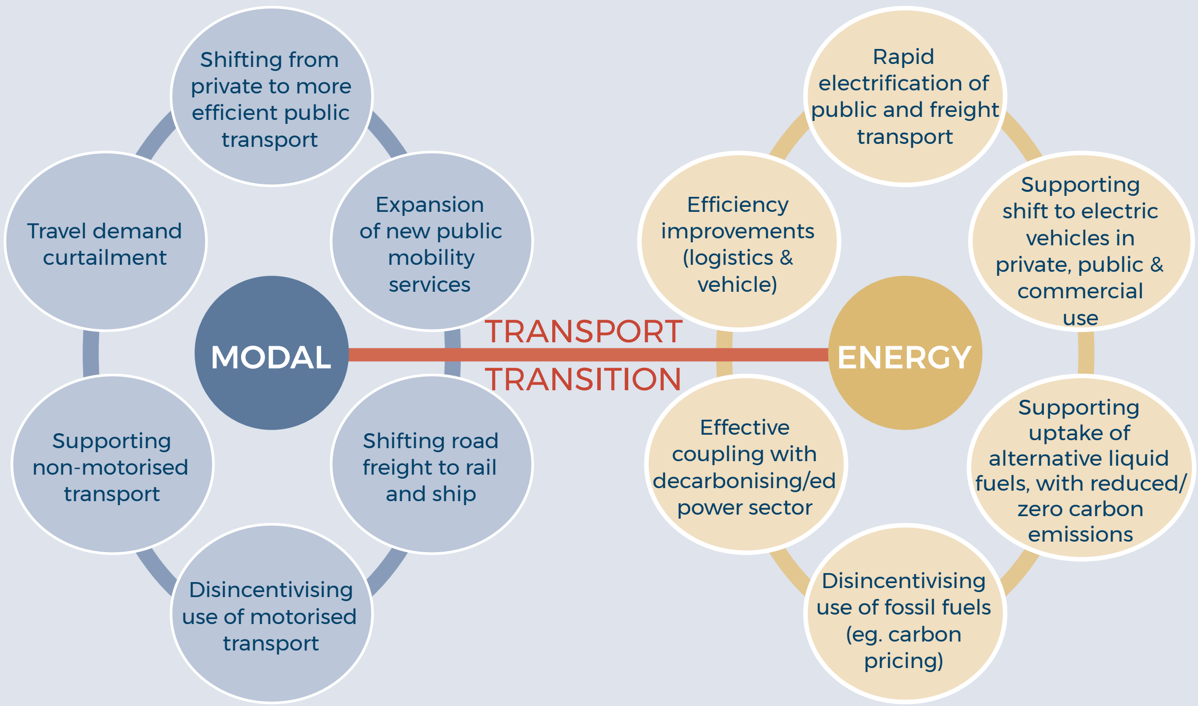
The second relates to changes in energy use or the energy mix in transport, ie, meeting energy needs more efficiently while generating less emissions. For example, the electrification of a bus rapid transit (BRT) system.

Popular measures for each lever are captured in Figure 4.

17 ITF, "ITF Transport Outlook 2019".

18 Author adapted from Christiansen and Olhoff, "Lessons from a decade".

Figure 4 Transport transition – levers and measures



Source: Fadiel Ahjum et al., *A Low-Carbon Transport Future for South Africa: Technical, Economic and Policy Considerations*, report (Berlin: Climate Transparency, 2020), https://www.climate-transparency.org/wp-content/uploads/2020/08/CT-Low-Carbon-Transport-SA-DIGITAL.pdf

These levers relate to broad policy areas which impact how people and businesses use transport within communities and economies. For example, urban planning that supports densification is an important lever for better service delivery in cities, including transport, where demand is reduced and transport needs are more equitably provided for, supporting better economic and social outcomes. Policy mechanisms to effect such changes, include:

- financial and pricing instruments (subsidies, taxes, direct payments, etc.);
- mandatory standards and regulations;
- infrastructure investment and support programmes for new/ non-motorised technologies and/or low-carbon fuels;
- public education and marketing; and
- national capacity building.

While the main levers and many of the policy measures and mechanisms are known, the feasibility of selecting the right mix of interventions and implementing them at pace to achieve a rapid low carbon transport transition by 2050 requires attention. This is compounded by the interlinkages between transport and other sectors, most importantly electricity and liquid fuel production, as well as important considerations relating to sustainable and inclusive development. Where the ITF high ambition scenario results in global CO_2 emission reductions in the transport sector of 30% by 2050 – from 7 200 $MtCO_2eq$ in 2015 to 5 000 $MtCO_2eq$ in 2050[19], decarbonising the transport sector in accordance with the Paris Agreement will require more ambitious targets, which our analysis suggests could be facilitated via a policy of electrification of transport.

The South African transport transition: Regional implications

In this paper, the analyses focus on the potential to decarbonise the South African transport sector, the largest in region, through exploring a combination of two packages of interventions. The first of these consists of vehicle technology shifts from the current dominance of internal combustion engines to various forms of electric and hybrid vehicles. The second is a concerted set of policy interventions resulting in lower transport demand (spatial planning, transport avoidance, promotion of non-motorised transport options), and a modal shift of freight and passenger transport. A full-sector energy model was used to understand the implications of these shifts for GHG emissions in the transport sector, in energy supply sectors and in the overall economy.

Transport sector overview

South Africa has the most developed transport and logistics sector in sub-Saharan Africa, reflected in its relatively modern infrastructure and effective trade facilitation.[20] Although road transport dominates, the country also operates regionally important ports and hosts the largest rail and air network on the continent. The transport sector faces significant challenges which encumber inclusive economic development and incur significant environmental, health and safety externalities. Primary challenges include: an unequal and inefficient public transport sector; partly the legacy of its underdevelopment during apartheid, the migration of freight from rail to road; and underinvestment in infrastructure resulting in ageing infrastructure with an increasing maintenance backlog.

In South Africa, the imperatives of a transport transition stem not only from the need to reduce emissions to abate climate change but also from the need to create a more equitable and efficient transport system. Many of the core elements of a transport transition – including improved, integrated public transport systems, urban densification, shifting freight from road to rail, and electrification – have the potential to address the socio-economic and environmental ambitions of the country as espoused in South Africa's National Development Plan.[21]

19 ITF, "ITF Transport Outlook 2019".

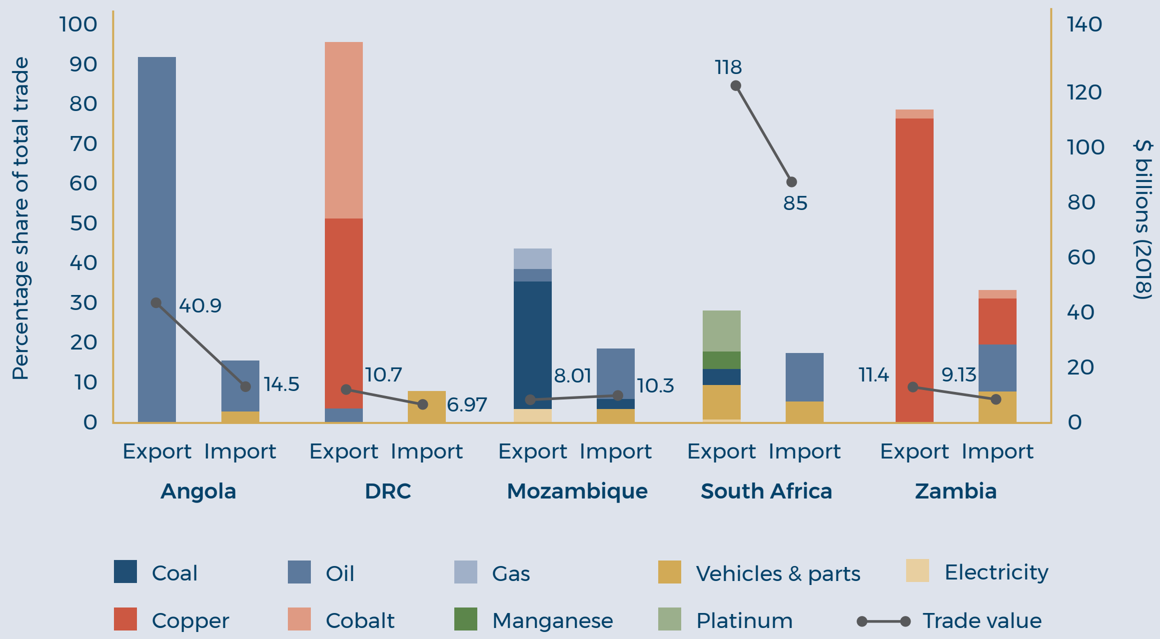
20 PricewaterhouseCoopers (PWC), 'Africa Gearing Up: Future prospects in Africa for the transportation & logistics industry,' https://www.pwc.co.za/en/assets/pdf/africa-gearing-up.pdf.

21 Republic of South Africa, *National Planning Commission, National Development Plan 2030 – Our Future-Make It Work*, (Pretoria: National Planning Commission), https://www.nationalplanningcommission.org.za/assets/Documents/ndp-2030-our-future-make-it-work.pdf.

The transport sector within SADC is similarly encumbered by the difficulties facing South Africa, albeit with differing historical socio-economic development trajectories. Expensive, unreliable transport services coupled with insufficient energy supply have been identified as a major hurdle to regional growth.[22] Like South Africa, road transport is the primary means of land transport in the region. The SADC Regional Infrastructure Master Plan's Transport Sector Plan outlines measures to integrate and harmonise transport policy across the region to better facilitate regional trade. Of these, the road network is identified as a vital component of the vision for a seamless integrated regional transport system. Vehicle technology and fuel choice are critical pillars in realising this vision and presently the region lacks standardised fuel quality specifications and tariff mechanisms governing the sales of new and used vehicles, especially with regard to energy efficiency and emissions standards.[23]

In terms of trade volumes and value, South Africa, Angola, Zambia, the DRC and Mozambique represent close to 80% of the annual SADC GDP. The global energy transition is of particular consequence to these countries as economic activity is concentrated in either fossil-fuel or new energy minerals and technologies, as illustrated in Figure 5.

Figure 5 Trade of key energy commodities, vehicles and components for selected SADC member states (2018)



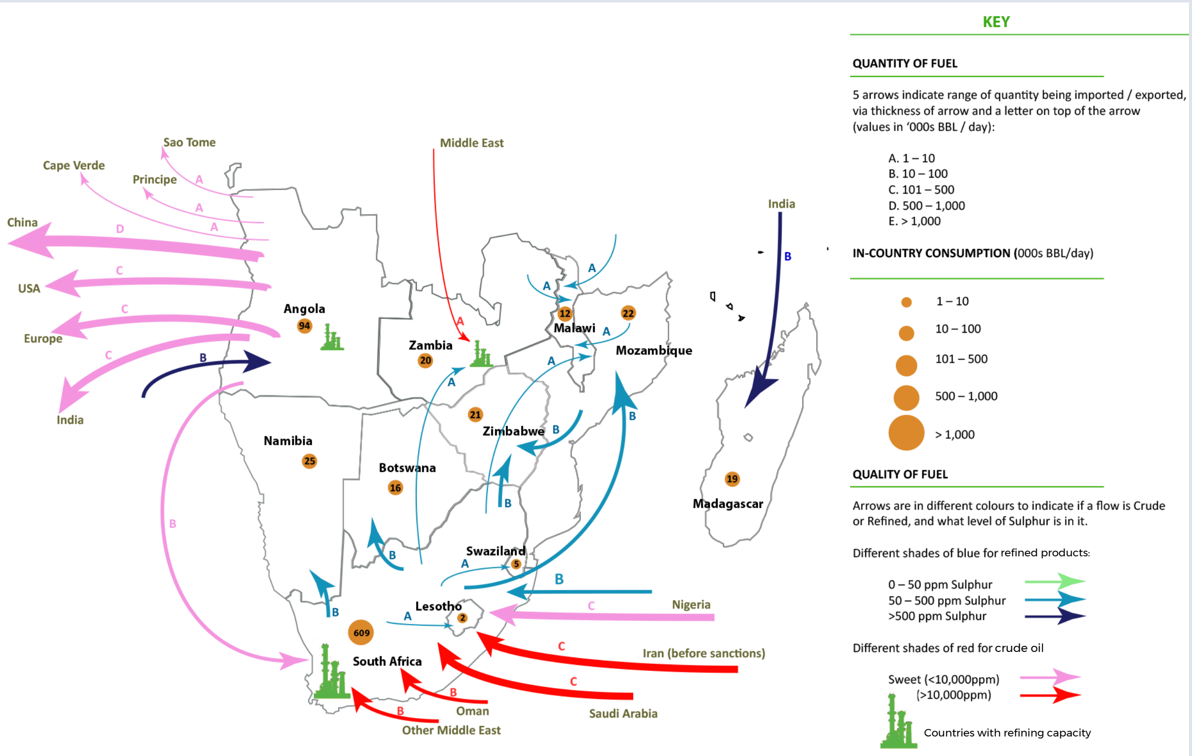
22 SADC, *Regional Infrastructure Development Master Plan, Executive Summary*,' August 2012, https://www.sadc.int/files/7513/5293/3530/Regional_Infrastructure_Development_Master_Plan_Executive_Summary.pdf.

23 UN Environment Programme (UNEP), "SADC Regional Framework for Harmonisation of Low Sulphur Fuels and Vehicle Emission Standards" (workshop, SADC Regional Framework for Harmonisation of Low Sulphur Fuels and Vehicle Emission Standards, Johannesburg, June 6–7, 2019), https://www.unenvironment.org/events/workshop/sadc-regional-framework-harmonisation-low-sulphur-fuels-and-vehicle-emission.

Angola's export revenue is almost entirely dependent on petroleum products (90%) while importation of refined petroleum products totalled 13% of import costs. Similarly, Mozambique's export revenue comprises mainly coal and gas while being reliant on importing petroleum products. In contrast, in the spectrum of economic transition, the DRC and Zambia by scale of trade represents the bulk of SADC trade in key minerals for the new energy transition. South Africa's economy is in comparison relatively diversified by portfolio and magnitude. Platinum, manganese, coal, and vehicles are key export segments (27%) while vehicle components and petroleum products are key import segments (18%).[24]

Noteworthy is the reciprocal importation of vehicles and vehicle components by its SADC neighbours and, as shown in Figure 6, the similar flow of petroleum fuels between member states.

Figure 6 Southern Africa petroleum fuel flows (2010–2013)



Source: International Council on Clean Transportation (ICCT), "Request for Proposals: Fuel and vehicle flows in Western and Southern Africa", https://theicct.org/sites/default/files/CCAC%20Africa%20Clean%20Vehicles%20and%20Fuels%20RFP.pdf

24 See: The Observatory of Economic Complexity, https://oec.world/en/visualize.

Concerning the regional trade in vehicles and fuel, the International Council on Clean Transportation (ICCT) notes that:[25]

> Limitations on importation of second-hand vehicles vary across the subregion. Angola allows individuals to import any aged vehicle but not motor companies. Botswana prohibits import of vehicles with more than 100,000 km of mileage. Age limits for second-hand imports are set in Lesotho (8 years) and Mozambique (5 years for cars; 9 years for vans), while South Africa bans all second-hand vehicles with a few exceptions. South Africa is a major manufacturer of vehicles and has the second highest motorisation rate in Sub-Saharan Africa (after Congo-Brazzaville)... When comparing fuel and vehicle standards Mozambique can implement at least Euro 2[26] vehicle emission standards, based on current fuel quality. Once South Africa implements its 10ppm standard for both gasoline and diesel, it plans to set a Euro 5 vehicle emission standard. Given that Mozambique and South Africa supply most of Southern Africa's fuel, it is conceivable that all the countries could likewise implement higher vehicle standards to match the fuel quality.

Status and trends in transport sub-sectors

Public and private passenger transport

Unlike South Africa, most SADC member states lack regular detailed statistical censuses specific to transport utilisation and modal choices.[27] Selected case studies on public transport however suggest similar trends and indicators across the region.[28]

The South African public transport system is characterised by inefficiency and inequality. For urban and rural poor, access to school, work and public services entails long commutes, ie, higher demand for passenger kilometres (km). Informal and poorly integrated transport networks also necessitate long walks to, from and in-between public transport options – increasing already lengthy commutes. Furthermore, embedded inefficiencies in the allocation of urban space (giving priority to private vehicles) contribute to continued exclusion and inaccessibility, as well as high levels of congestion and urban pollution.

25 ICCT, "Request for Proposals".

26 'EU fuels: Diesel and gasoline', https://www.transportpolicy.net/standard/eu-fuels-diesel-and-gasoline/.

27 UN Economic and Social Council, Economic Commission for Africa (ECA), *Africa Review Report on Transport: A Summary*, E/ECA/CFSSD/6/6, 29 September 2009, (Addis Ababa: ECA, 2009), https://sustainabledevelopment.un.org/content/documents/AfricanReviewReport-on-TransportSummary.pdf; International Association of Public Transport (UITP), *Report on statistical indicators of public transport performance in Africa*, report (UITP, 2010), https://www.yumpu.com/en/document/read/4316617/report-on-statistical-indicators-of-public-transport-performance-uitp; and Ajay Kumar and Fanny Barrett, *Africa Infrastructure Country Diagnostic, Stuck in traffic: Urban transport in Africa*, summary of Background Paper 1 (World Bank, 2008), https://eu-africa-infrastructure-tf.net/attachments/library/aicd-background-paper-1-urban-trans-summary-en.pdf.

