wattnow

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SAIEE THE OFFICIAL PUBLICATION OF THE SOUTH AFRICAN INSTITUTE OF ELECTRICAL ENGINEERS | NOVEMBER 2020

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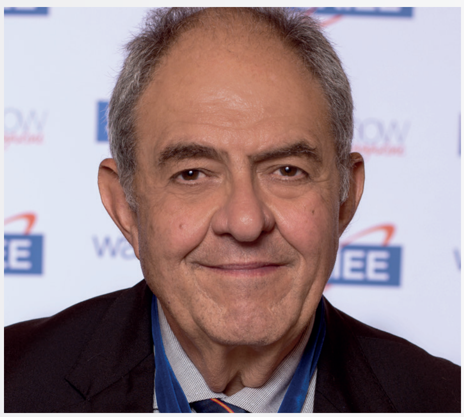

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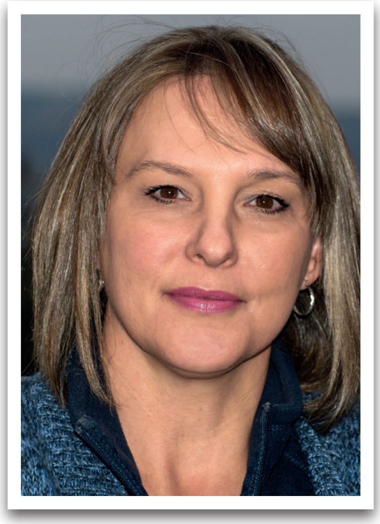

As we are nearing the end of 2020 - many of us will sigh with relief! What a year it's been - one to be soon forgotten - but will be written in history as one of the most challenging years for all - globally!

I am not going to bore you with details on why - you should know the reasons by now!

Now, because this year has thrown us into the deep-end - many companies and industries had to reinvent themselves, with all of us, working virtually has become the norm. So, has electric vehicles become the talk of the town, of late.

This issue features Electric Vehicles, and our first feature article "Powering the transforming mobility landscape", written by Ouma Bosaletsi explains that with approximately ten years of significant promotions and appealing Electric Vehicle (EV) purchase incentive schemes, EVs still represent barely 1% of the global automotive market. It could be argued that the optimistic predictions by analysts happened a bit early and that the rapid EV uptake is about to occur following the falling EV purchase price, increased drive range combined with the design cool factor. Read this article on page 34.

Page 38 features a report on "A low carbon future for South Africa", which discusses the Technical, Economic and Policy Considerations. In South Africa, the contribution of transport to national energy-related CO_2 emissions is estimated to be approximately 14%. Road transport is responsible for about 90% of transport emissions and 90% of total fuel consumption in transportation.

We also say goodbye to Dr David Proctor, who sadly passed away in September 2020. Read his obituary written by Dr Brian Austin, on page 18.

As this is the last issue of wattnow for the year, I would like to take this opportunity to thank all the contributors who made an effort in writing articles in these trying times. For those of you, who availed your time in presenting the wattnow Tech Talks - a HUGE thank you!

I wish all our members and readers a very merry festive season - until next time!

Enjoy the read!

SAIEE - reflecting on 2020

SY GOURRAH
2020 SAIEE PRESIDENT

As we draw to a close of this rather dramatic year, one tends to reflect on the economic turmoil, the hardships, the financial losses, the loss of loved ones, the lessons learnt, the opportunities that arose and many more memories of the year. We are all looking forward to an end of this unprecedented year and a well-deserved break in December.

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The SAIEE has taken the opportunities presented during 2020 to launch some fantastic leap forwards using the chance to make use of cyber technology. Our dedicated staff continue to work from home, utilising the electronic platforms that have been enhanced to support the functions of the SAIEE. Numerous Sections and Chapters have been launched during this past year with exciting webinars. Webinars are being held weekly with a range of topics, thereby allowing our members and non-members to enhance their knowledge, participate in the discussions and build new networks, both nationally and internationally. The past webinars featured experts in their fields in various formats such as individual lectures and panel discussions and will continue to do so. The webinars have been immensely valuable to the attendees as a transfer of knowledge and as being able to interact with other people during these challenging times.

The SAIEE had to reinvent itself, allowing us to increase the interaction with all stakeholders, increasing the visibility of our organisation and adding to your member benefits.

I would also like to take this opportunity to wish all our readers and their families a Blessed Christmas and a prosperous New Year. Please continue to practise safe social distancing over the festive season and stay safe.

S Gourrah | SAIEE President 2020
Pr. Eng | FSAIEE

Dear Valuable SAIEE member,

SAIEE CHARGE REWARD PROGRAMME

We are pleased to announce further information regarding the Charge Rewards Programme. As a start, the name has been finalized as the "Charge Rewards Programme", with a related awesome logo to go with it. I hope you like it! Secondly, applicable points for corresponding qualifying points accumulation and redemption events are now published.

Dating back from the 1st of December 2019, SAIEE members in good standing (fees paid in full) will be awarded their Charge points for qualifying past events. Additionally, members in good standing will be able to accumulate Charge points for qualifying events from now on. Accumulated points can be redeemed for qualifying events as published. Accrued points are valid for five years, after which they expire and a new cycle begins from a zero base.

As a member, you will receive a unique URL that will take you to your page that provides the number of points accumulated to date in due course.

Please familiarise yourself with the Charge Rewards Programme and accumulate those points! I welcome your comments/suggestions to improve the Charge Rewards Programme. Please forward those to leanetse@saiee.org.za, and let's get the SAIEE working for you!

For more information, on how this programme works, click here.

Yours faithfully,

Leanetse Matutoane
Operations Manager

CHARGE REWARD PROGRAMME

MEMBER LOYALTY

We appreciate our Member's support for 110 years

REWARD

A unique reward programme exclusive to SAIEE Members

FEEDBACK

We received your feedback and we listened to added benefits

LOYALTY CARD

Earn Charge Rewards by attending events, courses or writing articles

SATISFACTION

We want you, our Valued Member to feel satisfied when working with us

LOYALTY PROGRAM

Redeem your Charge Points towards CPD credits

QUALITY

We guarantee top quality events, courses, and services

SERVICE

We are here to serve you, our Valued Member better

RESPECT

We respect you and want to see value for your hard-earned money

SUPPORT

We are here to answer any queries you might have

For more information:

Visit your Membership Porthole on the SAIEE Website:
www.saiee.org.za

Alternatively, call Connie on 011 487 3003.

SAIEE
CHARGE
rewards programme

Annual SAIEE Awards a go...

The South African Institute of Electrical Engineers (SAIEE) has decided to host our prestigious annual SAIEE Awards evening on the 26th of February 2021, despite restrictions on gatherings and face to face engagements.

"2020 has been a year that will not be forgotten any time soon. No sooner had we tried to settle into it than COVID-19 was declared a pandemic. The resulting lockdown has had a deadly effect on the economy, not only locally but globally. Businesses have had to navigate their processes in a changing environment having to consider additional health stipulations like social distancing and PPE. Output was restricted, whilst costs escalated. Salaries were cut, retrenchments were abounding as unemployment figures soared. Bringing it closer to home, voluntary associations bore the brunt of this economic downturn as companies reviewed their policies regarding paying for employees professional associations. This dual effect has resulted in the slow collection membership fees" said Leanetse Motutoane, Operations Manager, SAIEE.

He added: *"Voluntary associations depend on membership fees for survival in providing services to their members. Amongst those services is networking, which is one of the most important benefits as a VA member. Pre-COVID-19, networking occurred naturally through organised physical events. Fast forward to now where the new normal is meetings through electronic platforms, virtual meetings and webinars kept professionals busy working from home. This too has had its downside as people have gradually become webinar-fatigued, evidenced in attendance figures thereof. Cabin fever has also crept in, to the point that everyone wants to go back to "normal".*

What is "normal" is to celebrate the achievements of our engineering professionals and, to that end, the Annual SAIEE Awards does not disappoint. This year's awards evening, which would typically have taken place in the 4th quarter of the year, will take place on the 26th of February 2021 as a physical event. It will be a welcome turn of events to celebrate these achievements in a physical format whilst adhering to the stipulations if the day."

The SAIEE EXCO has resolved to go ahead with the awards, which include the Engineer of the Year Award, the SAIEE President's Award and many others, using online nominations and virtual meetings to support judging.

"Following one of the hardest years in the history of South Africa and the SAIEE, we have not had a single physical event from my inauguration to the President's lecture to the Bernard Price Memorial lecture or even our monthly council meetings. We have not even met our new members.

As things improve we would like to connect at the annual awards evening - to honour the outstanding award recipients for their hard work, our members for their continuous support and to welcome our new members", said Sy Gourrah, SAIEE President.

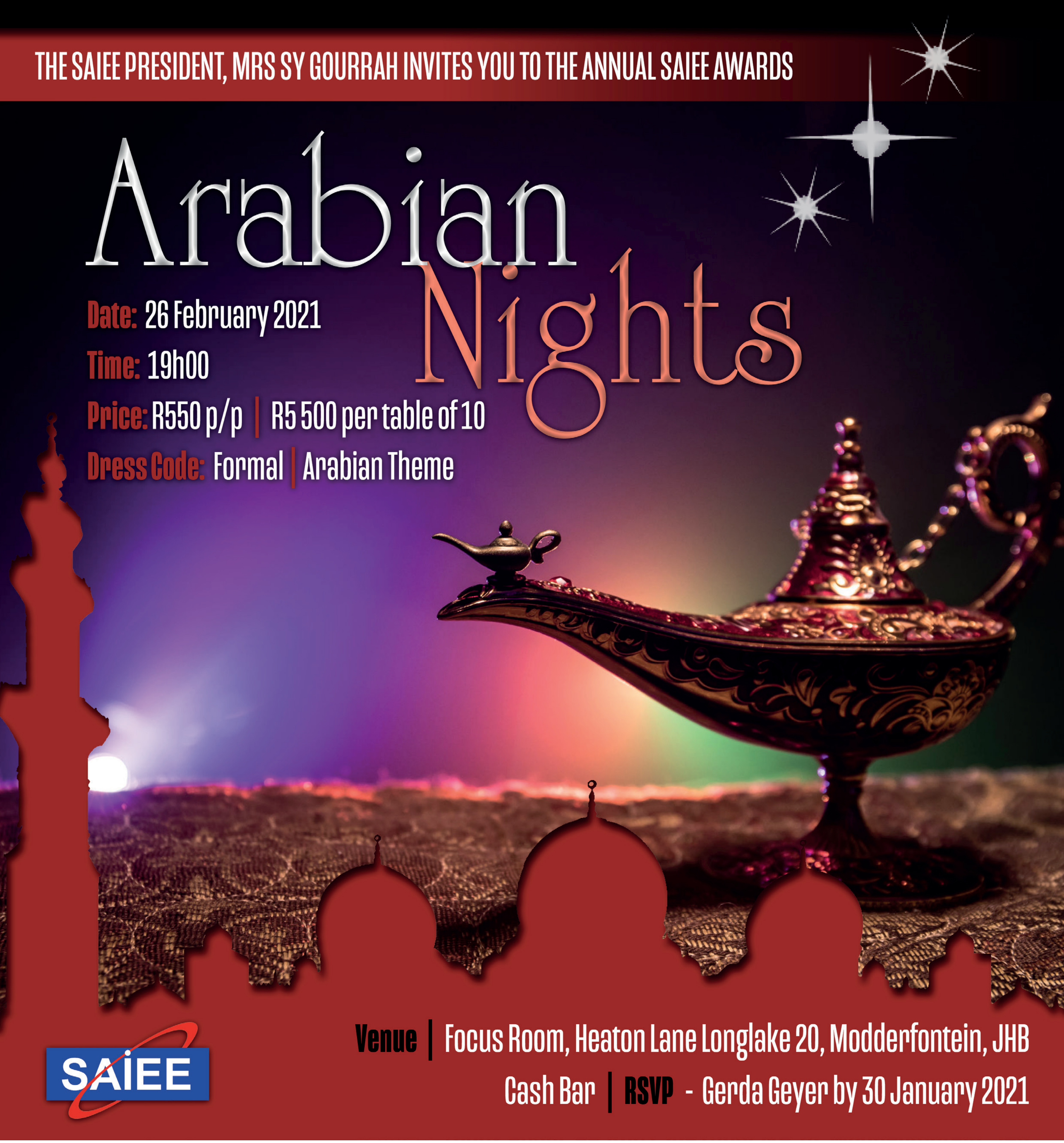
The SAIEE has called for nominations for the following awards:

SAIEE PRESIDENT'S AWARD - recognises significant current contributions in any sector of electrical, electronic, telecommunications and computer engineering in South Africa.

SAIEE ENGINEER OF THE YEAR AWARDS – recognises a member of the SAIEE who has energetically and voluntarily worked towards promoting electrical science and its applications for the benefit of SAIEE members and the Southern African community through his involvement in Institute affairs.

SAIEE ENGINEERING EXCELLENCE AWARD - recognises an SAIEE Member, Senior Member, Fellow or Council Member who has excelled in Electrical Engineering and demonstrated above-average involvement in supporting the SAIEE with its aims and objectives as well in their capacity that supports and mentors those with whom they interact in the workplace.

KEITH PLOWDEN YOUNG ACHIEVERS AWARD - recognises the most outstanding young achiever of the year in the field of Electrical/electronic engineering. Innovative, entrepreneurial action plus an infectious enthusiasm to succeed are the qualities exhibited by young achievers. Whether a Young Achiever works in large progressive companies or organisations, or smaller dynamic ones, is of no consequence – it is the spirit of achievement, creativity and leadership that count. These rare qualities must be recognised and



nurtured wherever they are found.

In 2019, the SAIEE decided to add another prestigious award to our stable, and created the **THE SAIEE WOMEN IN ENGINEERING AWARD** – recognises a female SAIEE Member, Senior Member, Fellow or Council Member who has excelled in Electrical Engineering. She demonstrates above-average involvement in supporting the SAIEE with her aims and objectives as well in her capacity that supports and mentors colleagues. Her peers and competitive counterparts have high regard for her integrity in all her engineering business dealings. This woman is a role model of the highest calibre.

NOMINATE HERE

UJ's Prof Saurabh Sinha receives highest distinction by world's largest technical professional body

Professor Saurabh Sinha, the Deputy Vice-Chancellor of Research and Internationalisation at the University of Johannesburg (UJ), has been elevated to a Fellow by the Institue of Electrical and Electronics Engineering (IEEE).

This is a remarkable achievement, as an IEEE Fellow is the highest distinction only reserved for select IEEE members in recognition of their extraordinary contributions in any of the association's fields of interest.

IEEE is the world's largest professional association for the advancement of technology, with more 400 000 members whose technical interests are rooted in electrical and computer sciences, engineering and related disciplines. Out of a membership number in over 160 countries "less than 0.1% of voting members are selected annually for this member grade elevation" (ieee.org). Apart from the technical aspect, the associated professional development reinforces the prominent role that IEEE plays to advance technology for the benefit of humanity.

Says Prof Sinha: *"Over the years, I have seen tremendous growth in IEEE activities internationally, with a particular focus across Europe, Africa and the Middle East. My focus on educational advancement lies in building technology capacity and establishing centres of excellence in partnership with professional bodies and civil society to bridge the current technology divide.*

It is with great appreciation and sincere gratitude for the confidence my peers had in me to nominate me for the IEEE Fellow status. It is a major technical and international achievement." He said the technical achievement brings forward our significant role and opportunity in the area of microelectronics education.

"As an academic, much of my contribution has derived because of working in teams of students, research fellows and others. I look forward to the continued journey and with hope to have others attain a similar status in future."

Prof Sinha is an esteemed academic having authored or co-authored over 130 publications in peer-reviewed journals, books and at international conferences. Over the last two decades, his research has been supported by the National Research Foundation, Armscor, Council for Scientific and Industrial Research, Eskom, Square Kilometre Array as well as the private sector.

In addition, he is the managing editor of the South African Institute of Electrical Engineers (SAIEE) Africa Research Journal and an active member of several professional societies. Among others, during 2014-2015, he served as an IEEE Board of Director and Vice-President: Educational Activities (VP: EA). He has been an IEEE member since 1999 and volunteer since 2002. To our knowledge, in IEEE's history of over 130 years, at the time, Prof Sinha was the first South African to serve the IEEE Board and in the role of VP.

Prof Sinha, a rated researcher (NRF) and registered professional engineer (ECSA), is also a Fellow of the South African Institute of Electrical Engineers (SAIEE) and the South African Academy of Engineering (SAAE). He is also a member of the Academy of Science of South Africa (ASSAf). wn

SAIEE WIE donates sanitary towels to the Phateng Secondary School learners in Mamelodi township

- By Maite Sako, SAIEE WIE Vice-chairperson

The South African Institute of Electrical Engineering (SAIEE), Women in Engineering (WIE) chapter launched the sanitary towels drive in July 2020 as part of their initiatives to keep a girl child at school. When the first batch was delivered on the 17th July, it was during the COVID-19 pandemic, and the girls were not at school, but the principal and staff managed to come and receive the donation on their behalf. The second batch was delivered on the 28th August 2020. To date, a total of 650 packs of sanitary towels have been donated to the Phateng secondary school.

SAIEE WIE chapter prides itself in making sure that a girl child remains in school even through their menstrual period to promote education. There is always a great need for sanitary towels, and lack thereof can impact negatively on a girl child because sometimes they have to stay away from school during their monthly period.

The principal shared a heartwarming message and highlighted that this gesture is very close to home as it reminded him of our history.

Furthermore, he indicated that some girls end up leaving school because of not having sanitary towels. Seeing SAIEE WIE donating sanitary towels to restore the dignity of our girls, it meant a lot for them. Lastly, he concluded that by taking care of our communities, we are empowering and building our nation; and in one way or the other, alleviating poverty and all the social ills that exist.

SAIEE WIE received a confirmation from the principal that the girls received the first batch of the sanitary towels on 8th August 2020 and the second batch on 22nd September 2020 respectively. This was SAIEE WIE's first project, and the SAIEE WIE team would like to say a big "Thank You" to everyone who contributed towards this initiative. Your support is greatly appreciated. wn

SAIEE
WOMEN IN ENGINEERING CHAPTER

TO JOIN OUR CHAPTER, EMAIL US.

ABB launches ABB Ability™ Safety Plus for hoists ensuring the highest level of personnel and equipment safety

Suite includes the first Safety Integrity Level 3 certified mine hoist brake system, hoist monitor and hoist protector on the market

Global technology company ABB is launching ABB Ability™ Safety Plus for hoists, a suite of mine hoist safety products that brings the highest level of personnel and equipment safety available to the mining industry.

The products include Safety Plus Hoist Monitor (SPHM), Safety Plus Hoist Protector (SPHP) and Safety Plus Brake System (SPBS) including Safety Brake Hydraulics (SBH).

Designed in accordance with the international 'safety of machinery' standard (IEC62061), the products have been independently certified by research institute RISE (Research Institute of Sweden) which works with companies, academia and the public sector in industrialization, quality assurance and certification.

ABB Ability™ Safety Plus for hoists includes the new ABB SIL 3 Safety Plus Brake System (SPBS), which is the mining industry's first fully independently certified Safety Integrity Level 3 (SIL 3) mine hoist brake system.

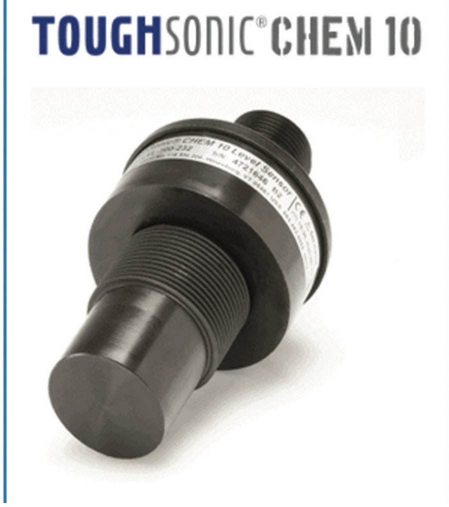
SPBS will increase the safety of personnel riding mine hoists as well as the safety of the equipment, hoist and shaft infrastructure.

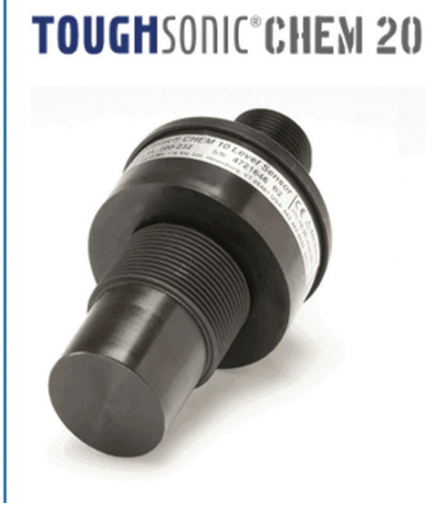
The new SPHP provides enhanced protection for the mine hoist and mine shaft infrastructure equipment.

ABB SIL 3 SPBS handles the application of the safety brakes during emergency stops and the prevention of brake lift. ABB SIL 3 SPHP monitors the speed and position of the hoists. It also monitors the instrumentation used by personnel accessing or using the hoist from different levels, for example, at gates and maintenance platforms, emergency stop buttons and remote lockout points. The ABB SIL 3 SPHP interfaces with the safety brake system to bring or keep the hoist to a safe state. It also interfaces with the drive and hoist control system.

"This is a significant milestone in mine hoist safety representing a world first for fully certified Safety Integrity Level 3 hoisting," said Oswald Deuchar, Global Product Line Manager for Hoisting, ABB. *"Labor safety is a key priority for mine operators and increasing legislation underlines this imperative. The ABB Ability™ Safety Plus for hoists suite of products, SIL 3-rated components and self-diagnostics will ensure high availability of the mine hoist while providing the highest level of safety. These products are ready-made safety solutions, which are exhaustively tested in house, and designed for tough mine environments."*

ABB offers safe, optimized and fit-for-purpose hoisting solutions designed by mining engineering teams, and has almost 130 years of experience in hoisting with more than 1,000 hoisting solutions installed worldwide, integrated with a portfolio of advanced digital services such as ABB Ability™ Performance Optimization for hoists to ensure highest availability and productivity. wn





SENIX OFFERS A WIDE RANGE OF OEM & CUSTOM ULTRASONIC SENSORS

INSTROTECH, local representative of Senix Corporation, has on offer the smart and rugged ToughSonic line of ultrasonic non-contact Distance and Level sensors, a value-add partner for the Original Equipment Manufacturers (OEM) and Custom Sensor markets.