28 'The African commute: City transport trends,' *Engineering for Change*, May 3, 2018, https://medium.com/impact-engineered/the-african-commute-city-transport-trends-cf369e5106bd; Infrastructure Consortium for Africa, 'Urban Transport in Sub-Saharan Africa – Diagnostic Study and Project Development and Investment Pipeline,' https://www.icafrica.org/fileadmin/documents/Publications/ICA_Urban_Transport_Study_-_Summary_Oct16.pdf.

Long commute times and the cost of public transport are key barriers to further patronage.[29] In 2013, lower income groups spent more than 20% of their monthly household income on transport.[30] Despite the fact that rail is significantly cheaper than mini-bus taxis and buses (which are substantially more affordable than private car use) the trend away from public transport (specifically rail) reveals the increasing dysfunctionality of the South African public transport system.[31]

Private vehicles make up the largest share of vehicles contributing to transport emissions. With respect to passenger vehicles, the motorisation rate (vehicles per thousand persons) is estimated to have increased by 6%, from 120 to 130 revealing an increasing trend in private motorised travel over the past decade.[32]

South Africa has a well-developed automotive manufacturing industry, reportedly responsible for 7.5% of GDP and employing 113,532 people across the assembly, components and tyre manufacturing sub-sectors. This presents additional policy challenges and opportunities when considering technology choices for future road vehicles.[33]

With an estimated population of 60 million, South Africa accounts for 16% of the SADC population of 363 million, of which the DRC comprises the largest population share at 25%.[34] The SADC population is projected to increase to approximately 700 million by 2050 with South Africa reaching approximately 75 million or 10% of the projected SADC population. If the trend of a continued preference for private vehicle ownership persists in South Africa and is reflected regionally, unsustainable resource utilisation and infrastructure expenditure is likely to occur.

Commercial transport and freight: road, rail and maritime transport

In South Africa, , the majority (85%) of commercial and freight transport is by road with existing rail capacity not fully utilised due to significant cost and losses associated with

---

29 Government of South Africa, Statistics South Africa, *National Household Travel Survey 2013* (Pretoria: Statistics South Africa, 2014), http://www.statssa.gov.za/publications/P0320/P03202013.pdf; Rose Luke and Gert Heyns, 'Public transport policy and performance: The results of a South African public opinion poll,' *Journal of Transport and Supply Chain Management*, no. 3 (2013), http://dx.doi.org/10.4102/jtscm.v7i1.96.

30 Philip van Ryneveld, *Urban Transport Analysis for the Urbanisation Review*, policy research report, https://csp.treasury.gov.za/Resource%20_Centre/Conferences/Documents/Urbanization%20Review%20Papers/Paper%209%20-%20Urban%20Transport%20Analysis.pdf.

31 Londeka Ngubane, 'The state of public transport in South Africa,' *SaferSpaces*, https://www.saferspaces.org.za/understand/entry/the-state-of-public-transport-in-south-africa.

32 Government of South Africa, "National Household Travel Survey 2013".

33 Government of South Africa, *Discussion Document on South Africa's Motor Trade Industry*, (Pretoria: Statistics South Africa, 2018), http://www.statssa.gov.za/publications/D63011/D63011February2018.pdf; Johannes Jordaan et al., "Economic and socio-economic impact of SA automotive industry", presentation, (Pretoria: Econometrix, 2018), https://pdfslide.net/documents/economic-socio-economic-impact-of-sa-tomsacozawp-contentuploads201811sa-automotive.html; and Anthony Dane, Dave Wright and Gaylor Montmasson-Clair, "Exploring the Policy Impacts of a Transition to Electric Vehicles in South Africa" (policy research paper, TIPS, Pretoria, 2019), https://www.tips.org.za/research-archive/sustainable-growth/green-economy/item/3646-exploring-the-policy-impacts-of-a-transition-to-electric-vehicles-in-south-africa.

34 UNDESA, "World Population Prospects 2019".

inefficiency.[35] Increased demand for freight transport has, to a large extent, been met by an increase in heavy vehicles, in part due to deregulation which has contributed to the underutilisation of rail.[36] SADC trade is inextricably linked to South Africa for whom intra-regional exports comprise approximately 60% of trade. Angola, Namibia, Zimbabwe and the DRC account for 6–7% of intra-trade facilitated primarily via road.[37] Fuel and lubricants, accounting for an average 40% of vehicle operating costs.[38]

This trend contributes not only to higher GHG and air pollutant emissions, but also to the faster deterioration of roads and increased maintenance costs. Excluding urban roads, the current backlog of road maintenance in South Africa is estimated to cost $27 billion.[39] To put this into perspective, it is almost double the annual health expenditure of South Africa for 2019.[40] Approximately 78% of South Africa's road network is thought to be older than its original design life and 30% of the road infrastructure is rated as being in either 'poor' or 'very poor' condition.[41]

As with the SADC situation, South Africa's rail infrastructure and rolling stock is ageing, poorly maintained and deteriorating rapidly in the face of a significant capital investment and maintenance backlog.[42] Although land and air transport dominates intra-state trade within the region, maritime transport and associated ports are a vital economic backbone to regional development owing to the substantial international trade by member states. Most regional exports are via the South African port of Durban, emphasising the current critical enabling role of the land transport sector.[43] With more than 95% (by volume) of South Africa's imports and exports shipped by sea, maritime shipping and transport plays a critical role, yet South African ports are 'characterised by high costs and substandard productivity relative to global benchmarks.'[44] The maritime shipping industry is dominated by international companies but includes a small portion of South African shipping companies operating through off-shore subsidiaries.[45] This reflects international trends associated with

35 Jan H. Havenga, 'The importance of disaggregated freight flow forecasts to inform transport infrastructure investments,' *Journal of Transport and Supply Chain Management* 7, no. 1 (2013), http://dx.doi.org/10.4102/jtscm.v7i1.106; Jan H. Havenga , Anneke De Bod and Zane P. Simpson, 'A Logistics Barometer for South Africa: Towards sustainable freight mobility,' *Journal of Transport and Supply Chain Management* 10, no. 1 (2016), https://doi.org/10.4102/jtscm.v10i1.228.

36 Government of South Africa, Department of Transport, *Green Transport Strategy for South Africa: 2018–2050*, (Pretoria: Department of Transport, 2018), https://www.transport.gov.za/documents/11623/89294/Green_Transport_Strategy_2018_2050_onlineversion.pdf/71e19f1d-259e-4c55-9b27-30db418f105a.

37 Alexis Habiyaremye, 'Fast tracking the SADC integration agenda to unlock regional collaboration gains along growth corridors in Southern Africa' (policy research paper, SA-TIED, Pretoria, 2020) https://sa-tied.wider.unu.edu/article/fast-tracking-sadc-integration-agenda-unlock-regional-collaboration-gains-along-growth.

38 Jan H. Havenga, "A Logistics Barometer for South Africa".

39 Townsend and Ross, "The road maintenance backlog".

40 Republic of South Africa, National Treasury, *Estimates of National Expenditure 2019 – Abridged Version* (Pretoria: National Treasury, 2019), http://www.treasury.gov.za/documents/National%20Budget/2019/ene/FullENE.pdf.

41 Government of South Africa, "*Green Transport Strategy*".

42 SADC, 'Transport', https://www.sadc.int/themes/infrastructure/transport/. Thereafter: SADC, "Transport"; Anneke de Bod and Jan Havenga, 'Sub-Saharan Africa's rail freight transport system: Potential impact of densification on cost,' *Journal of Transport and Supply Chain Management* 4, no.1 (2010) https://doi.org/10.4102/jtscm.v4i1.13.

43 SADC, "Transport".

44 PWC, "Africa Gearing Up".

45 Government of South Africa, Department of Transport, *SA Maritime Transport Sector Study: Growth of a South African Maritime Transport Industry* (Pretoria: Department of Transport, 2011), https://www.transport.gov.za/documents/11623/20720/Part+1GrowthSAMaritimeTransportIndustry.pdf/353cc851-cb16-4c55-aeec-21a6cc2c0dae.

the globalisation of the shipping industry in a free trade environment. Nevertheless, the shipping industry is of critical importance to the South African economy, requiring 'massive investment in infrastructure, innovative technology, and proper management' of ports and integrated transport systems and effective regulation of the shipping industry.[46]

Aviation: Passenger and cargo

OR Tambo International Airport in South Africa is the largest SADC aviation hub. In 2018, it hosted the majority of the 74% of passenger traffic (32 million people) and 62% of freight traffic (1,160 million tonne-km) within the SADC region.[47] Similarly to other segments of the transport sector, aviation demand is increasing yet the sub-sector faces challenges when it comes to an aging air fleet and lack of funding for retrofitting the current fleet, limited scope for continued fiscal support and a lack of integrated transport planning.[48] In terms of passenger transport, scheduled domestic traffic dominates, accounting for approximately 24 million passenger trips a year, followed by scheduled international flights at 10.3 million passenger trips per year. However, only about 10% of South Africans currently use air transport, reflecting broader trends in income inequality and transport use. When discussing airfreight, international traffic dominates, accounting for 83% of all volumes, the majority (55%) of which is inbound. Demand for both passenger and freight aviation is forecast to grow at a level slightly above to approximately 2x GDP of the growth rate over the next 30 years.

Transport emissions profile

Oil products (eg, gasoline, diesel and kerosene) are the primary SADC transport fuels, estimated at 99% (1177 PJ) of the final energy consumption by transport (1190 PJ) with road transport responsible for 93% of the total consumption by mode (see Figure 7).

As the largest energy consumer in the region, in 2015 emissions from the transport sector in South Africa were estimated to account for 10.8% of the country's total GHG emissions, and 14% of energy related CO_2 emissions. Upstream emissions from the production, refining and transportation of liquid fuels (not included in the transport sector) also contribute significantly to South Africa's GHG emissions, largely emanating from the emissions-intensive coal-to-liquids conversion process, which accounts for 7.7% of national emissions while meeting only 20% of the country's petrol and diesel needs.[49] The emissions intensity

---

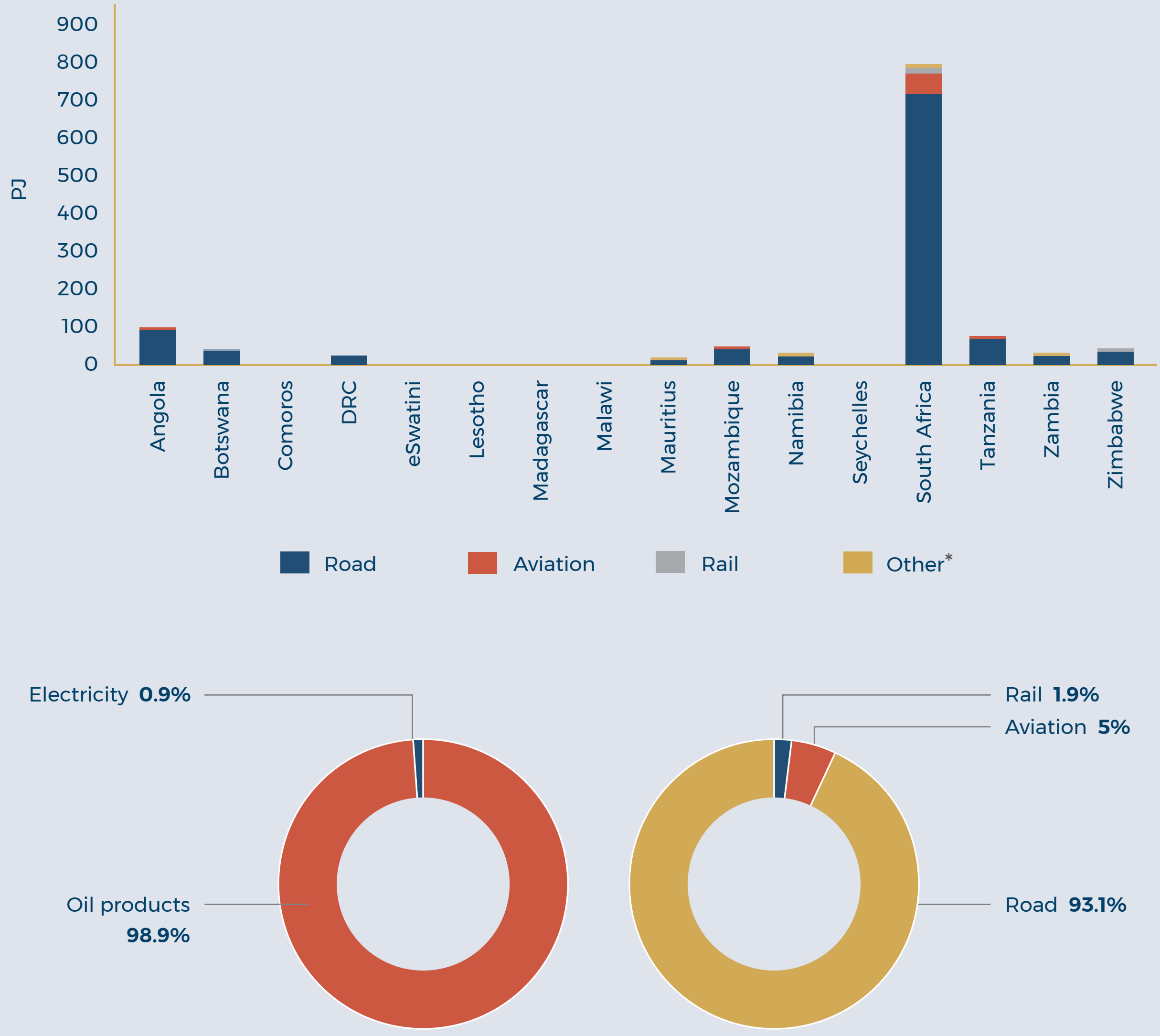
46 Government of South Africa, Department of Transport, *Comprehensive Maritime Transport Policy for South Africa* (Pretoria: Department of Transport, 2017), https://www.transport.gov.za/documents/11623/44313/MaritimeTransportPolicyMay2017FINAL.pdf/4fc1b8b8-37d3-4ad0-8862-313a6637104c.

47 World Bank, "World Development Indicators".

48 Government of South Africa, Department of Transport, *National Airports Development Plan: Annexure A* (Pretoria: Department of Transport, 2015), https://www.transport.gov.za/documents/11623/19945/ANNEXUREA_NationalAirportsDevelomentPlanAugust+2015.pdf/3a3876ae-b78e-4568-9379-36ab7af324de.

49 Government of South Africa, Department of Environmental Affairs, *GHG National Inventory Report, South Africa* (Pretoria: Department of Environmental Affairs, 2019), https://www.gov.za/documents/south-africas-greenhouse-gas-inventory-report-2000-2015-27-jun-2019-0000.

Figure 7 Estimated SADC final fuel consumption by mode and key fuels (2018)

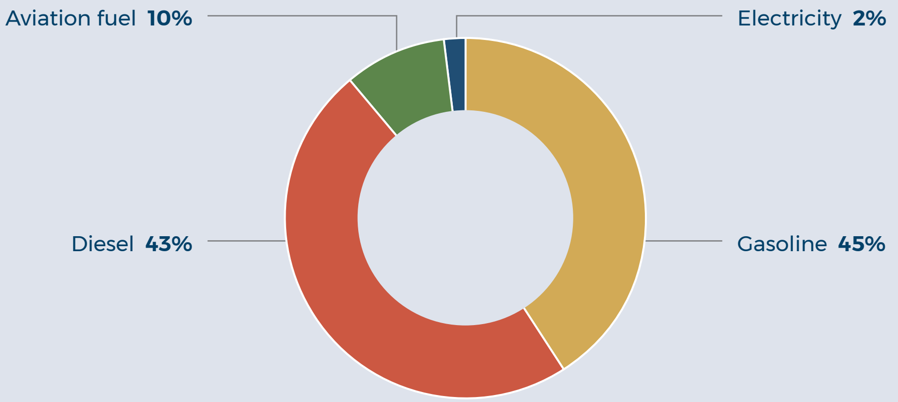


Note: * Other includes domestic maritime navigation

Source: International Energy Agency (IEA), 'Data and statistics', https://www.iea.org/data-and-statistics/

of liquid fuel production and the electricity sector highlight the importance of integrated energy supply chain transitions. With road transport accounting for the majority of fuel demand and 93.1% of the sector's emissions, it is the area with the greatest mitigation potential (see Figure 8).

Figure 8 Transport Fuel Commodity Split for South Africa (2015)



Source: Bruno Merven, Faaiqa Hartley and Fadiel Ahjum, "Road freight and energy in South Africa" (Working Paper, Southern Africa – Towards Inclusive Economic Development (SA-TIED), 2019, https://sa-tied.wider.unu.edu/article/road-freight-and-energy-in-south-africa

Green transport futures

The SADC GESAP[50] is the central framework for member states charting the community's vision for green industrialisation as the core of regional economic integration and cooperation. Promulgated in 2012, the GESAP provides guidance for 10 sectors deemed regionally significant, outlining specific measurable targets by which to implement the adopted strategies. Transport, as the backbone to economic integration, is one such sector for which several challenges, as highlighted earlier, are identified. The Regional Infrastructure Development Master Plan[51] and the RISDP 2020–30[52], which both emphasise transport infrastructure, provide a foundation for the GESAP's transport strategies and targets which are summarised in Table 2. The strategies, a synthesis of regional and national planning policies outline three transport themes addressing: infrastructure and climate change; green multimodal passenger and freight transport; and regional low carbon vehicle trade.