For over 30 years, Senix has been engineering and manufacturing custom ultrasonic devices for OEM world-wide, and custom-built Level and Distance sensors in every sector. Some applications include, airports, vehicle/equipment manufacturing, food processing, nautical environments, stationary and mobile tanks, and remote monitoring locations.

Senix sensors can easily connect to common automation equipment, control relays, alarms, displays, motor controllers, and more. Senix also has LoRA wireless capabilities and cloud-based monitoring software as well as experts-on-call to work with users to tailor the right solution for specific applications.

Senix offers a robust line of ultrasonic non-contact sensors of exceptional intelligence and durability. When paired with SenixVIEW software, users can tailor these devices to each unique project to ensure optimal outcome. Over 60 parameters can be modified, including range, gain, filtering options, and control of switches and outputs.

Contact INSTROTECH, manufacturer and distributor of process control instrumentation and specialized systems - sales@instrotech.co.za

COMTEST's SPECIAL OFFER - FLUKE BUY1GET1FREE!

COMTEST, Fluke's official South African importer is offering one free Fluke for every Fluke purchased*, from any South African-based, authorized Fluke dealer. Fluke is a world-leader in the manufacture, distribution and service of electrical and industrial test, measurement and diagnostic electronic test equipment. The promotion is valid until December 31, 2020.

For further information about the offer, please view the video.
and go to COMTEST's website www.comtest.co.za for ***Terms and conditions.**

Casting of foundation WTG 6 at Roggeveld Wind Farm

CONCOR'S EXPERTISE PAVES SA'S RENEWABLE FUTURE

Concor is completing its 10th wind farm project where the majority was constructed as an engineering, procurement and construction (EPC) contractor, highlighting its niche expertise and capability in this segment.

According to Concor contracts director Joe Nell, the company has been especially busy during the fourth round of the Renewable Energy Independent Power Producer Procurement (REIPPP) programme.

"We were awarded five projects during this last round, and were able to successfully implement four of them at the same time," says Nell. "This performance is testament to our highly skilled and experienced teams on the ground, and our strong balance sheet to apply all necessary resources to each project's particular demands."

He highlights the tight timeframes in these projects, which were capable of delivering power to the national grid within two years of the project agreement being signed off. In most projects, Concor met a schedule of just 16 to 17 months, which included an initial four-month design phase.

The company's contracts began with one of the country's first wind farms – the 60-turbine project at Jeffreys Bay. More projects followed near Noupoort, De Aar and Loeriesfontein – often remote and with challenging conditions related to geology or weather. Four projects were then run concurrently – Perdekraal East in the Witzenberg district, Excelsior near Swellendam, Golden Valley near Cookhouse and Kangnas near Springbok.

"The most recent wind farm is Roggeveld, in the mountains between Matjiesfontein and Sutherland, where cold conditions and snowfalls forced the site's closure on numerous occasions," says Nell. "This created its own challenges which added to the experience of our teams."

The wind farms that Concor has constructed now contribute over 1,000 MW of electricity to South Africa's grid capacity. Nell says the company's success in these projects has been based on its corporate values: care, trust, delivery, agility and teamwork. wn

Datacentrix facilitates smooth sailing for Zutari data centre relocation

From left: Andre Naude – Network Engineer (Zutari); Cheney Harris - Project Manager (Zutari); Francois Jacobs – Business Unit Manager (Datacentrix); Stephan Botha – IT Operations Integrator (Zutari); and Andre Trouw – Cisco Network Engineer (Datacentrix).

Local engineering firm, Zutari (formerly Aurecon Africa), has successfully relocated its data centre, including storage area network (SAN), storage and server infrastructure, following the organisation's move of its Tshwane-based head office from Lynwood Manor to Newlands, Pretoria. The project, which required a tight turnaround time, was completed by Datacentrix, a high performing and secure ICT solutions provider.

COVID-19-related complications forced Zutari to place a hold on the relocation, originally planned for earlier in the year. The company was able to resume its plans in July, but the project now had to be completed within a very short timeframe to expeditiously vacate the previous office space.

There was no formal tender process for this project, explains Stephan Botha, IT operations at Zutari, but the company raised the discussion with several vendors and ultimately opted to partner with Datacentrix. "We have built a strong relationship with Datacentrix over the past two years, and knew that they could bring the requisite technical expertise, with a proven track record in relocating data centres. Other contributing factors included cost effectiveness and a detailed pre-move preparation plan.

"Essentially we ended up with a four-day window within which to relocate the data centre, including backup power equipment, to the new offices. This time pressure was considerably eased with the amount of preparation completed by Datacentrix beforehand, which incorporated rack consolidation – decommissioning old and irrelevant kit so that the number of racks to be moved was halved – and the general reorganisation of some technology," Botha says.

"We worked hand-in-hand with Zutari to complete a lot of the leg work beforehand, holding regular workshops with the client ramping up to the move," adds Deon Insel, Senior Account Manager at Datacentrix. "Having started discussions early in 2020, prior to lockdown, we were well prepared for execution when the time came. The way in which the move of the data centre was undertaken specifically was a tremendous time-saver, continues Botha. "This is where the real magic came in, with complete racks being moved as opposed to taking the equipment apart and then reassembling on the other side."

From an enterprise infrastructure perspective, Datacentrix ensured that all backups and archiving were completed prior to the move. Further, the organisation completed a network redesign for greater redundancy, including the devising and deployment of an enhanced Wi-Fi setup, as well as cabling.

From a technology perspective, the move was seamless, with users experiencing no disruption whatsoever. In addition, Zutari has seen improvement to network stability as well as greater consistency in operations, even though the new building is not as yet completed, states Botha. "The project was very competently deployed and will serve Zutari well into the future. We have built a close relationship with Datacentrix over the past few years and find the company to be an exceptional partner, one that we use as often as possible and will continue to do so."

Says Insel: "The complexity of these projects is often only visible to business when they go wrong. The fact that Datacentrix continues to deliver these in a way that appears seamless to our clients is a testimony of our strong technical capability across multiple platforms, vendors and disciplines." wn

DAVID EDWIN PROCTOR
B.SC(ENG), PHD
1932 - 2020

Dr David Proctor died in Johannesburg on 26th September 2020 of complications following surgery. He was 88.

BY DR B.A.AUSTIN

OBITUARY - DAVID EDWIN PROCTOR

Dr David Proctor:

electronics engineer, radio scientist

He had spent his career at the National Institute for Telecommunications Research (NITR) of the CSIR based, initially, on the campus of the University of the Witwatersrand ("Wits"), in Johannesburg and then at the former Observatory site in the city. Born in Johannesburg and educated at Kearsney College, a private boarding school near Durban, the young Proctor moved around the country, depending on where his father, a Methodist minister, happened to be serving at the time.

After leaving school David Proctor's interest in radio and electronics led him to work as a technician at the NITR but it was clear that he had the academic ability to attend university. However, money was tight. Fortunately, the Faculty of Engineering at Wits had had the foresight to set up a part-time process by which ex-servicemen, returning from the war, were able to complete their degrees over six years. And so, after spreading the first two years of the degree over four, while continuing to work at the NITR, he graduated with a degree in electrical engineering in 1962 and immediately became a research officer at the NITR. In 1967, at the instigation of the NITR Director Dr Frank Hewitt, who had detected UHF emissions from lightning during his own research in the early 1950s, Proctor established a new research programme with the purpose of measuring and characterising such radio emissions that occur during lightning activity. In doing this he was following in the footsteps of Basil Schonland and Dawid Malan who had made fundamentally important discoveries in the field of lightning research when based at the Bernard Price Institute of Geophysical Research at Wits many years before. Proctor's dedicated and almost single-handed research programme was to become his life's work and over the following thirty and more years he established himself as one of the leading authorities in the world in the field of lightning investigation using both radio and radar techniques.

The test site was situated north of Johannesburg at Nietgedacht. It consisted of two intersecting baselines, roughly 30 and 40 km long, at the ends of which were situated VHF (253 MHz) radio receivers with an additional one at their point of intersection. The network's purpose was to receive the sferics (lightning-induced radio noise) produced by the lightning stroke processes and from them to determine the position and other features of the emitting sources in three dimensions.

The fifth receiver provided redundancy to confirm the adequacy of the

and geophysicist

locating system. Proctor pioneered this intermediate baseline, time-of-arrival (TOA) technique, which included dedicated microwave links to feed the data directly from each receiver to the "home" station at the intersection of the two baselines.

Subsequently, for operational reasons, the observing frequency was moved up to UHF (355 MHz). The accuracy of the method depended on knowing the positions of the five radio receivers very precisely and for this purpose Proctor used a Tellurometer, the microwave distance-measuring instrument invented by Dr Trevor Wadley, also at the NITR, to fix those positions to within 10 cm.

The radio receivers, as well as most of the ancillary equipment, were designed and even constructed by David Proctor himself. In doing this he displayed his prodigious talent as an electronics engineer who was also more than a little handy with a soldering iron. At the home station, the output of each channel was displayed on two cathode ray tubes (CRTs) that operated alternately to accommodate the "flyback" at the end of each horizontal sweep. All the screens were photographed by two rotating drum cameras on a common shaft. Accurate timing was provided by a 1 MHz crystal-controlled clock.

Thus, twelve CRTs were involved, two of which were spares. As Proctor rather laconically remarked many years later, "Even those who enjoy reading records that can be deciphered easily, found that reading the more complicated variety was a mild form of torture …". He estimated that it took about one man-month's effort to locate 100 sources accurately.

A measure of the value of any research is its publication in the international scientific literature. Proctor published his first paper in the U.S. Journal of Geophysical Research in 1971. It was not to be his last. Between 1971 and 1997 he published twelve papers, all involving detailed analysis of the results obtained from that time-of-arrival network as well as from the radar system that augmented it. The radar experiments followed on from the work of Hewitt when Proctor, in the mid-1970s, pressed into service three synchronised radar transmitters, their respective receivers and their associated antennas that operated on wavelengths of 5.5, 50 and 111 cm. Their purpose was to locate the source of lightning and to measure how its properties changed according to the probing radar wavelengths.

In addition, two other radars, operating at very much shorter wavelengths of 3 and 5.5 cm, were also used. On purely theoretical grounds the longer wavelength radars were expected to receive reflections from the lightning strokes which were invisible at the very much shorter wavelengths. This proved to be the case and it confirmed that intervening precipitation was shielding the lightning emissions at that shortest wavelength. Of particular interest were the estimates Proctor was able to make of a parameter called the radar cross-section of the lightning stroke. He concluded that the radar echoes received were caused by many reflectors distributed throughout the volume of a cloud.

This work, along with that carried out in New Mexico at about the same time, is regarded as the most thorough conducted to date.