50 SADC, *Green Economy Strategy and Action Plan*, https://www.sadc.int/files/4515/9126/1250/SADC_Green_Economy_Strategy_and_Action_Plan-English.pdf.

51 SADC, "Regional Infrastructure Development Master Plan".

52 SADC, *Regional Indicative Strategic Development Plan (RISDP) 2020–2030 Blueprints*, 4th Draft, 27 March 2020 (SADC, 2020), https://imanidevelopment.com/wp-content/uploads/2020/03/4th-Draft_RISDP-2020-30-Blue-Prints2.pdf.

TABLE 2 GREEN ECONOMY STRATEGY AND ACTION PLAN FOR SUSTAINABLE DEVELOPMENT: TRANSPORT ACTION PLAN

Strategies	Action List	Time Frame
Promote investments in climate-resilient transport infrastructure	T1.1. Establish incentive schemes for the promotion of innovative materials for road, railway and airport infrastructure in order to increase resilience to floods, storms, coastal erosion and higher temperature.	Long Term
	T1.2. Conduct assessment studies on the adaptation of key transport infrastructure highly exposed to climate change impacts (eg, to sea level rise)	Medium Term
Promote green public transport networks and multimodal transport	T2.1. Encourage the establishment of public-private sector models to invest in and operate green transport systems	Short Term
	T2.2. Promote investments in 'green ports'	Long Term
	T2.3. Mobilise investments in railways and inland waterways transport modes	Long Term
	T2.4. Increase access to public transport, especially for the poor and marginalised	Short Term
	T2.5. Conduct assessment studies for multimodal transport	Short Term
Encourage regional trade in low-carbon emitting vehicles	T3.1. Harmonise regulations on vehicle emissions and vehicle import bans	Medium Term
	T3.2. Provide incentives to the regional trade in low-carbon emitting vehicles, eg, through custom tax rebates or exemptions	Short Term
	T3.3. Encourage the reduction (or reform) of harmful subsidies on gasoline and diesel (based on assessments of economic implicationsofthe reallocation of the subsidies)	Medium Term

Source: SADC, *Green Economy Strategy and Action Plan for Sustainable Development*, https://www.sadc.int/files/4515/9126/1250/SADC_Green_Economy_Strategy_and_Action_Plan-English.pdf

Similar to the GESAP strategic vision for transport, South African transport policy underscores the importance of transitioning to an accessible, cost-reflective and affordable low carbon transport system. This is evident in the National Transport Master Plan 2050[53] (NATMAP), the primary policy basis for transport planning in South Africa.

Building on the NATMAP and in response to the National Climate Change Response White Paper,[54] which advocates a climate-resilient and low carbon economy by 2050, the revised South African Green Transport Strategy was published in 2018.[55] The strategy, in harmony with the GESAP, considers various policy interventions that could contribute to substantially reducing 'GHG emissions and other environmental impacts from the transport

53 Government of South Africa, Department of Transport, *National Transport Master Plan (NATMAP) 2050 Synopsis Report* (Pretoria: Department of Transport, 2017), https://www.transport.gov.za/natmap-2050.

54 Government of South Africa, Department of Environmental Affairs, *National Climate Change Response White Paper* (Pretoria: Department of Environmental Affairs, 2011), https://www.gov.za/documents/national-climate-change-response-white-paper.

55 Government of South Africa, "Green Transport Strategy".

sector by 5% by 2050'[56], while promoting economic growth and inclusive development. The interventions are based on ten strategic implementation pillars that are organised into five green transport intervention themes, as shown in Table 3. The three strategies emphasised in the GESAP are evidently espoused in the South African variant, presenting an opportunity for regional multilateral low-carbon transport infrastructure investment. In particular, regional trade in low-carbon emitting vehicles as a catalyst for SADC green industrialisation comprising vehicles, vehicles components and, importantly, energy supply.

BOX 1 GREEN TRANSPORT STRATEGY SHORT-TERM STRATEGIC TARGETS

1. To achieve modal shifts in the transport sector that reduce GHG emissions and other harmful emissions, reduce transport congestion and improve temporal, spatial and economic efficiency in the transport sector. In particular, achieve a 30% shift of freight transport from road to rail by a 20% shift of passenger transport from private cars to public transport and eco-mobility transport.
2. To convert 5% of the public and national sector fleet in the first seven years of the implementation of this strategy and an annual increase of 2% thereafter, to cleaner alternative fuel and efficient technology vehicles (ideally powered through renewable energy) and environmentally sustainable low carbon fuels by 2025, including the use of CNG, biogas and biofuels and the use of renewable energy to provide electricity for transport.
3. To reduce fossil-fuel related emissions in the transport sector by promoting norms and standards for fuel economy by putting in place regulations that promote improved efficiency in fossil fuel powered vehicles and improved environmental performance of fossil fuels.
4. To promote strategies and standards for delivering transport infrastructure, integrated transit planning and systems that build climate resilience in urban and rural communities, whilst minimising the environmental impact of transport infrastructure.
5. To develop best practice guidelines to ensure that integrated, climate-friendly transport options are incorporated into land use and spatial planning at national, provincial and local levels.
6. Invest in sources of green energy's infrastructure, such as biogas filling stations, electric car charging points, GIS integrated information and communications technology platforms for locating stations, regulating future pricing and providing statistics.

56 Government of South Africa, "*Green Transport Strategy*", 3.

TABLE 3 GREEN TRANSPORT STRATEGY THEMES AND PILLARS (SOUTH AFRICA)

Implementation Themes	Strategic Pillars
Climate Change Response Norms and Standards	1 Develop norms and standards for climate change response at national, provincial and local levels to ensure there is consistency in the way climate change responses are implemented across different jurisdictions.
Green Roads	2 Shift car users from individual private passenger cars to public transport, including rail. 3 Provide infrastructure to promote non-motorised transport and eco-mobility transport. 4 Provide transport infrastructure in a manner supportive of the eco-system, while not clearly compromising generations to come.
Green Rail	5 Extend the rail network to provide reliable, safe and affordable high- speed transport while switching to renewable energy trains.
Green Transport Technologies	6 Reduce the carbon footprint of over-reliance on petroleum-based fuels, by decarbonising the transport sector. 7 Promote alternative fuels, such as compressed natural gas (CNG) or biogas, and liquid biofuels as transport fuels. 8. Promote electric and hybrid-electric vehicles.
Green Fuel Economy Standards	9 Develop 'Green Procurement Guidelines' to promote efficient and low-carbon vehicle technologies. 10 Provide norms, standards and regulations that promote green fuel economy in vehicles and improve emissions standards of fuel in South Africa.

Source: Government of South Africa, "*Green Transport Strategy*"

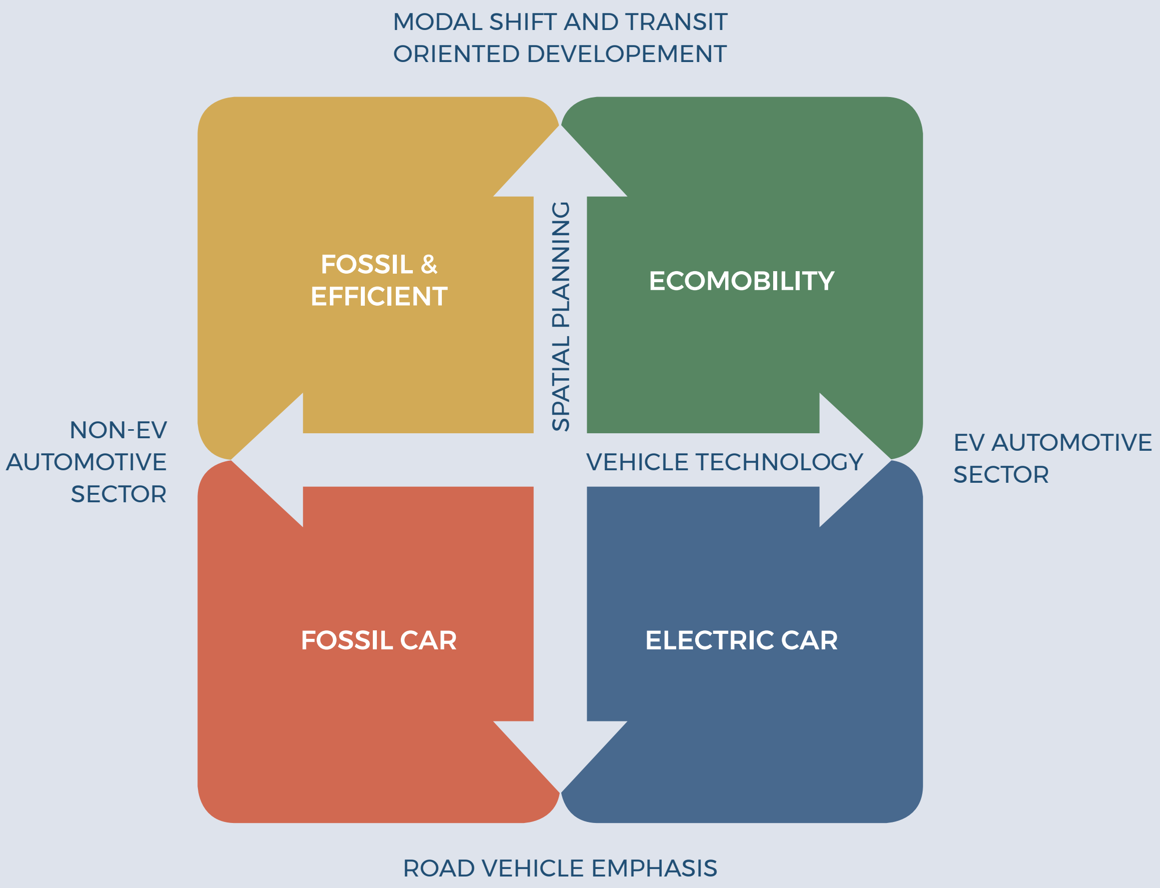
Modelling an ambitious transition in transport

To explore possible transport futures for their regional impact, a quantitative assessment of the South African road transport sector is conducted. Owing to the relatively good record of historical data and its significant role in the region in terms of emissions, vehicle fleet size, fuel consumption and supply, and vehicle production, a South African specific modelling platform is utilised. The South Africa TIMES (SATIM)[57] model allows for the interrogation of transport futures to gauge their influence on energy supply and demand, and their consequent economic and environmental impact.[58] The composition of mobility services are primarily a function of technology and spatial form. As such, vehicle technology and spatial planning, in tandem with modal shifting of transport services (an outcome of both land and transport development policy) form two key axes from which four transport scenarios are derived, as seen in Figure 9.

57 Bruno Merven et al., *SATIM Methodology, report* (Cape Town: University of Cape Town, 2019), https://zivahub.uct.ac.za/articles/SATIM_Methodology/7233905.

58 Adrian Stone et al., 'Providing a foundation for road transport energy demand analysis: The development of a vehicle parc model for South Africa,' *Journal of Energy in Southern Africa* 29, no. 2 (2018), https://doi.org/10.17159/2413-3051/2018/v29i2a2774.

Figure 9 Transport carbon pathways towards 2050



Source: Author developed

As depicted in Figure 9, the technological and policy landscape is thus defined by:

1 Vehicle Technology (horizontal axis)

Non-EV automotive sector: South Africa's auto industry remains slow in switching to EV manufacture, and the current EV importation tax remains such that the purchase cost of an EV remains at a premium to competing ICE technology. Domestic production of hybrid-ICE vehicles are cost competitive alternatives. Policies to encourage a shift to EVs (including cars, buses, minibus taxis and light commercial vehicles) are not pursued. A continuation of the existing fuel consumption pattern and vehicle technologies in the region would persist with the associated fossil-fuel infrastructure.

EV automotive sector: A transition in the domestic auto-industry towards EVs occurs. In South Africa, EVs are expected to reach cost parity with ICE and hybrid-ICE technology by 2030. Since South Africa contains more than 80% of the world's known reserves of platinum, a shift towards mineral beneficiation is assumed, which would result in a local hydrogen supply chain stimulating the production or assembly of hydrogen fuel-cell heavy vehicles (FCEVs). A reorientation of regional manufacturing is implied towards new energy technologies and key commodity value chains anchored in the extraction and beneficiation of local resources such as copper, lithium, cobalt and manganese.

2 Spatial Planning and Modal Shift (vertical axis)

Road vehicle emphasis: Development without a specific policy regarding modal shifting in freight or passenger transport results in a transport sector in which passenger transport is dominated by the use of private vehicles and freight transport is dominated by road freight.

Modal shift and transit-oriented development: Spatial planning and resource efficiency policies address increasing road congestion and local air pollution. Ambitious modal shifting in freight and passenger transport is implemented. Furthermore, Transit Oriented Development (TOD) reduces motorised transport demand.

The four transport futures are based on the interplay of these two sets of interventions. The accompanying modelling assumptions are described in Table 4.

TABLE 3 GREEN TRANSPORT STRATEGY THEMES AND PILLARS (SOUTH AFRICA)

Transport Pathway	Policy Narrative	Policy Levers	Technologies
Fossil-Car	• Non-EV local industry • No imperative for public transport and road-to-rail migration	• Expensive EV: cost at 25% premium to ICE technology in 2050 • No change in rail share of corridor freight • Declining public transport patronage	• Hybrid-ICE/ICE cost competitive vehicles • Late development of FCEV for heavy vehicles (ie, buses, trucks)
Fossil & Efficient	• Non-EV local industry • Public transport and road- to-rail migration • Reduction in motorised travel via TOD	• Expensive EV: cost at 25% premium to ICE technology in 2050 • 70% of road corridor freight migrated to rail by 2050[a] • Reversal of public transport defection to roughly 2012 modal share of rail • TOD reduces motorised travel demand by 10% in 2050	• Hybrid-ICE/ICE cost competitive vehicles • Late development of FCEV for heavy vehicles • Migration to rail in freight and passenger transport
Electric-Car	• EV local Industry • No imperative for public transport and road-to-rail migration	• Cost parity for electric drivetrains by 2030 • No change in rail share of corridor freight • Declining public transport patronage	• EV/FCEV cost competitive by 2030

Eco-Mobility	• EV local Industry • Public transport and road- to-rail migration • Reduction in motorised travel via TOD	• Cost parity for electric drivetrains by 2030 • 70% of road corridor freight migrated to rail by 2050 • Reversal of public transport defection to roughly 2012 modal share of rail • TOD reduces motorised travel demand by 10% in 2050	• EV/FCEV cost competitive by 2030 • Migration to rail in freight and passenger transport

Source: Government of South Africa, *Freight Shift from Road to Rail: The Socio-Economic Impact of a Modal Shift of Freight From Road to Rail to Achieve Maximum Greenhouse Gas Mitigation In the Transport Sector*, report (Pretoria: Department of Environmental Affairs, 2014), https://www.environment.gov.za/sites/default/files/docs/publications/freightshift_roadtorail.pdf

While cognisant of the NDC pledges by South Africa and its member states, the transport scenarios are modelled in the absence of a national GHG emissions constraint to gauge the direct impact of tabled measures on transport emissions. The results are contrasted with additional modelling which limits cumulative economy wide-emissions over the 2015–2050 period to a carbon budget of 8 Gt – representing South Africa's lower NDC range – and for which a previous analysis[59] suggested the budget as the economically sustainable threshold that the country could sustain. For clarity, the fossil fuel and eco-mobility scenarios are compared with this carbon budget as these comprise the two extreme contrapuntal emissions pathways for transport.

Exploring the technical feasibility of an ambitious transition

Growth factors

The primary drivers of growth in transport services are GDP and population growth. The SADC population of approximately 363 million (2020) is expected to reach ~700 million by 2050.[60] The South African population estimated at 60 million (2020) is projected to increase to 75 million by 2050 accounting for approximately 15% – 10% of the SADC population over the period.

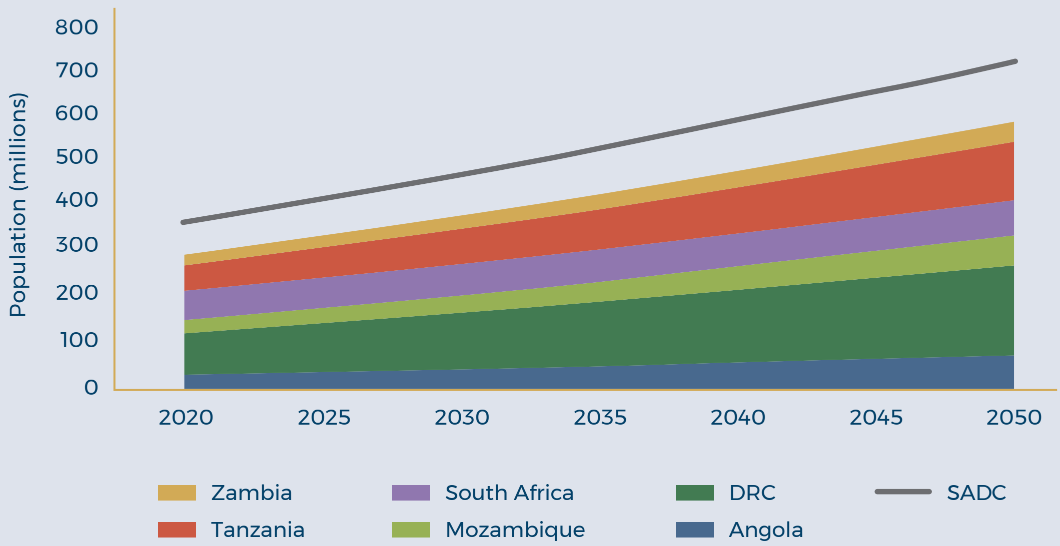
Population growth projected for SADC is contrasted against growth for South Africa and other key populous SADC member states in Figure 10. The DRC (27%) and Tanzania (18%) may account for nearly half the SADC population by 2050 with Angola and Mozambique sharing similar status with South Africa. In the SATIM model, densification and Transit Oriented Development (TOD) which would decouple the rate of demand for passenger

59 Bryce McCall et al., '*Least-cost integrated resource planning and cost-optimal climate change mitigation policy: Alternatives for the South African electricity system*, report (Cape Town, University of Cape Town, 2019), http://www.erc.uct.ac.za/sites/default/files/image_tool/images/119/Papers-2019/Alt%20IRP%20final%2007022019_2.pdf.

60 UNDESA, "World Population Prospects 2019".

motorised travel with population growth is an additional factor to consider. In this study, owing to a lack of local studies a conservative assumption about a potential reduction in passenger motorised travel in 2050 is adopted[61] which by proxy is in agreement with the SADC RISDP infrastructure objective pertaining to the Industrialisation-Urbanisation-Mobility Nexus in the context of smart cities to 'reduce congestion and greenhouse gas emissions and create liveable cities in the SADC region.'[62]

Figure 10 UN DESA projected population growth for SADC and key member states (2020)



Source: Author adapted from UNDESA, "World Population Prospects 2019"

GDP for the SADC region for the period 2010–2018, averaged approximately 3% per annum.[63] For the analyses, we adopt a similar growth rate on average over the period 2020–2050 for the South African economy (approximately 50% of SADC GDP) which also aligns to domestic aspirations.[64] Economic growth between 2018 and 2022 is based on medium term projections[65], as depicted in Figure 11.

61 Steven Pye and Hannah Daly, 'Modelling sustainable urban travel in a whole systems energy model,' *Applied Energy* 159 (2015), https://doi.org/10.1016/j.apenergy.2015.08.127.

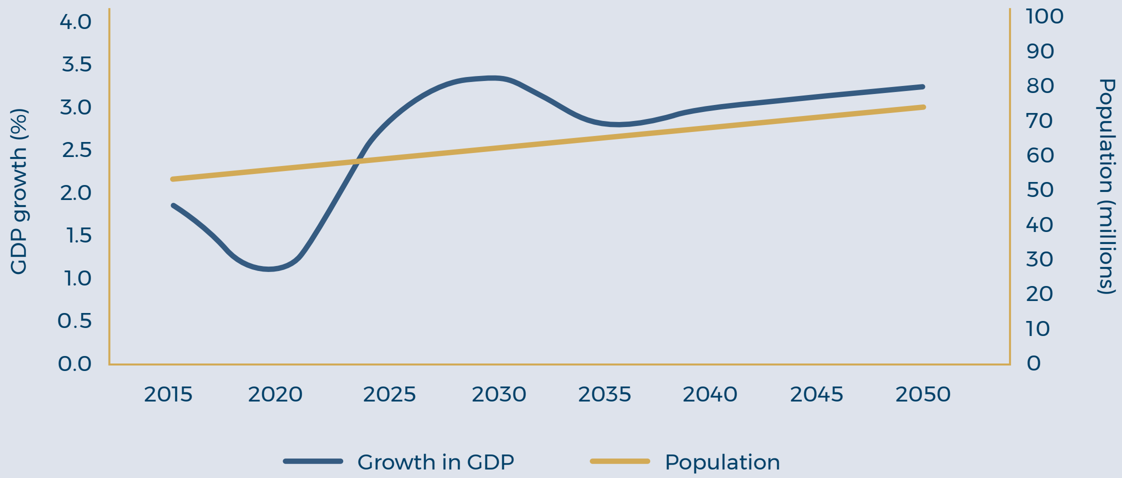
62 SADC, "Regional Indicative Strategic Development Plan".

63 SADC, "Regional Indicative Strategic Development Plan".

64 Government of South Africa, Department of Energy, *Integrated Energy Plan. Annexure B: Macroeconomic Assumptions* (Pretoria: Department of Energy, 2016), http://www.energy.gov.za/files/iep_2016.html.

65 Government of South Africa, National Treasury, *Medium Term Budget Policy Statement 2018* (Pretoria: National Treasury, 2018), http://www.treasury.gov.za/documents/mtbps/2018/mtbps/FullMTBPS.pdf; International Monetary Fund (IMF), *World Economic Outlook: Challenges to steady growth*, report (Washington D.C.: IMF, 2018), https://www.imf.org/en/Publications/WEO/Issues/2018/09/24/world-economic-outlook-october-2018.

Figure 11 Projected population and economic growth for South Africa



Source: Author developed from Government of South Africa, "Integrated Energy Plan"; Government of South Africa, "Medium Term Budget Policy"; IMF, "World Economic Outlook"; and UNDESA, "World Population Prospects 2019".

Fuel supply

South Africa, Angola and Zambia host the only crude oil refining capacity in SADC. With a total production capacity of 718,000 barrels/day (oil equivalent) South Africa hosts approximately 84% of crude-oil refining capacity and 90% when including synthetic fuel production from coal. The majority of South Africa's liquid fuels are refined from imported crude oil with approximately half of imported crude originating from Nigeria and Angola. Coal liquefaction (CTL) in South Africa is an important source of domestic liquid fuels and petrochemicals supply and a low-carbon transition will have a dramatic impact on both the domestic liquid fuels supply chain[66] and regionally.[67]

In 2012, South Africa gazetted the Cleaner Fuels 2 (CF2) regulations to improve the quality of local fuels from the current Euro 2 standard to the Euro 5 standard which would align with the SADC GESAP Strategy (Table 2) to improve vehicle emissions (T3). Gazetted in 2017 and estimated to cost $2.6 billion[68], the fuel specification has however not yet been implemented, with industry and government in disagreement regarding the responsibility for financing the refurbishment of the refineries. Nonetheless, in this model it is assumed

66 KPMG, *South African Petroleum Association, The petroleum industry's contribution to South Africa*, 2016, https://www.sapia.org.za/doc/SAPIA_15_November_Final.pdf.

67 South African Petroleum Industry Association, *Annual Report 2018*, 2018, https://www.sapia.org.za/Publications; ICCT, "Request for Proposals".

68 Government of South Africa, Department of Energy, *Discussion document on the review of fuel specifications and standards for South Africa*, Government Gazette No. 34089 (Pretoria: Department of Energy, 2011) https://www.gov.za/sites/default/files/gcis_document/201409/34089gon204.pdf; South African Petroleum Industry Association, 'Cleaner Fuels II', http://www.sapia.org.za/Key-Issues/Cleaner-fuels-II.

that the CF2 regulations will be effectively implemented by 2030. Existing South African crude oil refineries will either need to invest in refurbishment or cease production to observe these regulations. The establishment of a new, large refinery is also included as an option rather than assumed as a fixed investment.[69] A median global crude oil price is modelled at US $80/barrel[70] over the period 2030–2050. In addition, it is assumed that South Africa's existing CTL facility (see Box 2) retires in 2040. It is worth noting that this single development in the liquid fuels supply sector has a mitigation impact comparable to the decarbonisation of the entire South African transport sector.

Vehicle efficiency, speed & occupancy factors

BOX 2

South Africa operates a large coal-to-liquids facility – 150,000 bbl/day oil equivalent – which is responsible for close to a third of domestic liquid fuel supply on average. Operating with an efficiency of ~30%, its emissions are comparable in magnitude to the transport sector accounting for 12% of energy-related CO_2 emissions.

An increase in vehicle efficiency is an important mechanism to decrease emissions in the transport sector. However, we maintain conservative assumptions as reported in real world testing of road vehicles[71], and the model assumes an annual vehicle fuel efficiency improvement of 0.5% and 0.1% for public and freight road vehicles respectively, as is modelled in the Integrated Energy Plan.[72] Average vehicle speeds and passenger occupancy factors are assumed to be constant across the period.

The power sector

Decarbonisation of the power sector will determine, to a large extent, the feasibility of a low carbon transport transition if such a transition will primarily rely on the electrification of mobility. The SAPP, founded in 1995, was established to strengthen the transmission network and increase energy security to facilitate economic growth for all member states. By installed capacity, South Africa is the largest operator with 81% (48.5 GW) of the SADC capacity (60 GW) and in terms of demand, also the largest consumer responsible for 90% of local generation, and 85% of the SADC demand market (see Figure 12).[73] Consequently, as the largest SAPP member, South Africa's coal intensive electricity generation results

69 Africa Oil and Power, "CEF Partners with Aramco for New Refinery", https://www.africaoilandpower.com/2019/11/15/cef-partners-with-aramcofor-new-refinery/.

70 Prices pegged to 2015 real value.

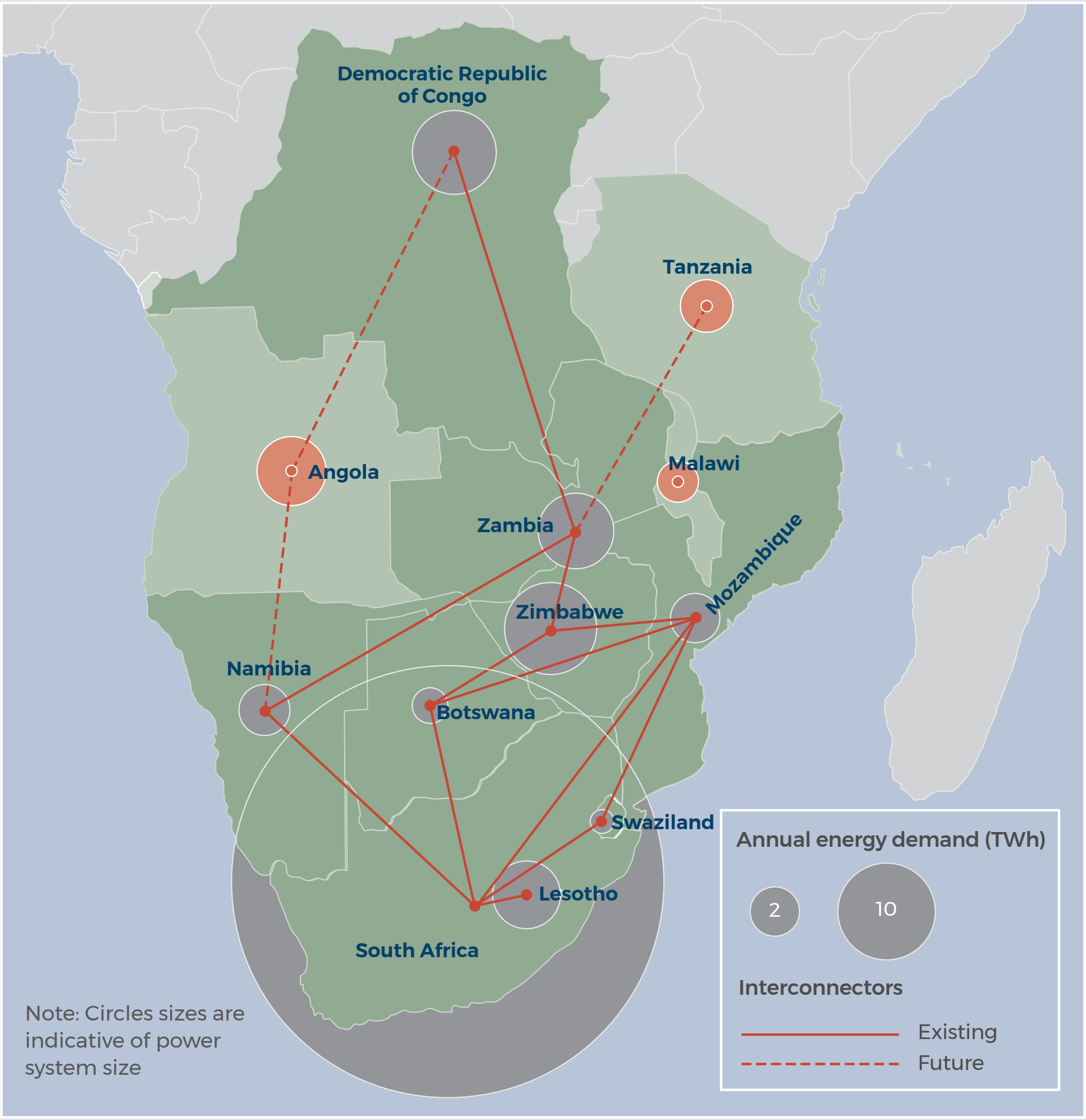
71 IEA, "Tracking Transport 2020".

72 Government of South Africa, Department of Energy, *Integrated Energy Plan*, Government Gazette No. 40445 (Pretoria: Department of Energy, 2016), https://static.pmg.org.za/161125IEP.pdf.

73 Jarrad Wright and John van Coller, 'System adequacy in the Southern African Power Pool: A case for capacity mechanisms,' *Journal of Energy in Southern Africa* 29, no.4 (2018), https://doi.org/10.17159/2413-3051/2018/v29i4a5581.

in the region having a disproportionately high GHG emissions factor of approximately 1 tCO_2eq/MWh.[74] RE installations in SADC have however grown sharply in the last decade, from 12 GW to 21 GW (2008–2017).[75] Hydropower projects remain the largest RE technology by capacity, despite impressive growth of solar and wind technology portfolios of 72% during this period, albeit primarily deployed in South Africa.

Figure 12 Schematic of the existing SAPP with planned additions, 2016



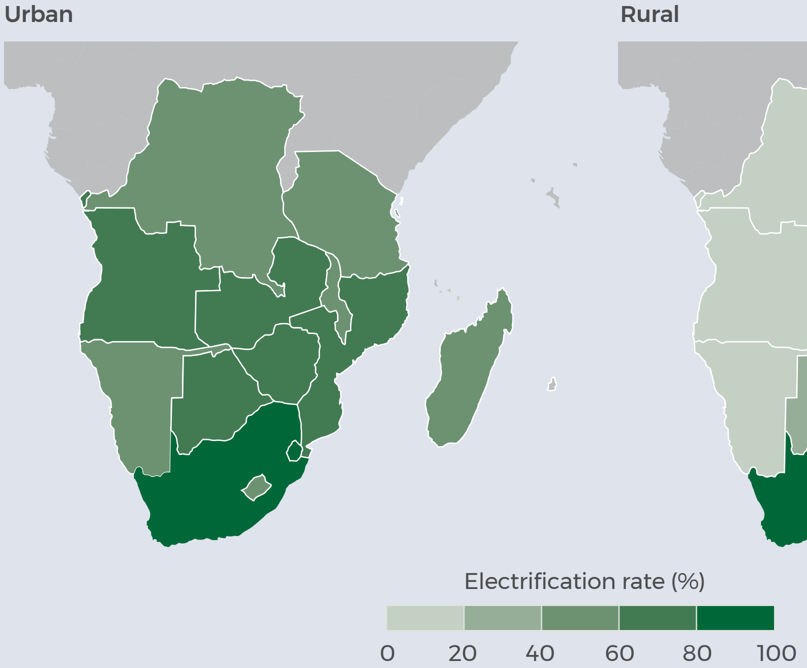
Source: Jarrad Wright and John van Coller, 'System adequacy in the Southern African Power Pool: A case for capacity mechanisms,' *Journal of Energy in Southern Africa* 29, no.4 (2018), https://doi.org/10.17159/2413-3051/2018/v29i4a5581

74 Mayuresh Sarang, "Grid Emission Factor for the South African Power Pool" (presentation, Capacity building workshop on development of CDM activities and NAMA for public and private sector in Zimbabwe, Montclair Hotel, Nyanga, August 24-26, 2016), https://unfccc.int/files/na/application/pdf/module_3_2.sb_case_studies.pdf.

75 Renewable Energy Policy Network for the 21st Century (REN21), *SADC Renewable Energy and Energy Efficiency Status Report 2018*, report (Paris: REN21 Secretariat, 2018), https://www.ren21.net/wp-content/uploads/2019/05/SADC_2018_EN_web.pdf.

Challenges remain to electrify the region which is still home to the lowest energy access rates and supply reliability in the world. The SADC average electricity access in 2016 was 48% with a sharp distinction between rural (32%) and urban populations (75%), as seen in Figure 13. In contrast, South Africa's average electricity access rate was estimated at 86% (2016) with 93% access for urban dwellers and 68% for the rural population.[97]

Figure 13 SADC urban–rural disparities in electrification rates



Source: Stockholm Environment Institute (SEI), *Renewable energy mini-grids: An alternative approach to energy access in southern Africa, report* (Nairobi: SEI – Africa World Agroforestry Centre, 2016), https://mediamanager.sei.org/documents/Publications/SEI-DB-2016-SADC-mini-grids.pdf

BOX 3 MICROMOBILITY AND MINI-GRIDS

Mobility in rural areas suffer from a lack of adequate transport infrastructure, such as poorly maintained roads, infrequent motorised alternatives due to remote locations (affecting fuel cost and supply) and the cost of provisioning regular transport services to communities characterised by low population densities owing to the expansive geographic locales they inhabit. The introduction of motorcycle taxis along with mobile phones are credited with significantly improving the livelihoods of rural communities via the connectivity these technologies provide to a range of services both physical and virtual.[a] Within Africa, Rwanda has pioneered the introduction of micromobility with the introduction of electric-bicycles (e-bikes), while in South Africa e-scooters form part of the road transport mosaic. Apart from alleviating congestion

BOX 3 MICROMOBILITY AND MINI-GRIDS (CONTINUTED)

and deferring road infrastructure investment in urban regions, e-bikes as a form of micromobility enables the provision of transport services to remote communities when coupled to a reliable source of electricity for which alternative transport fuel supplies are erratic and costly.