In 1986 the CSIR experienced a convulsion - and an ensuing crisis - when it was decided that all its research had to have some definable commercial objective and, even more alarmingly, that it had to be self-funding. Pure science, whose applications were undefined - and in many justifiable cases was impossible to define in those terms - was essentially doomed. As a result, the NITR ceased to exist and David Proctor was summarily transferred to a unit carrying the uninformative title of EMATEK where he soon saw his research come to a precipitate end.

However, he managed to persuade the Water Research Commission to support him and his miniscule team in a project with the objective of determining how lightning was related to precipitation while also considering lightning phenomena in their own right. In the subsequent internal CSIR report that was never published in the scientific literature because Proctor himself was required to bear the costs of publication, he was able to show, from the 773 lightning flashes measured with his TOA network, that lightning exhibited peaks of activity at two altitudes, nominally 5.3 and 9.2 km above sea-level, but with their characteristics being markedly different. In addition, his radar network mapped 658 flashes and from those results it emerged that lightning begins in regions with the highest electrical charge which is where the smallest raindrops were to be found. It was intended than an aircraft be used to fly into those parts of a cloud where lightning flashes begin in order to discover what characteristics were peculiar to that relatively small region.

Though Proctor designed the necessary equipment to do this, the six flights that were undertaken all took place on days when there were no storms! Since the aircraft was not dedicated to this project other more pressing needs always took priority when, as luck would have it, suitable meteorological conditions were just waiting to be exploited. In his closing comments to that 1993 report to the Water Research Commission, Proctor paid particular tribute to his technician, Dick Uytenbogaardt, "for his wisdom and for many hours of diligent and intelligent labour".

Whilst out in the scientific wilderness Proctor received an invitation to contribute to a book called "Handbook of Atmospheric Electrodynamics" which was published in 1995. He wrote the chapter entitled Radio noise above 300 kHz due to natural causes. He was awarded the PhD degree from Wits in 1977 based on a thesis entitled "A radio study of lightning". His last two papers were published in the Journal of Geophysical Research in 1997.

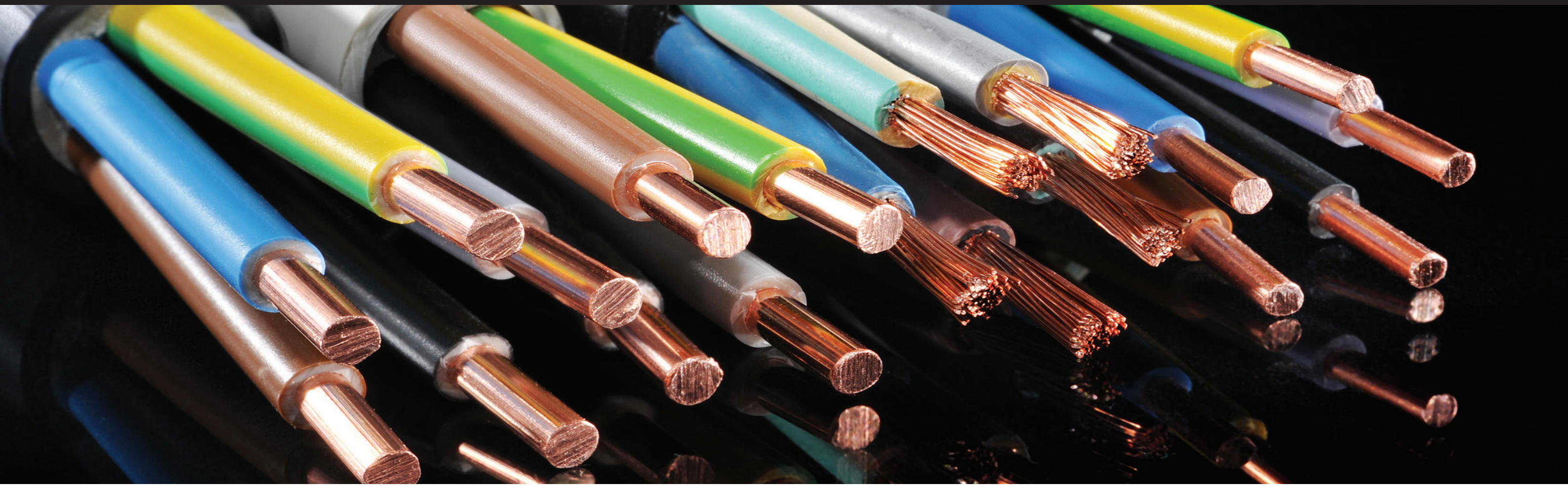
In one, he collaborated with four U.S.-based authors in comparing time-of-arrival techniques with another powerful method that used an instrument known as an interferometer to determine the features of lightning. It transpired that the two methods mapped two distinctly different aspects of the complex lightning stroke process and so were complementary. Thus, as is so often the case in scientific research, new avenues immediately opened up for exploration. Both papers bore Proctor's home address of Honeydew, South Africa, because his lifelong affiliation with the CSIR had, by then, come to an end. He had retired in 1992 while his two colleagues, who had assisted him for so long, had been retrenched by the CSIR the year before.

David Proctor had a remarkable career as an engineer, a radio scientist and geophysicist. His contributions to the understanding of the processes involved in the lightning stroke and all its attendant features was very significant and they are recognised as such among the world-wide community of scientists working in that field. His publications in the international scientific literature undoubtedly brought much prestige to South Africa

In 1963 he married Judy Stone. They had four sons, all engineers. wn

Copper Development Association Africa

Promoting the use of copper in Africa



Copper is found in all Energy Systems

Whether powered by sun, wind or water, efficient and renewable energy systems rely on copper to transmit the energy they generate with maximum efficiency and minimum environmental impact.

Superior conductivity of copper and recyclability

Copper is a preferred electrical conductor and an excellent thermal conductor. Superior conductivity allows smaller conductors to be used, saving space and cost.

Copper is infinitely recyclable without any loss of performance and is nearly indistinguishable from freshly mined copper. It is estimated that 80 percent of all copper ever mined during the past 10,000 years is still in use somewhere today. Estimates also reveal that 33 percent of today's world annual copper demand is supplied by recycled copper.

Copper's contributions towards reducing greenhouse gas emissions

Increasing the cross section of wires and cables, overhead railway lines, and motor and transformer windings can significantly increase electrical energy efficiency. Incorporating one extra kilogram of copper can save between 100 and 7,500 kilograms of greenhouse gas emissions (CO_2). Every conductor in an electrical system has a built-in resistivity. This means that part of the electrical energy it carries is dissipated as heat and lost as useful energy. Generating this wasted electrical energy produces carbon emissions and consequently contributes to global warming. An important initial decision, in seeking to reduce these losses, is to use copper as the conductor.

Renewable energy

Copper plays an important role in renewable energy systems. By using copper instead of other lower electrical energy-efficient metal conductors, less electricity needs to be generated to satisfy a given power demand.

Copper has long been used in solar heating/hot water systems, where it is commonly used in heat exchangers. Now, it promises to become equally valuable in photovoltaic (PV) and wind systems.

Longer-term programmes, such as wind powered production processes and the electrification of thermal processes, are less certain and will require economic incentives and significantly more development to build technical viability. However, in light of the very large savings potentials, close to 300 million tonnes of CO_2 per year, they are worthy of further investment and investigation. It should be clear then that CDAA shares the European Copper Institute's vision for a low-carbon economy and will pursue it with all of the resources at its disposal. We urge policymakers to support a reasoned balance between the energy needed to manufacture the building blocks of that new economy and the overarching goals for reduced energy demand and carbon emissions.

The CDAA and ECI role in reducing energy consumption

The CDAA and European Copper Institute have developed strategies that will both trigger and support substantial carbon reductions in the downstream industrial, residential and service sectors.

Electric motors account for a large amount of the electricity consumed by industry. Energy-efficient motor driven systems could save electricity consumption, resulting in reduced maintenance, improved operations and reduced environmental costs.

Cable size is very important for the correct operation of any electrical circuit. Selecting too small conductors for an application could compromise the operation of the circuit: it causes voltage drop, poor performance and in extreme cases the cable temperature will increase enough to melt the insulation. On the contrary, selecting too large conductors increases costs and weight. Please view Leonardo ENERGY's website for courses offered:

http://www.leonardo-academy.org/course/index.php?categoryid=72

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SAIEE Central Gauteng Centre donates to grade 12 learners in Gauteng

When the South African President announced that the country would go into alert level 5 lockdown the morning of the 27th March 2020, everything that we knew changed completely. That was the beginning of the new normal that we find ourselves in 8 months later. Since then, the year 2020 has been challenging for all, there was a paradigm shift in the education structure as online learning was introduced, and working from home became the new normal for most employees.

BY NEO MAPAPANYANE

With strict lockdown restrictions of wearing face masks in schools, this became a severe burden on some parents who barely could afford more than one mask per child, especially for those who have learners attending school daily. SAIEE Central Gauteng Centre (CGC) took upon themselves to help parents by donating face masks to the grade 12 learners in four different schools in Gauteng. This was our pay-it-forward initiative.

On the 2nd November 2020, SAIEE CGC Corporate and Social Investment (CSI) team led by Neo Mapapanyane visited Olievenhoutbosch secondary school in Centurion. The CSI team donated more than 100 face masks and sanitary towels to all grade 12 learners who were at school on the day. This included learners both in the General, and Mathematics and Science streams. After that, the CSI team spoke to all the grade 12 learners encouraging them to do their best in the upcoming exams. The message of the day was mainly on encouraging learners to live a purpose-driven life, have a vision board and always get rid of all distractions as they are severe thieves of time. The challenge that we encountered was that they do not have a school hall. Consequently, we had to go to every class to give them the masks we brought. But, this was managed effectively.

The second school that we visited was Dr WF Nkomo in Attridgeville on 4th November 2020, where we donated face masks and sanitary towels to 9 learners who are in the Mathematics and Science stream. The first question we asked them was, what would they like to be in life and all of them answered, architect, electrical engineer, dietician and mechanical engineer, to name a few. This group was very disciplined, motivated, and enthusiastic. There was a fantastic learner, Raisibe who said she plans to study Electrical Engineering in the future. Raisibe shocked us when she explained how she charges her cellphone battery from the kettle element. Her passion for engineering is astonishing. During her spare time, she enjoys fixing broken electrical appliances at home. She is one of the learners who applied for the Matrics in Antarctica competition, and if all goes well, next year January she will be heading to Antarctica. So, Matric in Antarctica is a competition where five matric students from the class of 2020

will be selected to go on an educational adventure. The other learner aspires to be one of the few to design and build something on the moon.

Thoko Thaba secondary school in Thokoza was the third school that we visited. The SAIEE CGC members donated 50 face masks and sanitary towels to the learners. As we did with other schools, we prepared a brief and powerful message of encouragement as they have started with their final exams. The message of the day began with a personal exercise where they had to answer these two questions: What is it that I want in life? And how bad do I want this? The response was encouraging and a few shared with us their plans for next year. However, there are still learners who are already in grade 12 and still uncertain about their plans after matric. It shows that there is still so much work that we still need to do. We are living in the times where you think the information can easily be accessed and young people should be informed and knowledgeable. But, this is not the case in most places. Unfortunately, there are still a few learners who do not know what they would like to study, where they will be studying, how to apply online and that they should apply before the end of September of their final year in High School. For this reason, the CSI team committed to go back to the same schools the following year and make sure that from the beginning of the year, the grade 12 learners are informed about any they need to know before they apply.