Cognisant of the disparities in electrification rates between urban and rural communities, all SADC member states have formulated rural electrification strategies. However implementation rates have not matched those of urban districts due to numerous difficulties which include the cost optimal expansion of the central network – sometimes over vast geographic territories – lacking basic infrastructure to service energy constrained communities.[b] Enabled by dramatic reductions in the cost of renewables, mini-grids have emerged in the last decade as a cost-effective alternative to the 'central grid expansion' paradigm wherein mini-grid systems can be deployed initially and integrated into the supply network as the system expands. The World Bank defines a mini-grid, typically ranging in capacity from the 10 kW to 10 MW scale, as 'electric power generation and distribution systems that provide electricity to just a few customers in a remote settlement or bring power to hundreds of thousands of customers in a town or city.'

Currently, Tanzania is the only SADC member with an official mini-grid electrification policy to address rural electrification.[c] As of 2016, 109 systems totalling 158 MW served 184,000 customers. These mini-grids are however predominantly composed of fossil-fuel technologies (46%) with Biomass (33%) and Hydro (21%) providing the bulk of the RE share: solar at 0.234 MW accounting for only 0.15% of installed capacity.[d] Noteworthy is that within the DRC, SADC's most populous member which rivals Malawi as having the lowest electrification rates, several solar-PV with storage projects are proposed to provide electricity to 150,000 people with a 24 hr service provision and with a five year implementation horizon.:

a Gina Porter, "Mobilities in Rural Africa: New Connections, New Challenges," Annals of the American Association of Geographers 106, no.2 (2016), DOI: 10.1080/00045608.2015.1100056

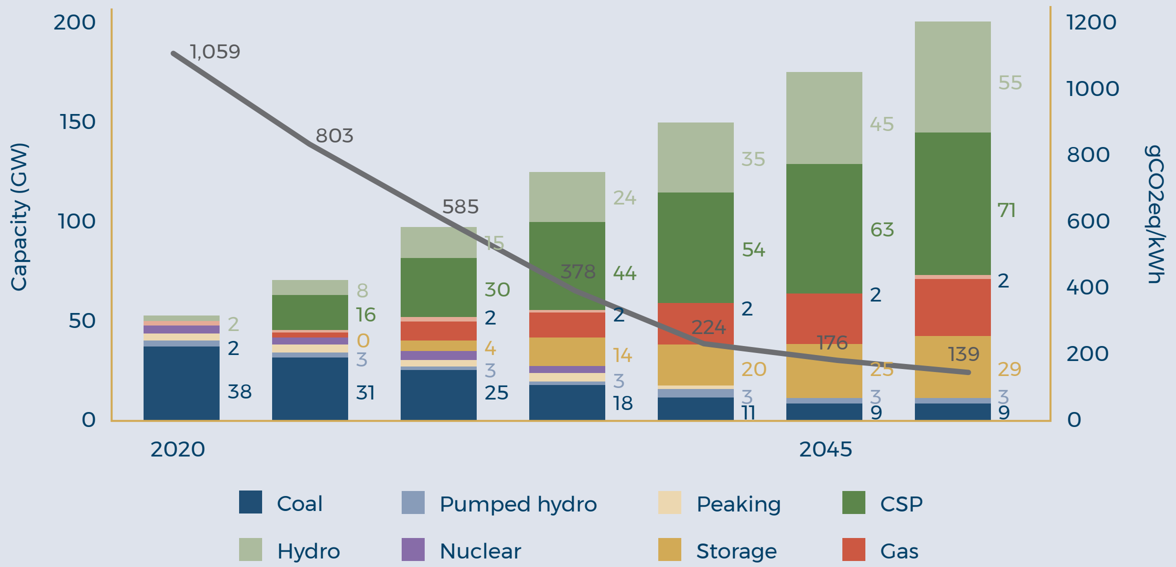
b World Bank, "Investing in Mini Grids Now, Integrating with the Main Grid Later: A Menu of Good Policy and Regulatory Options", report (Washington, DC: World Bank, 2019), http://hdl.handle.net/10986/31772

c Stockholm Environment Institute (SEI), "Renewable energy mini-grids: An alternative approach to energy access in southern Africa", report (Nairobi: SEI - Africa World Agroforestry Centre, 2016), https://mediamanager.sei.org/documents/Publications/SEI-DB-2016-SADC-mini-grids.pdf

d International Renewable Energy Agency (IRENA), "Policies and Regulations For Renewable Energy Mini -Grids", report (Masdar: IRENA, 2018), https://www.irena.org/publications/2018/Oct/Policies-and-regulations-for-renewable-energy-mini-grids

The SATIM model is a full-sector energy model and therefore includes a detailed representation of the power sector for South Africa with technology options for new generation, and accounts for any additional emissions in the power sector arising from transport electrification. In this work, the following assumptions are made for the development of the power sector: Minimum Emissions Standards requirements for the coal fleet are implemented from 2025; limits on the total new capacity of RE technology until 2030 after which there is no limit; and a stipulation that battery storage capacity needs to be supplemented with natural gas-fired generation capacity for added reliability. The result is that all new generation capacity is in the form of either wind, solar-PV or gas, with large amounts of battery storage to compliment the variability of the RE capacity, as seen in Figure 14. The GHG emissions intensity[76] of the grid declines from 1141 g/kWh in 2015 to 139 g/kWh in 2050, as older coal plants are decommissioned with some coal retiring early. By 2030, 51% of generation capacity is RE, and by 2050 this grows to 76%.[77]

Figure 14 South Africa's power sector – total installed generation capacity (2020–2050)



Source: Bryce McCall et al., "Least-cost integrated resource planning"

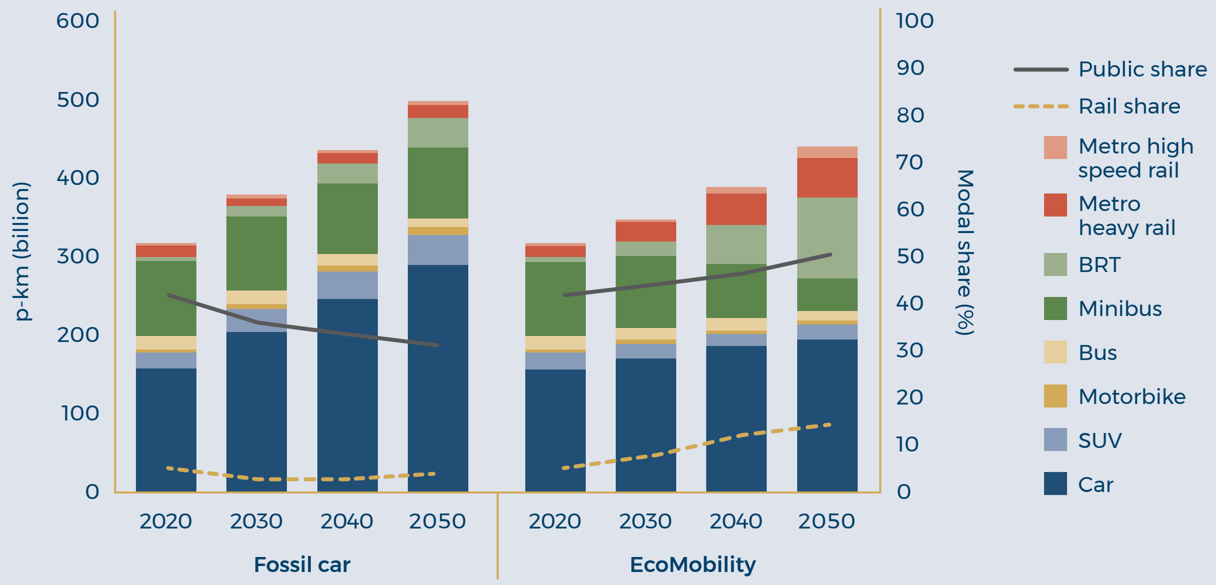
South Africa as a case study: Transport transition scenarios

As introduced in earlier sections, we focus the quantitative analysis on the South African road transport sector to explore the implications for road transport in SADC and the concomitant impact on energy supply. Referring to Table 4, four scenarios with an emphasis on road transport were introduced. The Spatial Planning and Modal Shift pathway results in a lower demand for passenger transport when compared to the Road

76 The intensity is calculated by accounting for all GHG emissions from electricity generation and the total delivered electricity at the point of use after transmission and distribution losses.

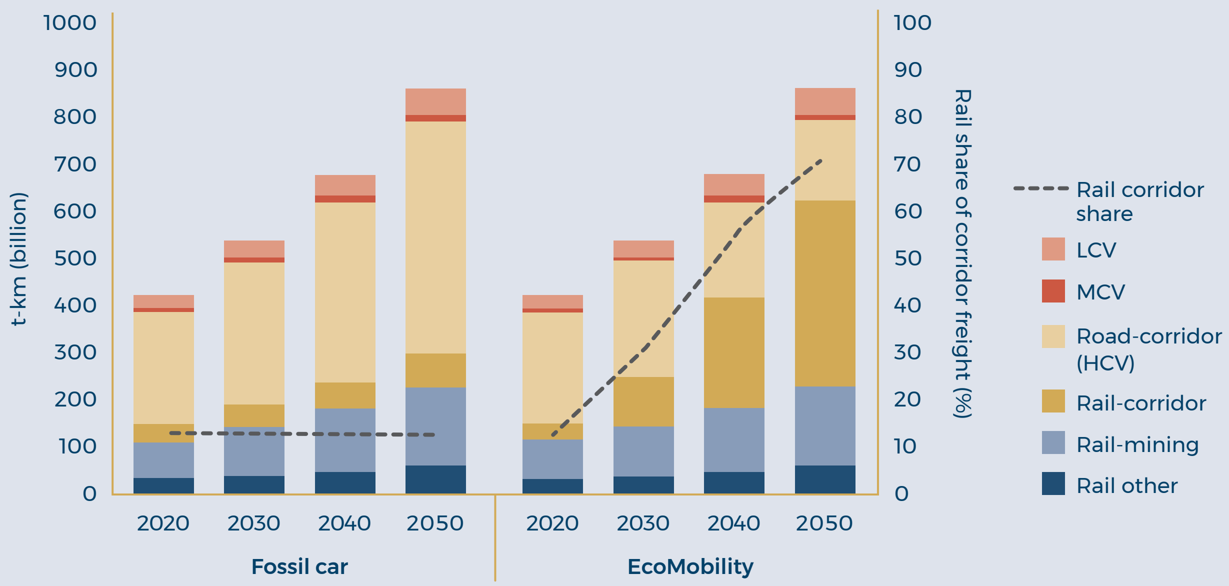
77 Bryce McCall et al., "Least-cost alternatives for the South African electricity system".

Figure 15 Modal split of passenger-km demand by technology



Source: Author developed from SATIM Model

Figure 16 Freight modal shares of tonne-km



Source: Author developed

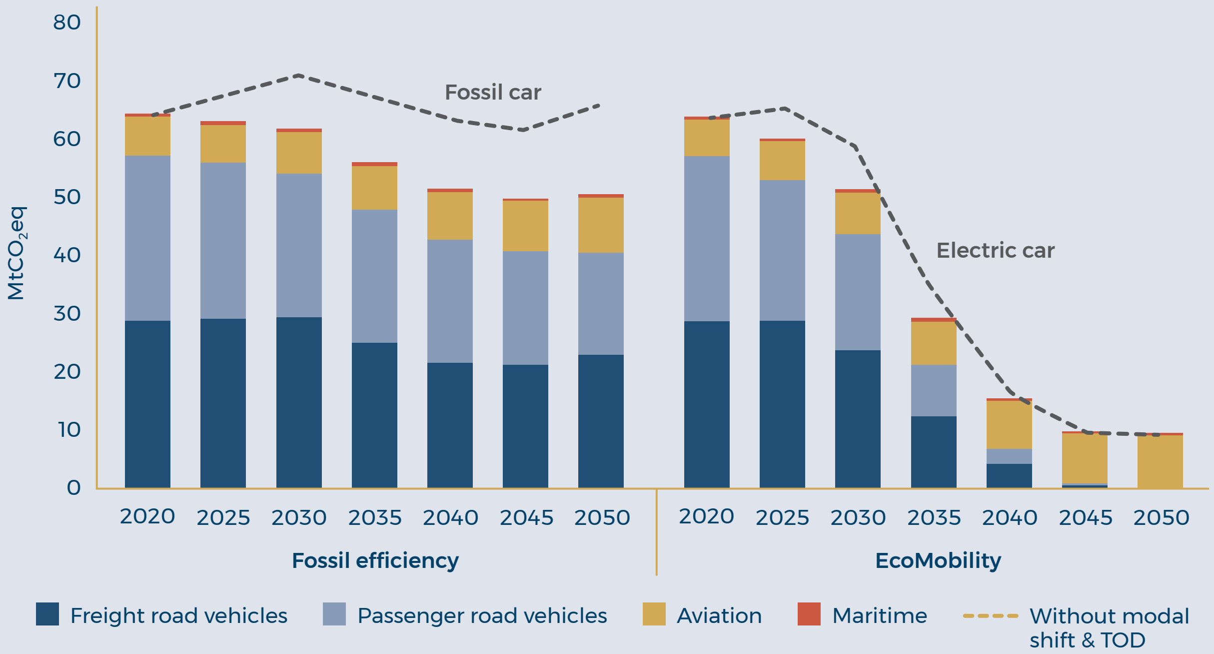
Vehicle Emphasis pathway (see Figure 15). Measured in passenger kilometres (p-km), the TOD intervention encourages a shift towards non-motorised travel. In contrast to the current captive modality experienced by low-income households, the TOD reduces demand for motorised travel by 10% in 2050. Public transport, in particular rail, is prioritised over private travel with public transport reaching a 50% modal share in 2050 with rail travel accounting for almost 20% of total passenger travel. Within the freight sector the volume of goods transported, measured in tonne-kilometres (t-km), remains constant but road corridor freight experiences a shift to rail from a share of approximately 15% to 70% in 2050 (see Figure 16).

The significance of modal switching highlights the interdependencies of the transport sector and upstream sectors, specifically the electricity sector, given significant increases in rail share in both freight and passenger demand. This also raises important questions not only about infrastructure investment decisions, but behavioural shifts and associated communication and incentive strategies. In other words, emission reductions will depend to a large extent on changing the way that people and businesses make decisions around and utilise transport infrastructure.

Emissions

In Figure 17, the GHG emissions associated with the Fossil-Efficient and Eco-Mobility scenarios are compared. Overlaying the graphs, total emissions associated with the Fossil-Car and Electric-Car Scenarios are also compared. Both EV scenarios demonstrate the potential for the rapid decoupling of transport activity from emissions in South Africa.

Figure 17 Emissions from the transport sector



Source: Author developed

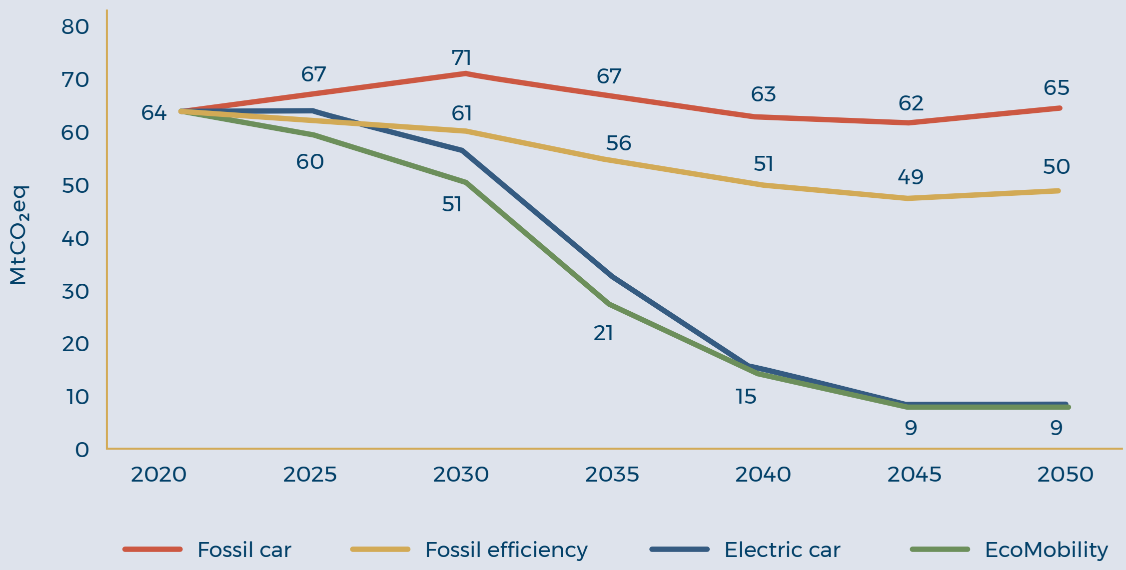
By 2050, aviation and maritime transport contribute the residual 9 $MtCO_2eq$ and 0.008 $MtCO_2eq$ in 2050, respectively.

In contrast, for the non-EV Fossil-Car scenario, emissions would peak at approximately 70 $MtCO_2eq$ and fluctuate at about 65 $MtCO_2eq$ in the case of no modal shift and TOD. This is due to the switch to Hybrid ICE passenger cars, which would gain a sizeable market share by 2030. Increased demand in the period 2045 to 2050 contributes to an increase in emissions by 2050 and highlights the limited potential for decarbonisation offered by fossil-fuelled hybrid vehicles.