The last school we visited was Phateng secondary school in Mamelodi. The SAIEE Women in Engineering partnered with SAIEE CGC CSI team to donate 20 face masks and sanitary towels to the learners that they are mentoring.

We shared the following message with them:
Embrace your inner sparkle. Embrace and love yourself exactly the way you are. Maya Angelou said "You alone are enough. You have nothing to prove to anybody." Embrace your background, your family and your roots, no matter the looks because that's your foundation and that's what makes you be you.

Life is not a competition, but it is a journey. Embrace your journey with all its difficulties and make sure that you make it great. Do not let the noise of other's opinions distract that. Write your vision down and do your best maximize your capability to make that vision a reality. Be willing to sacrifice your time, fun, sleep and create a future for yourself.

Our objective was to donate essential items that the class of 2020 need the most, face masks for all and sanitary towels for the girls. By the 13th November 2020, we managed to donate at least 179 face masks and 144 sanitary towel packs. Furthermore, we shared motivational and personal stories of our very own SAIEE CGC members: Mrs Neo Mapapanyane, Maite Sako, Thabiso Modikgetla, Christina Mohloki, Mantsie Hlakudi and Mr Teboho Machabe and Pascal Motsoasele.

As SAIEE CGC committee we would like to wish the class of 2020 all the best in their exams and their future endeavours. The year 2020 has never been easy, but we know that they will make it! wn

To join our centre, email us.

Large Customised Genset for Platinum Mine

Craig Bouwer, Projects and Product Manager for generator sets at Zest WEG.

Accommodating the space constraints of a South African platinum mining customer, Zest WEG is constructing a large diesel powered generator set to be delivered later this year.

The capacity of the 2,500kVA genset will also make it the largest unit yet to be fully load-tested at the company's genset manufacturing facility in Cape Town, according to Craig Bouwer, projects and product manager at Zest WEG.

"In addition to functional testing, we will be equipping ourselves to conduct load testing to 11kV on this unit," says Bouwer. *"With load-banks in-house, we will be stepping the voltage down to 400V during the testing, and drawing on MV specialists to ensure a safe and reliable process."*

The genset is a highly technical solution to match the customer's specific needs, he says. Based on the available space, it is housed within a 12 metre ISO shipping container with the electrically-driven radiator mounted on the roof.

Prime-rated at 11kV and powered by an MTU diesel engine, the genset has been designed in close consultation with the customer over a number of months. Having concluded the engineering design, construction is currently underway in Cape Town. Bouwer highlighted the detailed and time consuming nature of engineering design for a project of this magnitude and complexity.

"Stringent technical requirements demanded lengthy and ongoing collaboration not only with the customer, but between our engineering team and production operations," he says. *"The customer was particularly pleased with our flexibility and the extra effort we applied to ensure the optimal technical returnables for the project."*

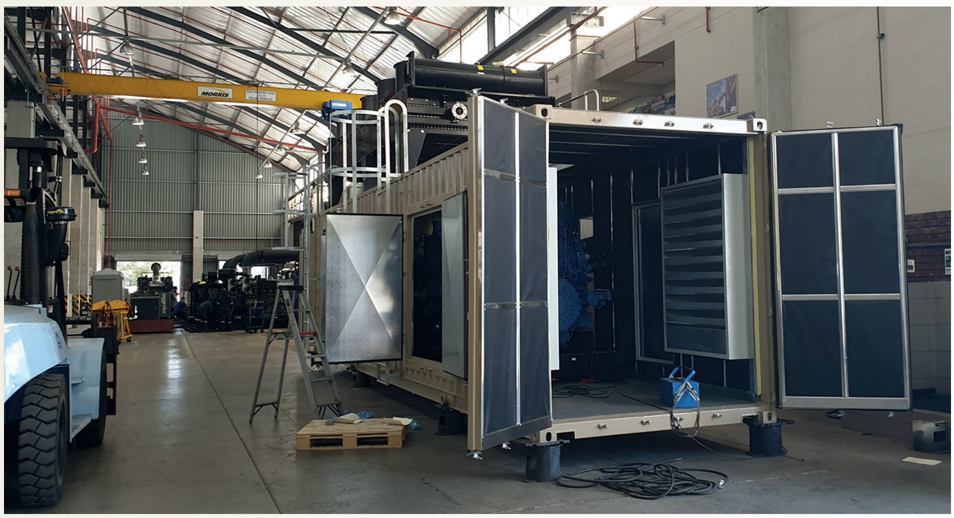
As one of the few Original Equipment Manufacturers (OEMs) capable of undertaking a customised genset of this capacity in-house, Zest WEG will also be supplying the control and protection panel from its extensive range of electrical equipment and products.

"To enhance safety and ergonomics, the control panel is in its own compartment within the ISO container," he says. *"A 1,000 litre bunded day tank has also been installed inside a separate compartment within the container, including a fuel cooler and filtration system."*

After engine has been positioned within the container and silencer mounted on the roof of the Zest WEG genset solution.

The WEG MV alternator, in front, coupled to the diesel engine.

The Covid-19 lockdown has had minimal impact on the work schedule, he notes, as planning and communication with the customer could continue regardless, dealing with various technical clarifications. To facilitate the transportation of this large unit to site, it will be shipped as three separate components: the genset, radiator and exhaust system. Once installation is complete – a process that Zest WEG specialists will supervise – its experts will conduct the cold and hot commissioning, and hand over to the customer. wn



During fitment of the engine and alternator within the generator enclosure at Zest WEG's local manufacturing facility.

Table top radiator with diesel engine coupled to WEG alternator.

SAIEE launches Entrepreneurship & Innovation Chapter

South African Institute of Electrical Engineers – Entrepreneurship and Innovation chapter launched on the 16 November 2020 during the Global Entrepreneurship Week.

The goal of the launch was for investors, government associations, business leaders and experts to join us as we shape up our economy with the aim to create employment. We are also calling on small businesses, students and individuals with great ideas to join us and become members so that you can benefit from the opportunities.

The event was opened by SAIEE's President Sy Gourah who gave an inspiring speech encouraging entrepreneurship and innovation. We had an amazing line up of local and international speakers who spoke on the following topics, Innovation & Skills Development for African SME's, Managing & Leveraging on Intellectual Property, Global and Local Investment Opportunities.

The aim of SAIEE EIC is to provide the best knowledge-driven innovation and entrepreneurial support for sustainable rapid economic growth for all. EIC will provide support at all levels of innovation, entrepreneurship, and successful running of businesses. EIC believes that the real work of innovation begins when they start implementing the desire to lead innovation in their respective endeavors.

Thank you to our partners, ESI Africa, Initiate and SAIEE wider community for support.

Our distinguished speakers included the following: Sandra Baer, Ms Thembile Ndlovu, Andre Hoffmann, Prof Cavin Mugarura, Dr Ernest Bhero, McKevin Ayaba, Eric Proudfoot, Sifiso Ndwandwe, Farouk Khailann, Cornelius Wicks, Mr Kganki Matabane and Yolanda Mabuto SAIEE Chairperson.

To watch the recording of the webinar, click here. wn

THE SAIEE ENTREPRENEURSHIP & INNOVATION CHAPTER

2020 LEADERSHIP

YOLANDA MABUTO
CHAIRPERSON

Founding Director: Divaine Growth Solutions & Globe International Partner
World Business Angel Investment Forum Member
BRICS Energy & Green Economy Director African Continent
WWCA African Ambassador | WEF

DR ERNEST BHERO
VICE-CHAIRPERSON

Professional Engineers (Electronics)
Advocate - High Court of South Africa

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University of Johannesburg

PALESA MORABE
MARKETING CO-ORDINATOR

Founding Director PALS Empowerment Solutions
Principal Associate: Future Leadership
SME & Skills Development Specialist

OUR VISION

Providing the best knowledge-driven innovation and entrepreneurial support for sustainable rapid economic growth for all, with due cognisance of previously disadvantaged groups and youth.

OUR MISSION

Entrepreneurial & Innovation Chapter (EIC) provides competitive advantage to its members and assurance to its stakeholders through the provision of timely knowledge-driven advice and exchange of information as well as wide-ranging and in-depth training. With a diverse pool of experienced mentors, and symbiotic partnerships, IEC will provide support at all levels of innovation, entrepreneurship, and successful running of businesses that will last for generations.

We call on any interested parties, who are members of the SAIEE, to join our chapter. Send a photo and your CV to entrepreneurchapter@saiee.org.za

Jaguar Land Rover's Pivi Pro infotainment system recognised by AUTOBEST awards

Jaguar Land Rover's new Pivi Pro touchscreen infotainment has been recognised by the prestigious motoring jury AUTOBEST, receiving the SMARTBEST 2020 award dedicated to the best connected technologies in the industry.

Jaguar Land Rover's new Pivi Pro touchscreen infotainment has an industry-leading design and shares electronic hardware with the latest smartphones.

The fast-responding and intuitive Pivi Pro system allows customers to make full use of Software-Over-The-Air (SOTA) technology, without compromising its ability to stream music and connect to apps on the move.

The always-on and always-connected Pivi Pro set-up sits at the heart of Jaguar and Land Rover models and its high-resolution touchscreen allows customers to control all aspects of the vehicle using the same processing hardware as the latest smartphones. In addition, customers can connect two mobile devices to the infotainment head unit at once using Bluetooth, so the driver and passenger can enjoy hands-free functionality concurrently without the need to swap connections.

AUTOBEST Chairman Dan Vardie said: *"This is one of the most ambitious prizes we offer, dedicated to the best connected technologies we have in the industry. This year, Pivi Pro proved to be unchallenged by any of the competitor's on-board connected technology, not to mention the simplicity in operation as the driver can focus on driving. Access to 90 per cent of commonly used functions from the display with a maximum of two clicks."*

Peter Virk, Director of Connected Car and Future Technology for Jaguar Land Rover said: *"Pivi Pro is testament to the incredible work within our software engineering teams and we're delighted to have been recognised with this award. With one Long Term Evolution (LTE) modem and eSIM dedicated to the Software-Over-The-Air (SOTA)*

technology and the same set-up looking after music streaming and apps, our latest cars have the digital capacity to keep customers connected, updated and entertained at all times anywhere in the world. You could liken the design to a brain, with each half enjoying its own connection for unrivalled and uninterrupted service. Like the brain, one side of the system looks after logical functions, like SOTA, while the other takes care of more creative tasks."

To enable almost instantaneous start-up, Pivi Pro has its own dedicated power source, so navigation is ready as soon as the driver is behind the wheel, while the embedded apps available – including Spotify, Deezer and TuneIn – provide full functionality even without your smartphone. Further connected features include Google and Microsoft Outlook calendar integration which enables the driver to view work diaries and even join important calls through the hands-free system. Meanwhile, weather at destination gives a forecast depending on the route entered in the navigation system.

Pivi Pro connectivity is provided by the latest dual-sim technology with two LTE modems enabling the system to carry out multiple functions at the same time, such as streaming media and downloading SOTA updates, without compromising performance. The cutting-edge connectivity also ensures minimal interruptions caused by coverage blackspots as it roams across network providers for the strongest signal.