Demand and modal shift

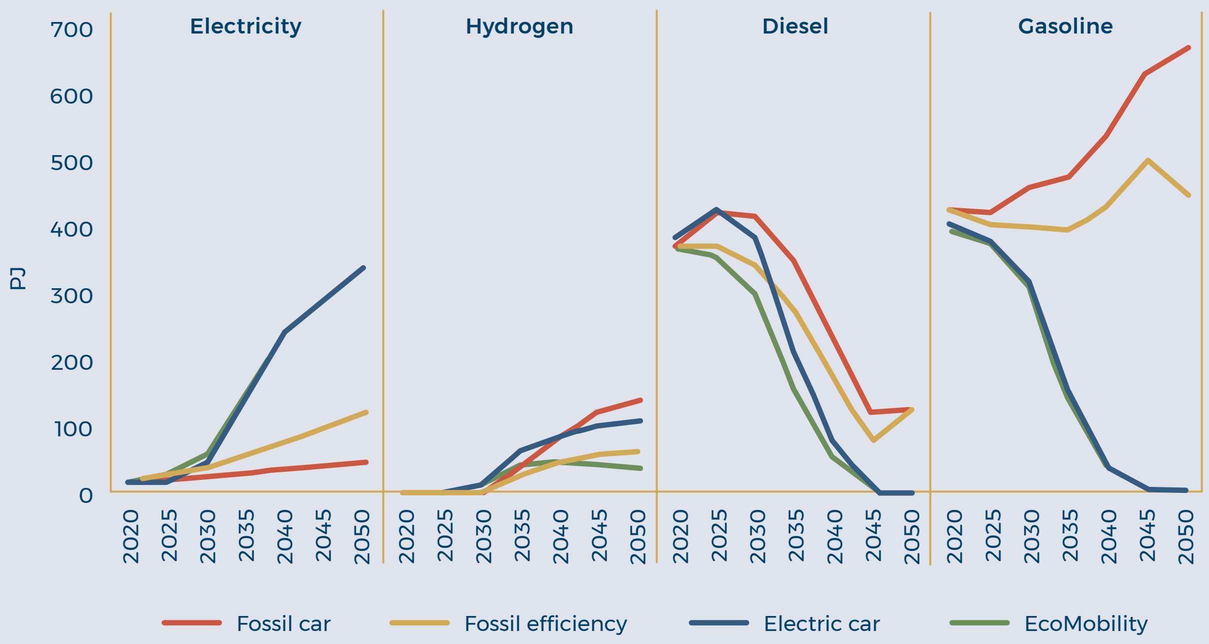
Modal switching has a substantial impact on direct emissions for the fossil fuel pathways but minimal impact for the electrified pathways in the transport sector (see Figure 18). An electric pathway benefits in the medium term as a noticeable decline in emissions would occur from 2025 (5 $MtCO_2eq$) to 2030 (7 $MtCO_2eq$), with cumulative avoided emissions totalling 80 $MtCO_2eq$. In contrast, emissions in the fossil fuel scenarios would benefit from a modal shift in the latter period 2030 (9 $MtCO_2eq$) to 2050 (15 $MtCO_2eq$), with cumulative savings of 145 $MtCO_2eq$. The large difference between the two technology pathways reflects the impact of a transition to EVs. The impact of both technology choice, fuel switching and modal shift is however important when quantifying energy supply for transport. Modal shifting is crucial to reducing final energy demand and improve both resource and economic efficiency.

Figure 18 The Impact of modal switching on direct transport emissions



Source: Author developed

Figure 19 Transport Fuels



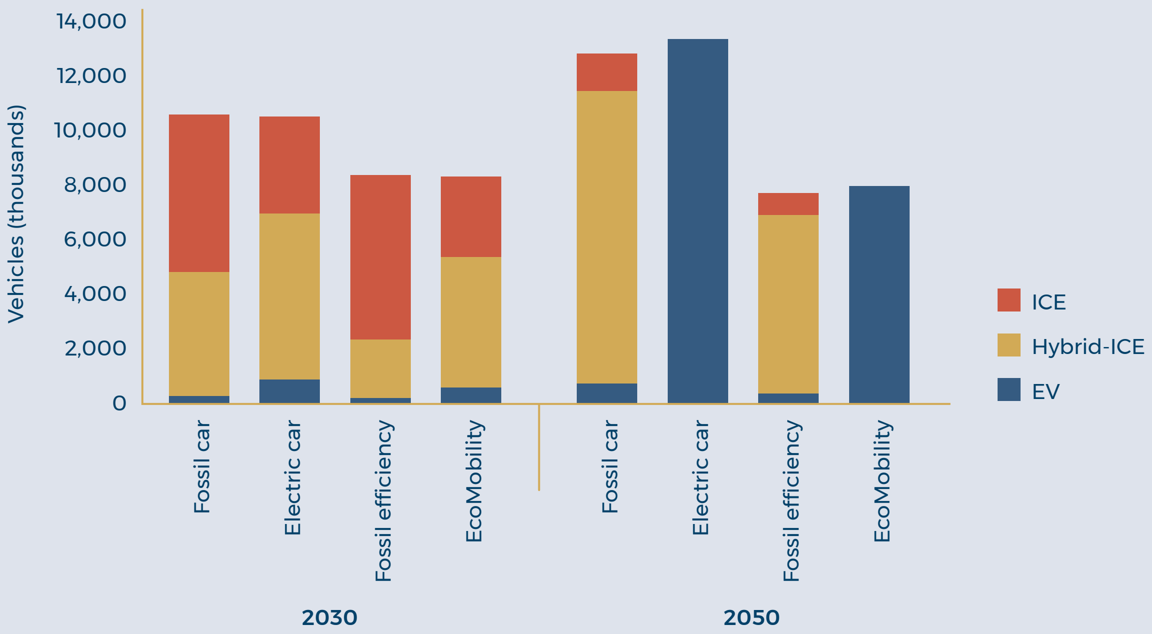
Source: Author developed

In contrasting the scenarios, modal shifting and TOD emerge as important interventions for long-term decarbonisation of both freight and passenger transport when considering the fuel supply chain. Figure 19 depicts the use of major transport fuels in each of the scenarios. Despite the negligible effect on emissions in the EV scenarios, one effect of considering the dimension of spatial planning is to reduce the net fuel demand.

In the EV scenario, liquid fuel demand for diesel is reduced in the early period as road to rail migration in freight occurs shifting fuel consumption to electricity. A modal shift also reduces the potential hydrogen demand in heavy vehicles towards electricity via rail.
A progressive decline in diesel results mainly from a switch to hydrogen for heavy vehicles in corridor freight transport. The notable dramatic shift in the petrol/diesel ratio in the non-EV scenarios would have a significant impact on the economics of domestic liquid fuels production.

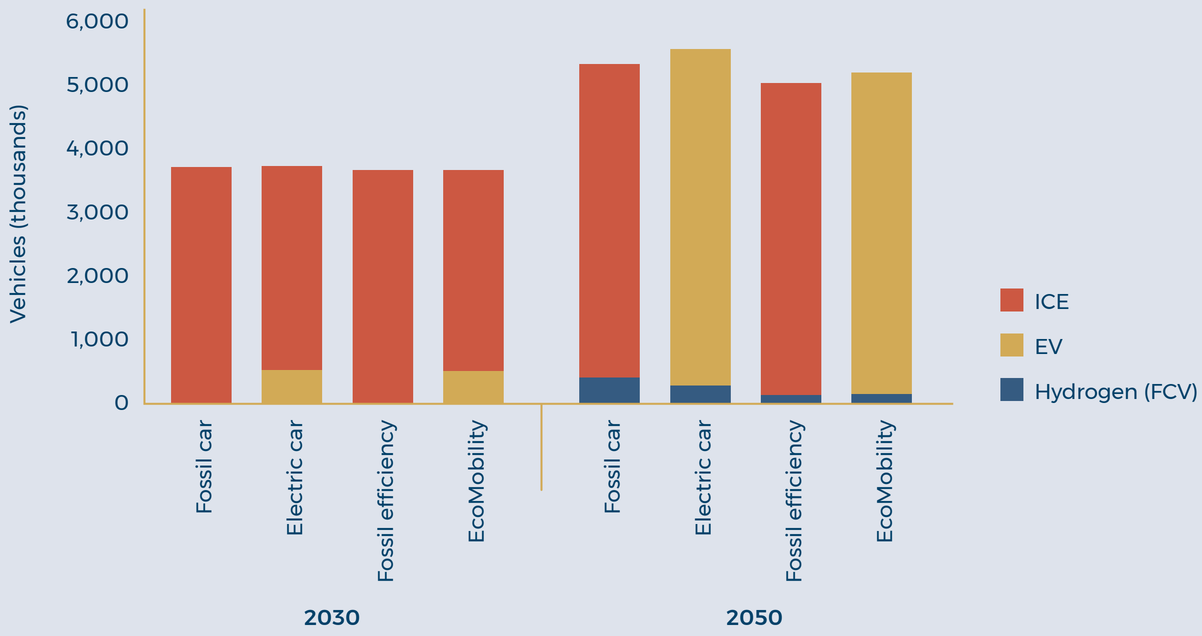
We compare potential vehicle technologies and population size as reflected in the scenarios, for private and public transport sub-sectors in Figure 20 and Figure 21 respectively. A domestic EV market has the potential to be fully electrified in 2050, whereas a non-EV market would prefer Hybrid-ICE vehicles in the private fleet, as well as hydrogen in the public fleet.

Figure 20 Private passenger road vehicles by population and technology



Source: Author developed

Figure 21 Public transport road vehicles by population and technology

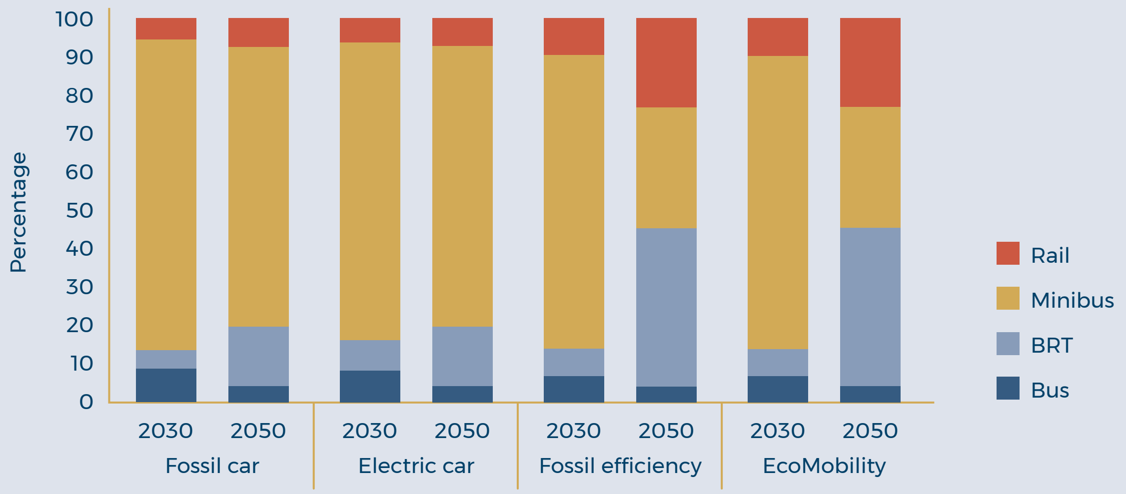


Source: Author developed

The key impact of modal shifting is to reduce the private passenger fleet size. A pathway with a road-vehicle emphasis results in a passenger vehicle population of approximately 13 million in 2050, nearly doubling from the current registered population of 7.4 million. In contrast, modal migration and TOD could reduce the vehicle population to approximately 8 million in 2050.

A decrease in the private passenger fleet is interestingly matched with a decrease in public transport vehicles to meet passenger demand: 250,000 compared to 225,000 (Figure 21), with a combination of rail and buses (including BRT) displacing minibus taxis by 2050 (Figure 22).

Figure 22 Modal composition of public transport by technology



Source: Author developed

Fuel switching in freight transport

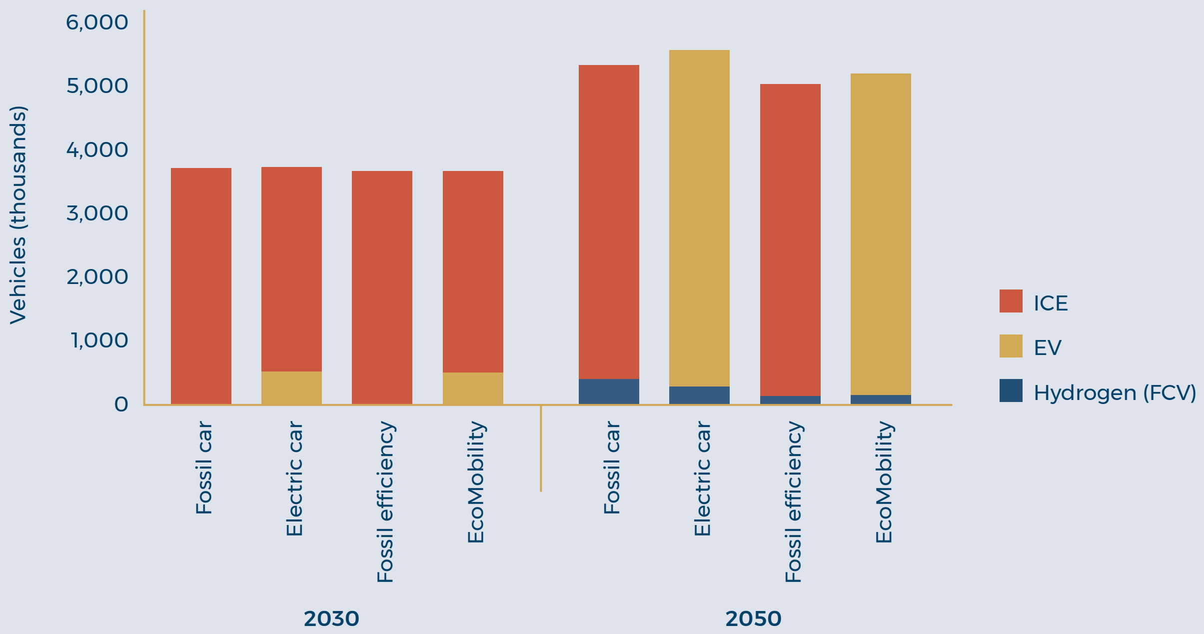
In the freight sector, the EV pathways result in the full electrification of light commercial vehicles (LCVs) and small to medium trucks in 2050. Previous analyses[78] indicated that the electrification of transport would result in higher GDP growth relative to non-EV scenarios. This is due to the reduction in fuel demand per vehicle-km (v-km) travelled relative to ICE vehicles and the concomitant decrease in national expenditure on fuel supply. The International Energy Agency reports that freight services are correlated to economic

78 Fadiel Ahjum, Faaiqa Hartley and Bruno Merven, "An assessment of the GHG mitigation potential of land transport pathways presented in the Green Transport Strategy for South Africa and their economy-wide impact" (Working Paper, University of Cape Town, Cape Town 2019; Bruno Merven, Faaiqa Hartley, and Fadiel Ahjum, "Road freight and energy in South Africa" (Working Paper, SA-TIED, Pretoria, 2019), https://sa-tied.wider.unu.edu/article/road-freight-and-energy-in-south-africa.

growth[79] which, as seen in Figure 23, results in an increase in the fleet size for the EV scenarios relative to their comparative Fossil scenarios.

For the Fossil-Car scenario, LCVs (which comprise the bulk of the freight road fleet population) continue to consume oil products. Refineries produce a set ratio of both diesel and gasoline for which the LCV vehicles are the primary consumers of the diesel product. Escalating demand for gasoline (as shown in Figure 19) beyond which local refineries can supply would subsequently require imported product. The decline in diesel consumption is largely due to the switch to fuel-cell heavy electric vehicles (FCEVs) for road corridor heavy vehicles where the bulk of diesel is consumed. This is due to the comparative high consumption of diesel for extended vehicle-kms along corridor routes where hydrogen fuel cells would present the cost optimal choice in the period 2030–2050.

Figure 23 Freight transport road vehicles by population and technology



Source: Author developed

In terms of technology utilisation, as shown in Table 5, the Fossil-Car scenario would have 17% of total v-km driven via hydrogen fuel-cell with the remainder fuelled by diesel. In contrast, for the Eco-Mobility scenario, the LCV fleet is electrified and, including light trucks, account for 94% of v-km driven in 2050 with fuel-cell heavy vehicles comprising

79 IEA, *The Future of Trucks: Implications for energy and the environment*, report (Paris: IEA, 2017), https://webstore.iea.org/the-future-of-trucks.

the remaining 6%. The reduction in corridor v-km when compared to the Electric-Car scenario (13%) is as a result of the road-to-rail migration as indicated in Figure 16. This is also evident when comparing v-km by technology shares for the Fossil-Efficiency and Fossil-Car scenarios in Table 5.

TABLE 5 SHARE OF FREIGHT VEHICLE-KM(V-KM) BY FUEL TYPE

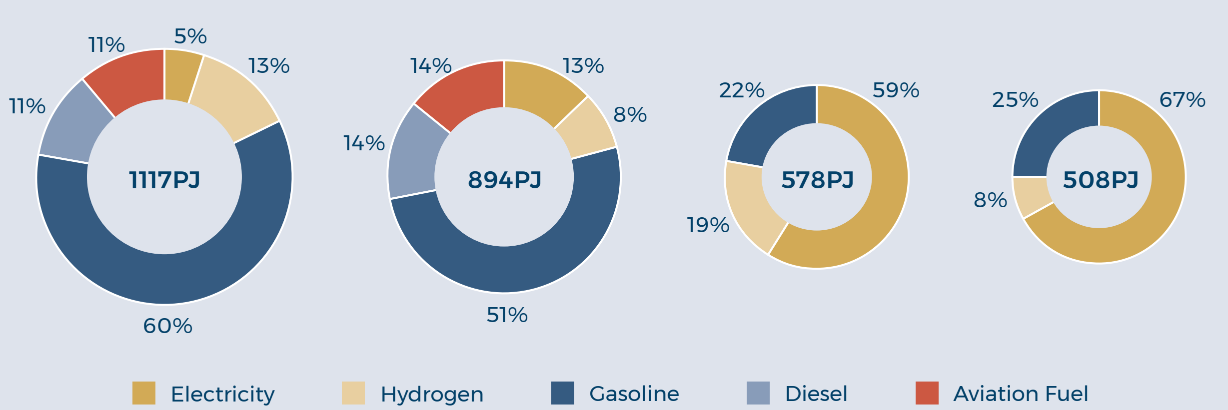
Scenario	Technology Type	2030	2050
Fossil-Car	Oil product Electric Hydrogen FC	100% 0% 0%	83% 0% 17%
Electric-Car	Oil product Electric Hydrogen FC	82% 15% 3%	0% 87% 13%
Fossil- Efficiency	Oil product Electric Hydrogen FC	100% 0% 0%	93% 0% 7%
Eco-Mobility	Oil product Electric Hydrogen FC	82% 15% 3%	0% 94% 6%

Source: Author developed (derived from SATIM model results)

Impacts on Fuel Demand

In the Eco-Mobility scenario, fuel demand is not only significantly lower, decreasing to 55% of the current fuel demand, but the transport sector's energy needs are also primarily met by electricity (67%) and hydrogen (8%) (see Figure 24). Aviation fuel accounts for the remaining 25% and comprise the bulk of emissions in 2050 (see Figure 17).

Figure 24 Total transport energy consumption and fuel composition in 2050 for the scenarios



Source: Author developed

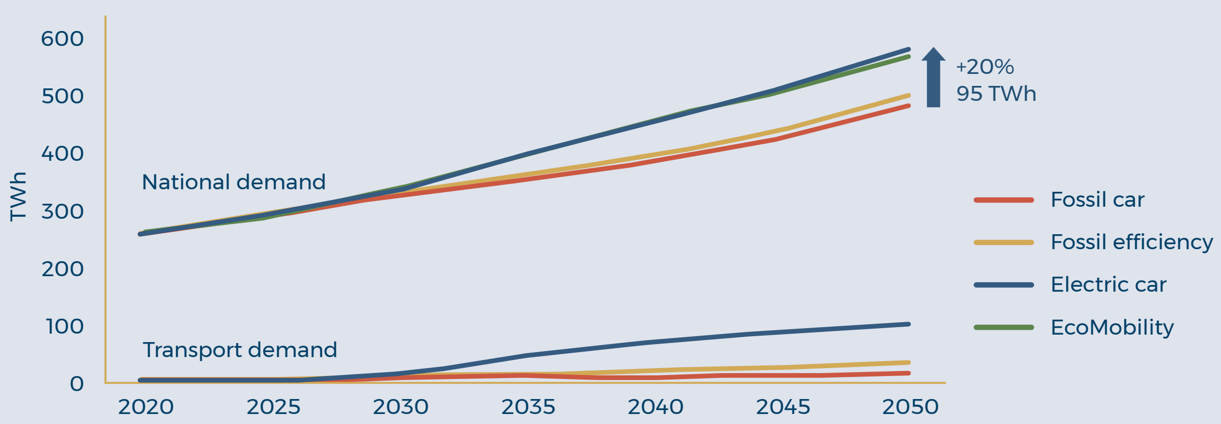
In contrast, for the Fossil-Car scenario fuel demand increases by 30% in 2050, of which a sizable portion is still met by fossil fuels. However, a greater share of hybrid vehicles substantially limits growth in fuel demand for a vehicle population which nearly doubles by 2050. Nevertheless, electric drivetrains, owing to their higher well-to-tank efficiencies, in tandem with modal switching confer greater savings in 2050. Marine vessel fuel usage is negligible at 0.1 PJ for both cases.

Impacts on Fuel Supply

Power Sector

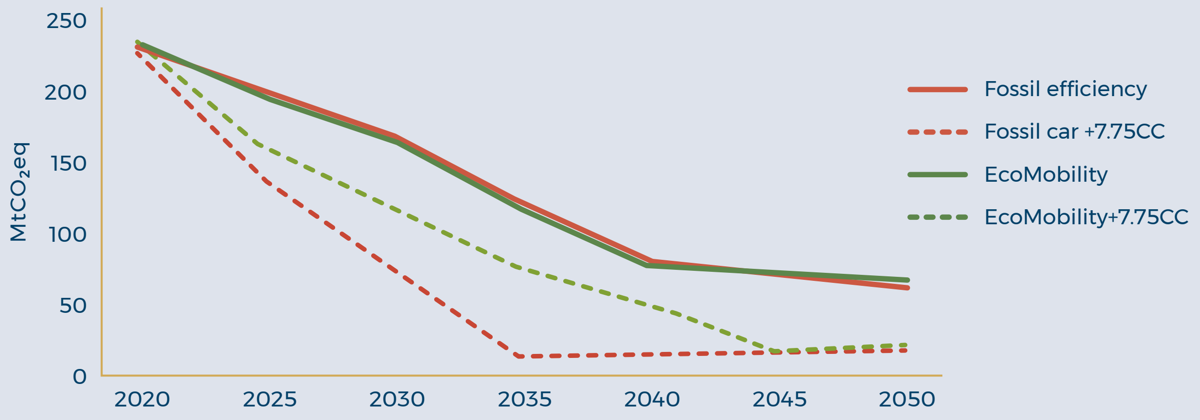
An electrified vehicle fleet, servicing a population of 75 million people in 2050, would require an additional 20% or 95 TWh (including transmission and distribution losses) for the Eco-Mobility scenario (Figure 25a). A cost-optimal power sector would effectively become low-carbon by 2050 and, in the absence of a national GHG emissions budget, its emissions trajectory is essentially invariant to the transition in transport (Figure 25b). However, when an emissions budget is applied to the economy, as would be the case when South Africa commits to its NDC, we note that, as depicted in Figure 25b, an ambitious transport electrification policy would result in increased emissions from the power sector relative to the Fossil-Car scenario. Higher emissions from the power sector for the Eco-Mobility scenario would persist until 2045. In the Fossil-Car scenario, a 8 Gt carbon budget requires earlier decarbonisation whereas in the Eco-Mobility scenario, due to the deployment of zero-emissions vehicles, additional carbon space is allocated in the budget allowing for an extended decarbonisation period. Effectively, the Eco-Mobility scenario results in the increased utilisation of the existing coal plants in the medium term and shows that there are sectoral trade-offs. Transport technology policy could thus alter the timing of closures of other emitting infrastructure even under ambitious mitigation scenarios.

Figure 25a Power sector: Electricity supply



Source: Author developed

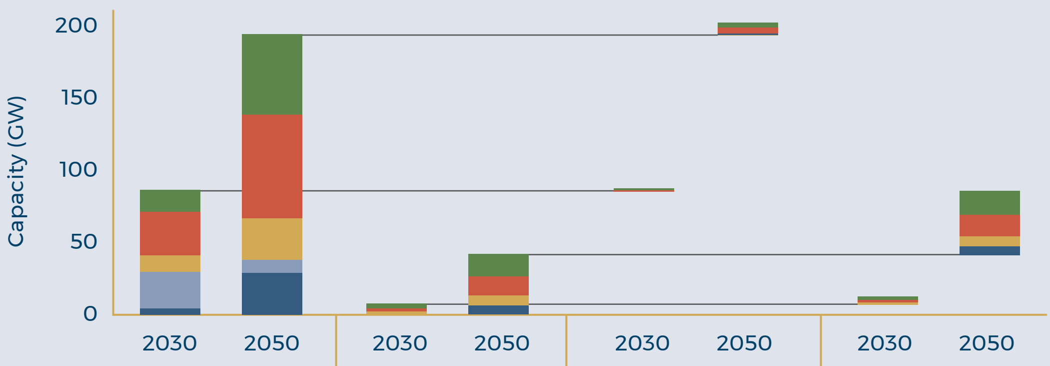
Figure 25b Power sector: Associated GHG emissions (including a 8 Gt carbon cap case)



Source: Author developed

When compared to the Fossil-Car scenario, the additional capacity required to support an ambitious switch to EVs would, in 2050, require an additional 41 GW for the Eco-Mobility scenario and 45 GW for the Electric-Car scenario (see Figure 26). In 2030, without an

Figure 26 The total power sector capacity required for the fossil-car scenario: Displayed with the additional capacity required for the other scenarios



	Fossil-car 2030	Fossil-car 2050	EcoMobility 2030	EcoMobility 2050	Fossil-efficiency 2030	Fossil-efficiency 2050	Electric-car 2030	Electric-car 2050
Wind	15	55	3	16	1	3	2	17
PV	30	71	2	12	1	4	2	14
Gas	11	29	1	7	1	1	1	7
Coal	25	9	-1	0	0	0	-1	0
Battery	4	29	1	7	0	1	1	7

Source: Author developed

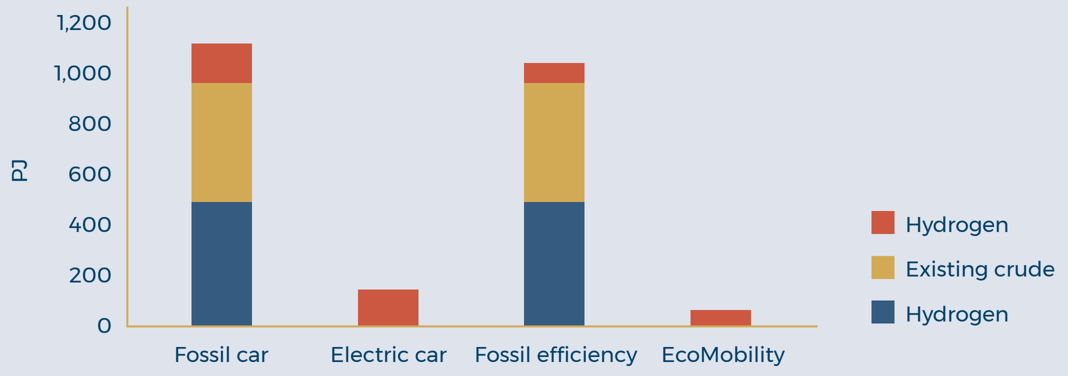
economy-wide emissions budget, the EV scenarios result in a decrease in the utilisation of existing coal capacity (-1GW) switching to renewables instead. The Fossil-Efficiency scenario also increases demand for electricity for rail transportation, requiring an additional 9 GW in 2050 compared to the Fossil-Car scenario.

Refineries

The existing CTL facility primarily consumes coal. Although the coal feedstock is supplemented with natural gas, the amount of gas that is able to displace coal is limited by plant design. The total CTL capacity in South Africa is approximately 150,000 barrels of oil equivalent per day, or roughly 246 PJ of product per annum. Of the total output, 83% is liquid fuels (ie, kerosene, gasoline and diesel) with the balance consisting of other commodities (eg, alcohols, waxes, methane rich gas). The facility is reported to emit on average approximately 55 $MtCO_2eq$ annually. The facility has an assumed technical life of another 20 years which, in the modelled scenarios, sees it retire at the earliest by 2040.

The Euro 2 to 5 fuel standard implementation (Clean Fuels Phase 2, CF2) would require the refurbishment of 50% of existing domestic crude refining capacity, with the remaining refineries decommissioned due to the investment cost. In the Fossil-Car and Fossil-Efficiency scenarios, an additional crude oil refinery with capacity of the order of 300,000 barrels per day may be required in 2050 to supplement increased demand (Figure 27). In this case, the new refinery would replace the forgone capacity as liquid fuel demand increases toward 2050. All in all, the two fossil fuel scenarios would see total domestic liquid fuel generally stagnate over the period 2030–2045 with a shift in the local diesel:petrol consumption ratio requiring importation to balance local production.

Figure 27 Total refinery capacity in 2050 for the scenarios

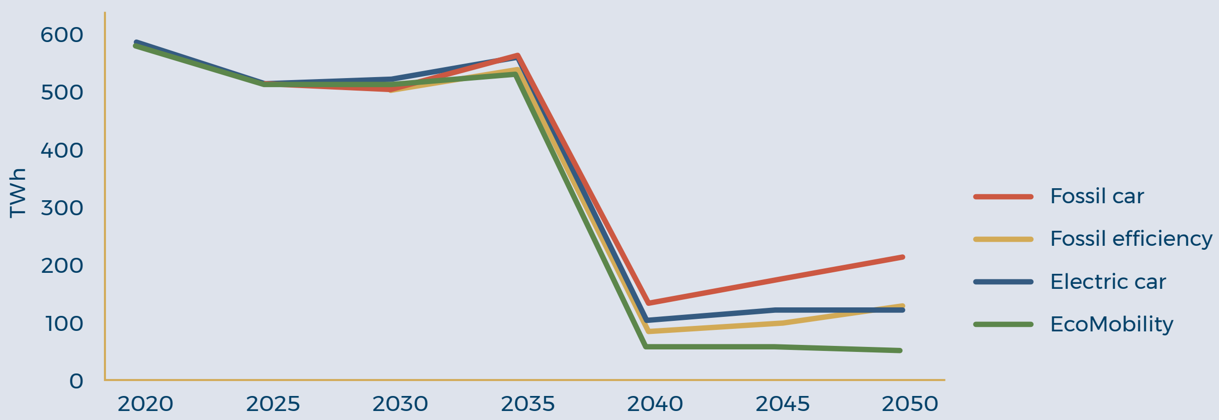


Source: Author developed

However, the two EV scenarios would negate the requirement for domestic refinery capacity as liquid fuel demand for transport would progressively decline (see Figure 19 and Figure 27). Also of note is the level of hydrogen production that would be curtailed if ambitious road-to-rail modal switching is implemented for freight transport: a reduction, in 2050, of 50% and 20% respectively for the Fossil-Efficiency and Eco-Mobility scenarios, when compared to the Fossil-Car scenario. The existing CTL facility is assumed to retire in 2040 and emissions from the refineries are, post CTL, primarily driven by the choice of process route for the production of hydrogen (see Figure 28). In 2050, emissions equate to 5 $MtCO_2eq$ for the Eco-Mobility scenario (solely from hydrogen production) in contrast to the 22 $MtCO_2eq$ in the Fossil-Car scenario for which hydrogen is responsible for 16 $MtCO_2eq$ and the remainder from crude-oil processing.

EV scenarios would negate the requirement for domestic refinery capacity as liquid fuel demand for transport would progressively decline

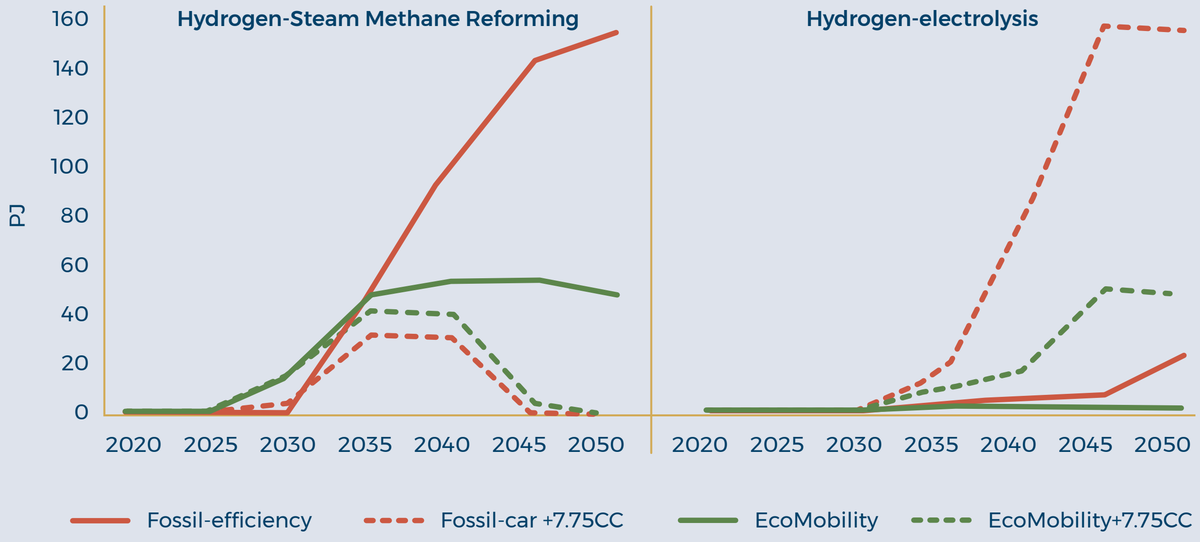
Figure 28 Refinery emissions



Source: Author developed

The emissions resulting from hydrogen production are due to the economic preference for natural gas via Steam-Methane-Reforming (SMR) in the absence of an emissions constraint. As illustrated in Figure 29, when an emissions constraint is applied, the choice of hydrogen supply switches from natural gas SMR to electrolysis. The electrolysis production route instead requires electricity with lower associated production emissions from a decarbonised power sector (see Figure 25).