Advanced SOTA connectivity enables customers to download and install software updates without having to visit a Jaguar retailer. Updates are downloaded in the background, with customers notified by an alert detailing the key changes. For updates that require the vehicle to be switched-off, customers can schedule a convenient time for installation.

Pivi Pro infotainment is available on a range of Jaguar products including F-PACE, E-PACE, I-PACE, XF and XE. For Land Rover products, the system is available on the New Land Rover Discovery, Land Rover Discovery Sport, Range Rover Velar, Range Rover Evoque and Land Rover Defender.

Although electric vehicle (EV) prices have decreased in the last few years, most still remain unprofitable for manufacturers, as EV production costs are exorbitantly high compared to cars powered by internal-combustion engines.

Consumers now pay significantly less for electric cars

BY: SIBAHLE MALINGA
ITWEB SENIOR NEWS JOURNALIST

This is one of the key findings of a new report from research firm Lux Research, titled "The Electric Vehicle Inflection Tracker: 2020 Edition". According to the report, consumers who buy EVs now, are likely to pay significantly less than they would have three years ago; however, this means many vehicle manufacturers are still not making any profit from sales, with some even losing money.

The research found that an average manufacturer's suggested retail price for a battery electric vehicle (BEV) declined to $33 901 in 2019 compared to $42 189 in 2016.

With the automotive industry being under pressure to reduce emissions, both from government regulations and from consumers who are growing more environmentally conscious, government policies, market expansion and the global economic downturn are among the reasons EV prices have declined.However, automakers could continue losing money from sales, unless certain elements are addressed, according to Lux.

Although many consumers are open to considering a plug-in vehicle for their next purchase, today, these vehicles remain less than 5% of overall sales. Those hesitant often cite concerns like limited range, slow charging and the higher price tag. The good news, according to the Lux research, is that most of the automakers' attention has been focused on making EVs that are profitable while addressing consumer pain points related to charging speed and range anxiety.

"Nearly all automakers now sell some form of BEV, so the focus has shifted to making them profitable," says Lux Research senior analyst and lead author of the report, Christopher Robinson.

"Consumers want to know how far can this electric car go and what will it cost? Fortunately, BEVs are consistently making progress on how far they can go, with the average range now 230 miles [370km]. Since 2011, range has consistently increased, with a CAGR of 13.7%."

As automakers continue to improve charging speed and minimise battery size, more consumers are expected to seek out EVs. Lux's long-term EV forecast projects it will take until between 2035 and 2040 for electric vehicles to make up more than half of all vehicle sales.

China remains the largest market for plug-in vehicles and has a unique BEV

ecosystem where models tend to be cheaper than in other markets.

The 10 models which provide the lowest cost per range are all China-specific models, with EVs from GAC, Hyundai, Kia, Chery and Chana reported as the most efficient vehicles in the country.

ADDRESSING PAIN POINTS

The high production costs of EVs primarily come from the batteries, which use raw materials as well as the expensive processes involved in battery production, notes the report.

Lux believes automakers should focus on their battery supply chain: battery shortages have already caused some automakers to reduce their BEV production plans. To fix this issue, which will only be exacerbated over the next few years as more electric vehicles come to market, automakers should secure raw materials like cobalt and lithium for their future vehicles.

In response to addressing some of the consumer pain points, electrified powertrains (the components that generate power) are a promising avenue to reducing or eliminating emissions from vehicles, according to the report.

Electrified powertrains make up a range of options, including lower-cost hybrid vehicles (HEVs), which use a battery to harness energy normally lost during braking BEVs, which are solely powered by electricity, and plug-in hybrids, which can be used in both ways. Among these powertrains, BEVs are seeing the most significant growth.

Currently, BEVs are more expensive and less convenient to use than their non-electric counterparts, but Robinson is of the view that technology will continue to close this gap.

In the near future, efficiency, front and centre will be the next major focus of BEV design, with automakers either downsizing packs to increase profitability or offering more range.

"We've seen a large focus on electrifying high-priced brands. This is because luxury brands offer vehicles at higher price points and are able to absorb the additional costs of the battery pack," adds Robinson.

"This is also partly due to the need to offset higher emissions of their larger internal combustion engines, which cause more emissions due to their vehicles being larger and more powerful." wn

Ground-breaking study charts future of electric vehicles in South Africa

Is South Africa ready for electric vehicles (EVs)? A study released in October reveals some fascinating insight into the future of these vehicles in the country.

The 2020 South Africa EV Car Buyer Survey complements the recent report published by the Department of Trade, Industry and Competition (DTIC) and the National Association of Automobile Manufacturers of South Africa (Naamsa).

The full findings of the survey were revealed at the Smarter Mobility Africa event on Wednesday 28 October 2020 by AutoTrader CEO George Mienie.

CONSUMER PERCEPTION VS INDUSTRY ASSUMPTIONS

According to Mienie, South Africa is still in the starting blocks when it comes to EV adoption – with only 2% of consumers owning an EV and 13% having driven one.

"The hope is that these insights lead to a tomorrow that is greener, cleaner and mutually beneficial to the automotive industry, and most importantly, the South African car buying consumer," he explained.

So, exactly how do consumers feel about EVs? The 2020 South Africa EV Car Buyer Survey yields some interesting results.

For instance, there is still a certain level of anxiety surrounding EVs.

CHARGING INFRASTRUCTURE AND TIME

"61% of respondents cited charging infrastructure as the biggest disadvantage of electric vehicles while 60% of respondents also believe charging time is a major disadvantage," revealed Mienie.

'RANGE ANXIETY'

Surprisingly, only 26% of respondents reported that "range anxiety" was a major disadvantage (previously this has been the most significant concern).

However, respondents were quite insistent that they would only purchase an EV with a relatively high range.

"A total of 39% of respondents said that an electric vehicle needs to have a range of 300 to 500km for them to

consider purchasing one. On the other hand, 44% of respondents said that they required more than 500km of range," says Mienie.

PURCHASE PRICE

Yet another major concern of consumers in the past has been the relatively high purchase price of EVs – but this is now less of an issue.

"In fact, 67% of respondents stated that they would be willing to pay more for an EV upfront, given that running costs were lower than a petrol/diesel vehicle," says Mienie.

POSITIVE FUTURE OUTLOOK FOR EV SALES

Most significantly, the majority of respondents – a meaningful 68% – said that they were 'likely' or 'very likely' to consider purchasing an EV in the future. Only 7% of respondents stated that they were 'unlikely' to consider purchasing an EV in the future.

"We're not talking about EV purchases in the distant future either. 74% of respondents stated that they would purchase an electric vehicle within the next five years," Mienie reveals.

Those consumers are most likely to purchase a BMW, Tesla or Mercedes-Benz EV (even though Tesla isn't currently available in South Africa).

"Over half of the respondents – 56% to be exact – trust BMW the most, 42% of respondents selected Tesla as the brand they would trust most while 36% of respondents selected Mercedes-Benz," said Mienie. wn

The 2020 South Africa EV Car Buyer Survey report is available for free, here.

Powering the transforming mobility landscape

With approximately 10 years of significant promotions and appealing Electric Vehicle (EV) purchase incentive schemes, EVs still represent barely 1% of the global automotive market. It could be argued that the optimistic predictions by analysts happened a bit early and that the rapid EV uptake is about to happen following the falling EV purchase price, increased drive range combined with the design cool factor. The expected growth in the EV market could present a strategic opportunity for power utilities to increase electricity sales and facilitate the integration of renewable energy resources.

BY I OUMA ET BOSALETSI I MSAIEE

Additionally, by accurately characterizing the exploitable flexibility from a population of EV batteries, EVs can provide ancillary services such as voltage and frequency regulation, that will help maintain the power quality and balance the grid. Power utilities therefore need not to passively wait for motorists to begin plugging in rather than filling up their vehicles.

Although the uptake is low in South Africa, the charging demand will be significant on the low voltage (LV) network if EVs clustered in one area charge simultaneously from the same local distribution LV network. EV load is flexible and potentially controllable. By optimally managing the EV load, the power utility may flatten the local demand profile by shaving peaks (that is EV charging prevented when the other local demand is high), filling valleys (that is EV charging encouraged when the other local demand is low) and allowing efficient use of excess available energy generated from renewable energy resources. Power utilities can support

the uptake by preparing to manage and control new EV load through smart grid technologies (i.e. smart meters, automation and analytic systems) and cost reflective electricity rates.

PREPARING TO MANAGE EV LOAD

Distribution networks will be impacted differently depending on the existing local distribution network rating, penetration and distribution of EVs, charging management procedures, charging behaviours and driving profiles. If power utilities are able to shape and manage the EV charging requirements as EVs are connected to the grid, EVs can potentially serve as a viable resource to the power grid while enabling EV owners to derive additional value from their vehicles. To unlock these benefits, power utilities can take the following steps, if they have not already done so:

- Develop electricity tariffs that incentivize off-peak charging
  Power utilities should consider designing electricity rates that encourage EV owners to charge during off-peak hours. The application of time-of-use energy prices make it cheaper to consume energy during off-peak hours and could potentially lead to consumers shifting their charging activities to off-peak periods and thus delaying the investments in additional network capacity.
- Offer green charging plans
  Renewable energy resources are self-dispatchable energy resources in that they cannot adjust the time of energy generation to the overall

energy demand. When operating at its maximum, renewables can generate more electricity than consumed onsite with the surplus electricity exported to the electric grid. To minimize renewable energy generation curtailment in hours when excess power is generated relative to the local demand levels, their variable generation behaviour can be supplemented with EV to effectively absorb the generated energy. In areas where excess renewable energy is generated during off-peak hours, power utilities can offer customers low charging rates.

- Innovate smart charging solutions
  By designing a platform to engage EV owners and coordinate their charging activities, power utilities may see EV charging as a potential benefit to the power grid. The platform may enable EV owners to set charging preferences, receive price signals and grid support requests, receive notifications on their vehicle's state of charge and locations of available charging stations. In this way power utilities can modulate the power flows between the EVs and power grid to balance the grid and improve power quality.
- Develop new grid services
  EVs have been identified as potential candidates to deliver ancillary services and demand side management since they have battery storage and their energy consumption can be shifted in time. This may require increased EV penetration scenarios, smart meter deployment or additional smart grid technology capabilities. The developed market structures will enable EV owners to derive additional value from their vehicles from payments received for demand response, delivery of ancillary services and other grid services.

In conclusion the power utility's role is integral to the rise of EVs. Further acceleration of EV adoption will resolve some of the power utilities challenges such as stagnant demand and requirements to integrate renewable energy resources. In addition EV batteries can potentially assist in balancing the grid and improving operating efficiency. Therefore by preparing to manage EV load, power utilises can help enable the increased penetration of EVs while at the same time secure its own role in powering the EV demand. wn

This paper is part of the efforts of the Climate Transparency Initiative, an international partnership of 14 research organisations and non-governmental organisations (NGOs) analysing G20 climate actions. It is part of a series examining the status, opportunities and challenges in decarbonising the transport sector in G20 countries.
Other papers on this topic can be downloaded from the Climate Transparency's website.