Figure 29 Hydrogen supply: The impact of an emissions constraint on the preferred process route: ie, natural gas vs electricity



Source: Author developed

BOX 1 HYDROGEN: BLACK TO GREEN[a]

Interest in hydrogen's role in the transition to a global net-zero energy system, specifically in applications for industrial and transport systems has increased in recent years. Multiple low and zero-carbon proof-of-concept projects are underway ranging from the production of steel and ammonia to public transit and corridor transport. Multiple production process routes for hydrogen exist and in order to distinguish conventional processes such as coal gasification from net-zero alternatives, a colour classification scheme has been adopted which has been suggested could provide a basis for net-zero production certification. The World Bank's Energy Sector Management Assistance Program (ESMAP) describes the colour coding as follows:

Black hydrogen – Hydrogen produced from coal via coal gasification and extraction.

Brown hydrogen – Hydrogen produced from lignite.

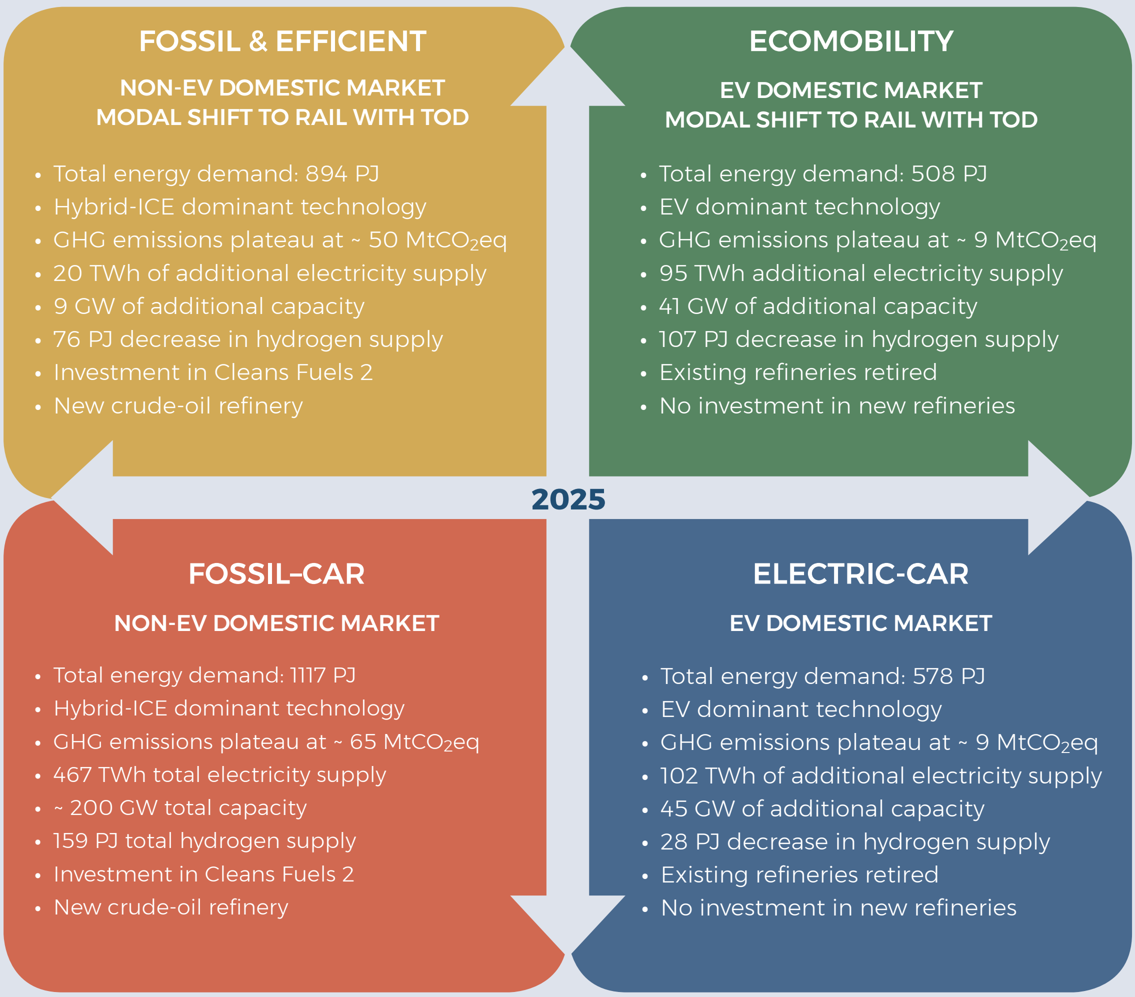
Gray hydrogen – This term usually refers to hydrogen produced via SMR, and it is the most common type of hydrogen produced globally. Gray hydrogen can also refer to hydrogen that is created as a residual product of a chemical process—notably, the production of chlorine from chlor-alkali plants.

a Skype interview, TMEA representative, 17 July 2019.

Conclusion

A full sector representation of the South African economy in a least cost modelling framework (SATIM) was utilised to assess the resultant economy-wide energy and GHG emissions for the South African road transport sector towards 2050. Assuming an average annual economic growth rate of approximately 3% over the period 2020-2050, with the population reaching 75 million in 2050, four scenarios were modelled. The scenarios contrasted policy choices about vehicle technology (Fossil-Car vs Electric-Car); modal shifting for passenger and freight road transport; as well as considerations of improved urban planning via Transit Oriented Development (Fossil-Efficiency vs Eco-Mobility). The scenarios as they compare for GHG emissions and energy demand are summarised in Figure 30.

Figure 30 Key outcomes in 2050 for the South African transport scenarios



Source: Author developed

Given the current levels of energy demand and emissions of the South African transport sector (897 PJ and 60 $MtCO_2eq$, respectively) the Fossil-Car scenario represents the most energy intensive future, with a total demand of 1117 PJ and GHG emissions of 65 $MtCO_2eq$ in 2050. In contrast, the Fossil-Efficiency scenario implements a modal shift which leads to: a shift in corridor freight with a 70% rail share; and an approximate 50% share of motorised travel between public and private travel, in combination with TOD (reducing motorised passenger travel demand by 10%). This has the effect of reducing the energy supply requirement (net of losses) to 894 PJ and emissions to 50 $MtCO_2eq$ representing a 20% decrease in energy demand and 23% decline in emissions relative to the Fossil-Car scenario. The Fossil-Efficiency scenario effectively plateaus growth in energy and emissions for transport, relying on Hybrid-ICE vehicle technology in combination with the above measures.

In the absence of a modal shift and TOD, a technological shift towards EVs as represented by the Electric-Car scenario would require 578 PJ, with transport emissions totalling 9 $MtCO_2eq$. The residual emissions comprise aviation and maritime emissions, which contribute 9 and 0.08 $MtCO_2eq$ since, by 2050, the vehicle fleet is electric with zero tail-pipe emissions. This includes hydrogen fuel-cell vehicles in the freight sector, which are essentially electric-drive trains. Compared to the Fossil-Car and Fossil-Efficiency scenarios, the reduction in energy demand is 48% and 35% respectively, and for emissions a reduction of 86% and 82%, respectively, would result.

The Eco-Mobility scenario, which comprises both a technological shift towards EVs and a modal shift with TOD similar to the Fossil-Efficiency scenario, results in the lowest energy demand for transport services. The energy demand totals 508 PJ with emissions of 9 $MtCO_2eq$. Relative to the Fossil-Car and Fossil-Efficiency scenarios, the reductions in energy demand are 55% and 43% respectively. The comparative emissions are similar to that of the Electric-Car scenario due to the electrification of the vehicle fleet. However, compared to the Electric-Car scenario, a reduction of 12% in energy demand results for a similar emissions profile. This is attributed to the effect of a modal shift with TOD.

Figure 17 depicts transport emissions for the Fossil-Efficiency and Eco-Mobility scenarios by sector composition in which the emissions of the Fossil-Car and Electric-Car scenarios (exhibiting similar emissions composition by sector) are also contrasted. The importance of targeting decarbonisation in both freight and passenger transport is highlighted by the measurable contribution to emissions of both sectors.

South Africa's vehicle fleet could potentially double by 2050, influenced largely by passenger vehicle adoption with low occupancy factors. Although, SADC member states would possess unique circumstances determining local private vehicle ownership, income remains a key determinant. The SADC population is likely to near double by 2050 and in line with the GESAP, economic growth aspirations would suggest an increasing motorisation rate for the region. Excluding South Africa, the entire SADC passenger vehicle fleet, estimated at approximately 5 million[80] is dwarfed by the South African passenger fleet of 7.5 million. In 2050, should the present motorisation rate (low by global standards) double, the SADC passenger vehicle fleet could quadruple and amount to either double or treble the South African fleet. This would have major implications for fuel supply and vehicle technology choices as the region seeks greater economic integration and harmonisation of vehicle emissions standards and fuel quality.

While the South African vehicle market nears saturation, SADC member states have been identified as emerging markets with most new vehicles sales occurring outside South Africa. SADC industrialisation, within the RISDP framework, could therefore include a regional expansion of the automotive manufacture and fuel supply chain. South Africa is a major global exporter of vehicles and platinum while the DRC and Zambia have global monopolies on cobalt and copper resources. The results indicate that electric vehicles (ie, battery and hydrogen fuel-cell technology), could form the basis of a regional value chain spanning both battery and fuel-cell vehicles given the regional resource endowment and manufacturing infrastructure (Figure 5). Corridor freight via road at present is the economic arterial link between member states owing to a lack of investment in rail infrastructure. The results suggest that while rail investment is an important component to reducing GHG emissions and energy consumption, road vehicles will persist, providing flexibility to the logistic sector. The span of distances between major freight hubs mimics the spatial structure of South Africa's economy and hydrogen FCEVs, in this transport segment, may complement battery electric vehicles in the vehicle fleet. The deployment of FCEVs would additionally be dependent on the pace and investment in alternative hydrogen fuels.

South Africa is a major global exporter of vehicles and platinum while the DRC and Zambia have global monopolies on cobalt and copper resources. The results indicate that electric vehicles (ie, battery and hydrogen fuel-cell technology), could form the basis of a regional value chain spanning both battery and fuel-cell vehicles given the regional resource endowment and manufacturing infrastructure

The future of crude-oil refineries is contingent on the future choice of vehicle technology. Both the Fossil-Car and Fossil- Efficiency scenarios require similar investment in the existing refineries to meet Euro 5 standards. As the largest refiner in the region, and with a switch to more fuel-efficient Hybrid-ICE vehicles, approximately only half of the existing crude-oil refineries are refurbished with the remaining capacity retired. If the economy grows

80 From an estimated motorisation rate of 16 vehicles per 1000 persons.

at an average rate of 3% over the horizon, a new refinery would be required in 2050. The capacity of the new refinery would be in the order of 300,000 bbl/day (Figure 27). Angola, which depends on oil products for more than 90% of export revenue ($41 billion in 2018) is most at risk from a transition to electric vehicles. Key markets such as China exist beyond the SADC boundaries, compounding the risk as globally electric vehicles are increasingly eroding new vehicle sales of conventional diesel and gasoline vehicles. Angola's renewable energy resources remain largely unexploited, with sizable solar resources (5%-6%) and hydropower potential (17% of large hydro) in SADC, electrification could enable economic diversification.

Regarding energy supply options for the South African transport sector, both the Electric-Car and Eco-Mobility scenarios would not need any further investment in the existing crude-oil refineries or require new capacity. Instead investment would be diverted to the power sector which would require an additional 102 TWh or 45 GW and 95 TWh or 41 GW of capacity, respectively, when compared to the Fossil-Car scenario (Figure 26). A cost-optimal expansion of the power sector would result in a rapid decarbonisation of the electricity sector post 2030 if no limitations are placed on investment in renewable energy. This would in turn facilitate the widespread adoption of EV technology with minimal impact on power sector emissions (Figure 25b). Although the emissions for the Eco-Mobility and Electric-Car scenarios are similar, the difference in energy demand, translates into an additional 7 TWh of electricity and 4 GW of supply capacity in the form of solar-PV and wind for the Electric-Car scenario in which no modal shift or TOD measures are implemented. The SAPP is dominated by South Africa's generation capacity and a future cost optimal expansion that favours renewable energy would decarbonise the grid and facilitate a green regional economic corridor.

Hydrogen as a future transport fuel could significantly displace diesel in the corridor freight fleet starting in 2030

Hydrogen as a future transport fuel could significantly displace diesel in the corridor freight fleet starting in 2030. The level of hydrogen demand is dependent on both the choice of road vehicle technology and modal shift (Figure 29). With modal shifting, hydrogen demand is displaced by electricity as rail is prioritised, whereas the non-EV scenarios, in the absence of EV alternatives, result in a preference for fuel cell vehicles in public transport. The scale of hydrogen production and associated emissions is largely reflected in the refinery emissions post 2040, when it is assumed the CTL facility retires (Figure 28).

The emissions associated with hydrogen production are due to the economic preference for natural gas as feedstock in the absence of an economy-wide emissions constraint. However, coupled with a decarbonising power sector, electricity via electrolysis would be the preferred fuel if an economy-wide GHG emissions budget is implemented. Mozambique's abundant natural gas resource may present a transitional opportunity for a source of hydrogen and act as an enabler of cleaner transport and green hydrogen. SAPP remains coal intensive with renewable energy additions not yet at scale comparable to the region's available resource. Such a strategy would align with the RISDP regional infrastructure development pertaining to oil and gas. However, in isolation, and without the strategic inclusion of Carbon Capture and Utilisation (CCU), such a path presents a high investment risk as globally, the trend of divestment from fossil-fuel and GHG emissions intensive activity gathers pace. The regional integration of infrastructure]may however offer a means to exploit the resource if considered in tandem with South Africa's synfuel infrastructure. Similar in magnitude to total transport sector emissions, the future of South Africa's CTL facility post 2040 is contentious given the high CO2 emissions intensity of its operation. Further analysis is beyond the scope of this study although it is recognised that the existing infrastructure currently provides an ideal proposition for hydrogen production and high value chemicals via CCU, perhaps providing a foundation for the establishment of the region's first green industrial estate. Based on South Africa's demand, future aviation fuel demand could account for 10-25% of total transport fuel demand in 2050. Given the nature of the synthetic fuel manufacturing process, an opportunity to extend the facility's operational life potentially exists for aviation fuel production via hydrogen and provides a means to a less disruptive transition in transport. However, it is acknowledged that the repurposing of the CTL facility requires further research beyond the scope of this study.

> The transport sector is pivotal to the industrialisation of the region via its coupling to the energy supply infrastructure and as a conduit of regional economic integration. Addressing future transport growth, the analysis has revealed that passenger modal shifting and freight road-to-rail measures are interventions of significance in reducing the energy requirement for transport in 2050

The SADC GESAP identified the poor state of existing infrastructure and need for climate resilience in future infrastructure. The continent's high susceptibility to the adverse impacts resulting from climate change[81] is a clarion call to safeguard livelihoods and regional economic prosperity. The transport sector is pivotal to the industrialisation of the region via its coupling to the energy supply infrastructure and as a conduit of regional economic integration. Addressing future transport growth, the analysis has revealed that passenger

81 Michelle Barnard, 'SADC's response to climate change – the role of harmonised law and policy on mitigation in the energy sector,' *Journal of Energy in South Africa* 25, no.1 (2014).

modal shifting and freight road-to-rail measures are interventions of significance in reducing the energy requirement for transport in 2050. Incentivising the adoption of alternative vehicle technologies is shown to be the prime lever with which to satisfy SADC's Green Transport Growth objective. Specifically, the electrification of transport in tandem with a low-carbon power sector offer the most benefit. Furthermore, while not the focus of this analysis, micromobility, in conjunction with mini-grids, is seen as a particularly attractive intervention to address both rural transport and electrification.

Author

Fadiel Ahjum

holds a BSc with Honours in Applied Physics from Murdoch University and an MSc (Eng) in Sustainable Energy Systems Engineering from the University of Cape Town (UCT). Fadiel is currently employed with the Energy Systems Research Group at UCT. His research interests include systems modelling applied to Water-Energy-Land systems and the economy wide sector coupling of transportation systems. Ongoing research includes the refinement of the group's South African TIMES model (SATIM) regarding hydrogen supply and the liquid fuels-chemicals industrial complex. Key milestones include the development of an integrated water-energy modelling framework for the World Bank's Thirsty Energy Programme. Fadiel also teaches and convened the group's MSc and Continuing Professional Development energy systems modelling course, and has consulted to the International Atomic Energy Agency regarding curriculum development for energy systems modelling.

Acknowledgement

SAIIA gratefully acknowledges the support of the Konrad Adenauer Stiftung for this publication; as well as SANEDI and Climate Transparency which facilitated the modelling analysis of the South Africa transport sector which this publication reproduces.

About SAIIA

SAIIA is an independent, non-government think tank whose key strategic objectives are to make effective input into public policy, and to encourage wider and more informed debate on international affairs, with particular emphasis on African issues and concerns.

SAIIA's occasional papers present topical, incisive analyses, offering a variety of perspectives on key policy issues in Africa and beyond.

Cover image

EV charging station (Christian Ender/Getty Images)

SAIIA
SOUTH AFRICAN INSTITUTE OF INTERNATIONAL AFFAIRS

African perspectives.
Global insights.

Jan Smuts House, East Campus, University of the Witwatersrand
PO Box 31596, Braamfontein 2017, Johannesburg, South Africa
Tel +27 (0)11 339–2021 • Fax +27 (0)11 339–2154
www.saiia.org.za • info@saiia.org.za