In South Africa, the contribution of transport to national energy-related CO_2 emissions is estimated to be approximately 14%. Road transport is responsible for approximately 90% of transport emissions and 90% of total fuel consumption in transport.

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A LOW-CARBON TRANSPORT FUTURE FOR SOUTH AFRICA:

TECHNICAL, ECONOMIC AND POLICY CONSIDERATIONS

The population, currently at 57 million, is projected to reach 75 million by 2050. An increasing motorisation rate along with a defection from public transport is evident. If South Africa achieves high economic growth rates without low carbon and resource efficient alternatives, transport energy demand and emissions will grow to 2050. The sector could become the largest emitting sector by mid-century.

It is therefore imperative to decarbonise the transport sector if South Africa is to reach its Nationally Determined Contributions (NDC) in accordance with its commitment to the Paris Agreement.

TRANSPORT IN SOUTH AFRICA IN 2050

A least cost optimisation modelling framework of the South African economy was used to contrast four potential transport pathways to 2050. The analysis considered future road vehicle technology pathways and policy levers targeting modal shifts and

GLOSSARY

BRT Bus Rapid Transit

CF2 Clean Fuels (Phase) 2

CTL Coal-To-Liquids

EV Electric Vehicle

GHG Greenhouse Gas

GTS Green Transport Strategy

HFCV Hydrogen Fuel-Cell Vehicle

HCV Heavy Class Vehicle (e.g. truck)

ICE Internal Combustion Engine

LCV Light Commercial Vehicle

MCV Medium Class Vehicle (e.g. light delivery trucks) Mt Mega-ton

NATMAP National Transport Masterplan

NDC Nationally Determined Contribution

PA Paris Agreement

P-KM Passenger-Kilometre

SATIM South Africa TIMES Model

SYNFUEL Synthetic Fuel

T-KM Tonne-Kilometre

TOD Transit Oriented Development

V-KM Vehicle-Kilometre

a reduction in motorised travel (see Figure 3). The findings show that:

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 an ICE vehicles.

The purchase cost of an EV is the key barrier to widespread adoption. Policy incentives to reduce the cost of ownership of EVs should therefore be prioritised with public-private participation targeting public transport.

A large electric vehicle fleet leads to a 20% increase in electricity demand by 2050. The corresponding investment in power generation replaces needs to upgrade existing refineries to improve fuel quality. No additional investment in new crude-oil refinery capacity would be warranted.

In the context of South Africa's NDC, an electric vehicle fleet, with zero tail-pipe emissions, potentially provides for a more equitable decarbonisation of the power sector by allowing the extended operation of existing coal plants in the near term. The increase in emissions from the power sector are balanced in the long term (2040-2050) by a zero GHG emissions road fleet.

Corridor freight heavy vehicles present an opportunity for a hydrogen supply chain in South Africa. Hydrogen as a transport fuel mainly replaces diesel in the corridor freight fleet. The level of hydrogen demand is dependent on both the choice of road vehicle technology and modal shift accounting for 6% to 17% of total vehicle-kilometres driven in freight road transport.

Shifting road vehicle-kms to rail is key to achieving substantial energy savings. A low carbon and functional transport system should therefore include public transit at its core, with rehabilitation of the rail system a priority. A backlog of road maintenance exists and, excluding urban roads, is estimated to cost R417 billion (Townsend and Ross 2018). A continued reliance on road vehicles will require additional revenue for both new road capacity and functional maintenance.

South Africa's Green Transport Strategy (GTS) is the current policy roadmap for informing low carbon transport policy in South Africa; and should therefore strive for a coherent and consistent approach to address emissions mitigation. The GTS promotes low carbon alternatives but potentially counterproductive measures are tabled which may defer or avoid investment in zero GHG emissions alternatives due to the likelihood of technology and supply chain infrastructure lock-in.

A transition to a low carbon and energy efficient transport future would result in disruptions to the existing liquid fuel supply chain. An implementation strategy spanning provincial and municipal boundaries is necessary to: minimise the disruption associated with restructuring of the fuel supply industry; and facilitate urban planning that promotes public transport and non-motorised travel. This requires streamlined vertically and laterally integrated development frameworks that conform to the strategic national objective of an affordable low carbon and energy efficient transport system. Key objectives for an ambitious transition in transport as indicated in this study are summarised in Table 1.

1. 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" (Paris Agreement Article 2.1 (a)). In the same decision (1/CP.21), countries requested the Intergovernmental Panel on Climate Change (IPCC) to produce a special report on the impacts of global warming above 1.5°. In response, in 2018 the IPCC produced the Special Report on Global Warming of 1.5°. The Report makes it very clear that a) we are already facing climate impacts; b) that these will be significantly worse at 2° than at 1.5°; and that global CO_2 emissions pathways consistent with keeping global temperature within the 1.5° limit require rapid global emissions reductions – 45% by 2030 (in relation to 2010 levels) and global CO2 emissions should reach net zero1 by 2050 (IPPC, 2018).

TARGET	MEASURES AND INTERVENTIONS
Freight	Prioritise rail systems along corridor routes.
	Investigate the potential for advancing the hydrogen fuel-cell value chain in South Africa.
	A hydrogen roadmap which considers the assembly or manufacture of hydrogen fuel-cell heavy vehicles for domestic and export markets.
Public transport	Streamline and integrate national and regional land and transport development policies.
	Harmonise transport policies and strategies within national climate and socio-economic imperatives (i.e. spatial development incorporating housing and affordable and efficient transport).
	Priority investment in rail, BRT and minibus infrastructure with a 50 year planning horizon.
	Deploy EVs in the public transport system. Schemes such as the Taxi Recapitalisation Programme and Carbon Tax revenue could provide a means for the subsidisation of electric public passenger vehicles.
	BRT systemic integration into the road network, prioritizing high speed BRT corridor lanes.
Electric Vehicles	Capacitate local auto-industry for an EV transition to reduce the risk of public investment in stranded infrastructure and technology lock-in.
	Incentives for the manufacturing of electric minibus taxis and light commercial vehicles as a catalyst for a domestic EV market.
Fuel Supply	Additional investment, in the near term, in the existing crude-oil refineries for the Euro-2 to Euro-5 standard is required for a continuation of ICE vehicle deployment.
	A holistic policy of electricity sector decarbonisation and EV deployment would not require the above investment in refinery refurbishment or new refineries.
	The domestic synfuel complex should be assessed for its potential as a green hydrogen-based supply of transport fuel and chemicals.

Table 1
Key recommendations for a low carbon and energy transport system in 2050

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. The conclusions to COP 25 urged all countries, in the light of their responsibilities and respective capabilities, to address the "emissions gap" between current mitigation commitments (in NDCs, and from Cancun, for 2020) and what is required, in their NDC updates in 2020.

Existing Nationally Determined Contributions (NDCs) under the Paris Agreement will result in global warming of 2.9-3.4°C (UNEP 2019). Countries will need to significantly increase their mitigation ambition in their NDCs updated in 2020, and in subsequent NDCs communicated in 2025, in order to keep the global effort to address the climate crisis on track.

What does this mean for a country such as South Africa? Previous mitigation analyses aimed at limiting emissions to 20502, based on mitigation potential (in turn based on available technologies and their costs). In the longer term, the Paris Agreement in its Article 4.1, requires countries to achieve peak GHG 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 and efforts to eradicate poverty".

This provides all countries with an envelope 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 CO2, and for there to be "deep reductions" in other gases. Long-term planning therefore should consider how to reduce emissions to zero in each sector of the economy, where this is feasible, and identify sectors and/or subsectors in which this is currently not possible, to look at future technology options, in the context of sustainable development challenges in the overall economy.

This paper therefore takes a closer look at the transport sector in South Africa in this context, to explore what the future GHG emissions of the sector will likely be under a number of scenarios featuring different policy options, and what would be necessary to decarbonize this sector in South Africa.

2. 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, but transport emissions are increasing at a rate faster than other energy-end-use sectors (IEA 2019). Road vehicles account for the bulk of transport emissions, approximately three quarters of global transport emissions (IEA 2019). In South Africa, this figure is even higher, with more than 90% of transport emissions arising from road transport (WWF 2016). Globally, despite advances in vehicle efficiency, alternative fuels and alternative mobility technologies, road transport emissions continue to increase – offsetting mitigation savings (ITF 2019). 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 and cadence of the transport transition.

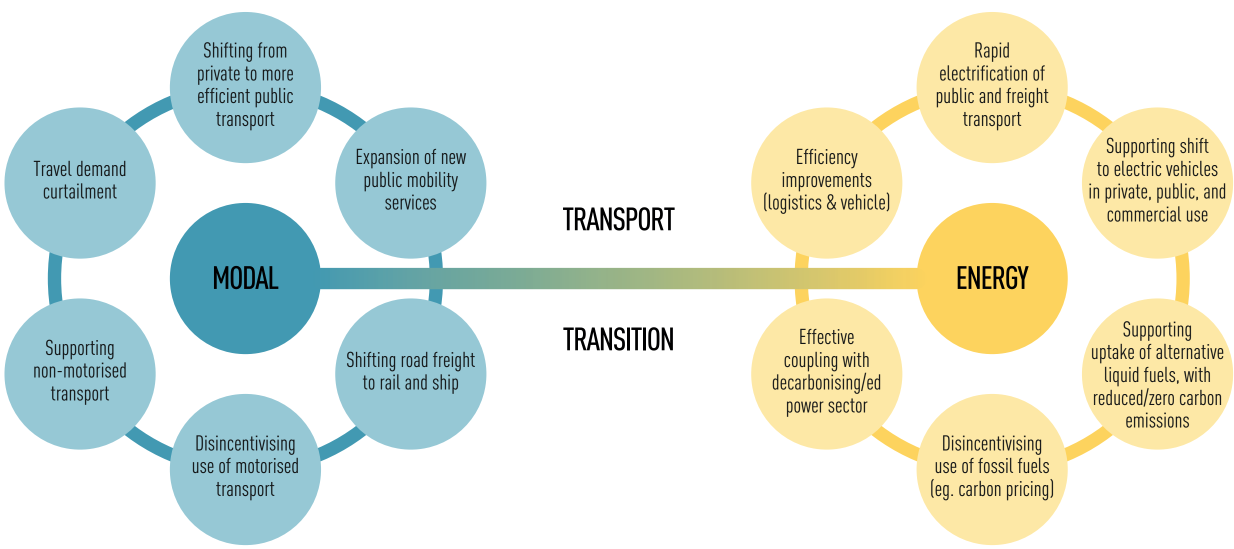
Specific, ambitious and actionable transport-related policies and targets are lacking at the national and international level, undermining climate objectives and the net zero targets outlined in the IPCC Special Report. According to the ITF Transport Outlook (2019), worldwide transport emissions are set to grow by 60% by 2050, even if current and announced mitigation policies are implemented. 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 over the next three decades drive the transport sector towards more efficient and lower-emitting technologies such as hybrid and electric vehicles. 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.

2.1 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 rest on two major levers.

1. 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.
2. Fuel Switching: The second relates to changes in energy use or the energy mix in transport, i.e. meeting energy needs more efficiently while generating less emissions. For example, the electrification of bus rapid transit (BRT). Popular measures for each lever are captured in Figure 1 below.

Figure 1: **Transport Transition Levers & Measures**



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 (2019) high ambition scenario results in global CO_2 emission reductions in the transport sector of 30% by 2050 – from 7 230 $MtCO_2eq$ in 2015 to 5 026 $MtCO_2eq$ in 2050, decarbonising the transport sector in accordance with the PA will require more ambitious targets which our analysis suggests could be facilitated via a policy of electrification of transport.

3. A TRANSPORT TRANSITION FOR SOUTH AFRICA

In this paper, we explore the potential to decarbonise the South African transport sector through exploring a combination of two packages of interventions, as outlined above. 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-motorized transport options), and a modal shift of freight and passenger transport. We use a full-sector energy model to understand the implications of these shifts for GHG emissions in the transport sector, in energy supply sectors, and in the overall economy.

3.1 South African 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 (PWC 2014). Though 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 the National Development Plan (RSA, 2011)

3.2 Status and Trends in Transport Sub-Sectors

Public & Private Passenger Transport

The South African public transport system is characterised by inefficiency and inequality. Under apartheid, transport infrastructure development and polices were used to enforce racially segregated cities and rural/urban divides, leaving the country with the legacy of a fragmented, unequal and inefficient public transport system. According to the 1996 White Paper on National Transport Policy, this contributed to a pattern of "low density development, spatially dislocated settlements and urban sprawl [which resulted] in inordinately long commuting distances and times, low occupancy levels, high transport costs and low cost recovery" (RSA 1996). For urban and rural poor, access to school, work, and public services continues to entail long commutes i.e. 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) contributes to continued exclusion and inaccessibility, as well as high levels of congestion and urban pollution.

Travel times and costs are increasing, along with congestion and pollution (TomTom 2019; IEA 2016). Hitge & Vanderschuren (2015) indicated that South Africans generally spend more time than the global average commuting via motorised travel (90 mins vs 70 mins for private travel) with travel times via public transport at an average of 110 mins. An ongoing trend of commuters migrating to mini-bus taxis and cars away from rail has increased road congestion with negative economic consequences (StatsSA 2019b; KPMG 2014). Long commute times and the cost of public transport are key barriers to further patronage (StatsSA 2014; Luke & Heyns 2013). Van Ryneveld (2018) states that, in 2013, lower income groups spent >20% of their monthly household income on transport. Despite the fact that rail is significantly cheaper than mini-bus taxis and buses, both which are substantially more affordable that private car use, the trend away from public transport (specifically rail) reveals the increasing dysfunctionality of the public transport system (Luke & Heyns 2013; Ngubane 2017; Van Ryneveld 2018).

The 2013 National Household Travel Survey, revealed an increasing trend in private motorised travel over the past decade (StatsSA 2014). With respect to passenger vehicles, from 2013 to 2018 the motorization rate (thousands of vehicles per person) is estimated to have increased 6%, from 119 to 126. The private vehicle fleet comprises the largest share in terms of vehicle population and transport emissions. While public transport is an important mode, largely informed by travel time and cost, a trend of increasing travel by private vehicle is evident. Furthermore, South Africa has a well-developed local automotive manufacturing industry - reportedly responsible for 7.5% of GDP (including multipliers[3]) and employing 113,532 people across assembly, components and tyre manufacturing sub-sectors. This presents additional policy challenges and opportunities with regard to technology choices for future road vehicles (StatsSA 2018; Jordaan et al. 2018; Dane et al. 2019).

With the population projected to increase to 75 million by 2050, a holistic national approach to reversing these trends is required.

Commercial Transport & Freight: Road, Rail & Maritime Transport

In the commercial transport and freight sector, the majority (85%) of transport is via road with existing rail capacity not fully utilised at significant cost and losses associated with inefficiency (Havenga 2013; Havenga et al. 2016). 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 (DoT 2018). 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 is estimated to cost R417 billion (Townsend & Ross 2018). To put this into perspective, this is almost double annual health expenditure for 2019 (NT 2019). 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 (DoT 2018).

South Africa's rail infrastructure and rolling stock is also ageing, poorly maintained, and deteriorating rapidly in the face a significant capital investment and maintenance backlog.

With more than 95% (by volume) of the country's imports and exports shipped by sea, maritime shipping and transport plays a critical role for the South African economy – yet South African ports are "characterised by high costs and substandard productivity relative to global benchmarks" (RSA 2011). The maritime shipping industry is dominated by international companies – but includes a small portion of South African shipping companies operating through off-shore subsidiaries (DoT 2011). This reflects international trends associated with 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 (DoT 2017).

Aviation: Passenger & Cargo

Similarly to other segments of the transport sector, aviation[4] demand is increasing yet the sub-sector faces challenges when it comes to the 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 (DoT 2018).

In terms of passenger transport, scheduled domestic traffic dominates – accounting for ~24 million passenger trips a year, followed by scheduled international flights at 10.3 million passenger trips per year (IATA 2014 cited in DoT 2015). However, only about 10% of South Africans currently use air transport, which reflects broader trends in income inequality and transport use.

3. This is inclusive of retail and aftermarket repair activities, although the manufacturing contribution represents most this amount (DTI 2018)

4. Aviation includes passenger and cargo transport, as well as non-commercial activity (eg. private sports, recreation, & private flights).

When it comes to airfreight, international traffic dominates – accounting for 83% of all volumes, the majority (55%) of which is inbound (DoT 2015). Demand for both passenger and freight aviation is forecast to grow at a level slightly above to ~2x GDP of the growth rate over the next 30 years.

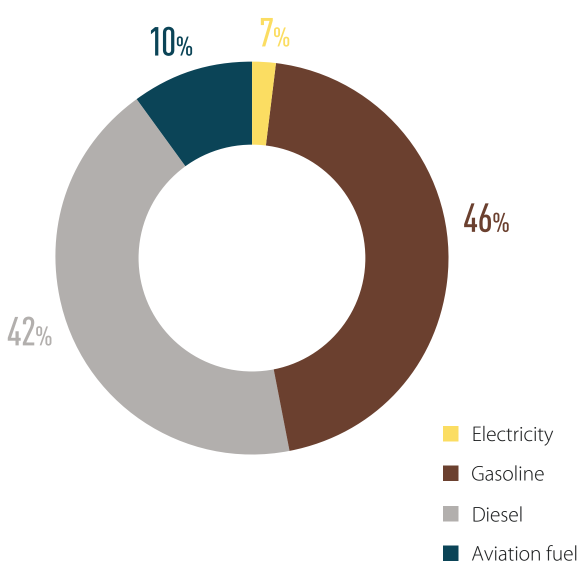
3.3 Transport Emissions Profile

In 2015, emissions from the transport sector 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 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 (DEA 2013). The emission intensity 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 (Figure 2) and 91.2% of the sector's emissions, it is the area with the greatest mitigation potential.

3.4 The Green Transport Strategy 2018-2050

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 (NATMAP 2050), the primary policy basis for transport planning in South Africa. Building from the NATMAP and in response to the National Climate Change Response Policy (2011), which advocates a climate-resilient and low carbon economy by 2050, the Green Transport Strategy was published in 2018[5]. The Strategy considers various policy interventions that could contribute to substantially reducing "GHG emissions and other environmental impacts from the transport sector by 5% by 2050", while promoting economic growth and inclusive development (DoT 2018). These are captured in Table 2 below.

Figure 2: **Total transport fuel consumption by fuel type**



Merven et al. 2019

Table 2 **Green Transport Strategy Themes & Pillars**

Implementation Themes	Strategic Pillars
Climate Change Response Norms & Standards	1. Develop norms & standards for climate change response at National, Provincial and Local level to ensure that 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.

DoT 2018

5. For an overview of the legislative and policy basis for climate change mitigation in the transport sector, see section 4.2 of the Green Transport Strategy (2018)

The Strategy also outlines six short-term strategic targets or "quick-wins", to be implemented within 5-7 years, captured in Box 1 below.

Previous analysis of the Green Transport Strategy found that the implementation of strategic targets and measures contained in the plan resulted in an emission reduction of ~70% in the transport sector by 2050, with a positive impact on economic growth and employment (Ahjum et al. 2019). The most important factor identified was a shift to electric vehicles, assuming costs become comparable with internal combustion engines: EVs being solely responsible for an emissions reduction of ~50% in transport relative to a scenario in which ICE vehicles predominate.

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 and 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 integrator ICT technology platforms for locating stations, regulating future pricing and providing statistics.

DoT 2018

4. MODELLING AN AMBITIOUS TRANSITION IN TRANSPORT

The South Africa TIMES (SATIM) model allows for the interrogation of transport futures to gauge their influence on energy supply and demand, and their consequent economic and environmental impact (Appendix A). As highlighted in Section 1, the composition of mobility services are a function primarily 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 depicted in Figure 3, the technological and policy landscape is thus defined by:

1) Vehicle Technology (horizontal axis):

a. Non-EV automotive sector: South Africa's auto industry remains a laggard in switching to EV manufacture, and the current EV importation tax remains over the period 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 and LDVs) are not pursued.

b. EV automotive sector: A transition in the domestic auto-industry towards EVs occurs. In South Africa, EVs 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 (HFCVs).

2) Spatial Planning and Modal Shift (vertical axis):

a. 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.

b. 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 3.

Figure 3: **Transport carbon pathways for South Africa towards 2050**

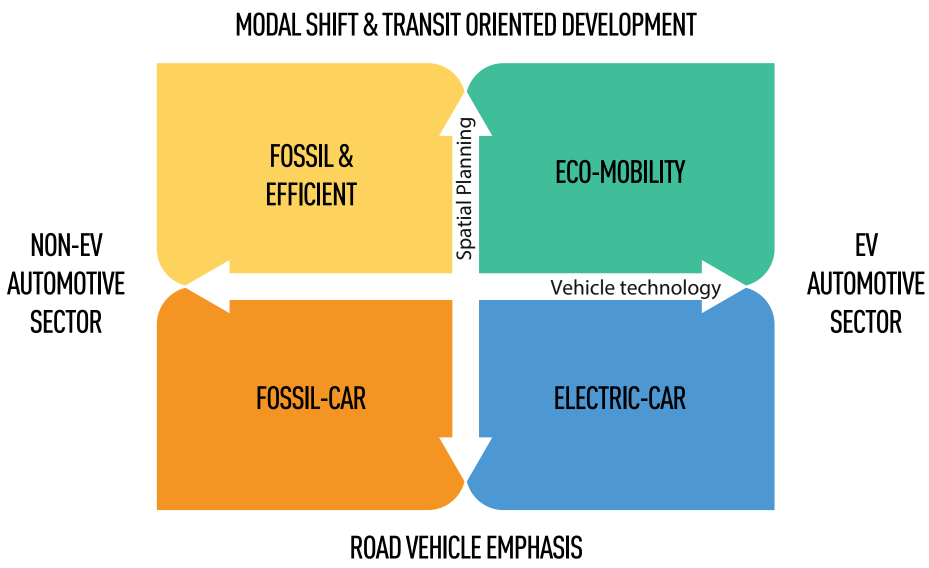


Table 3 **Summary of transport scenarios with key model assumptions**

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 HFCV for Heavy Vehicles (e.g. 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 freight road corridor migration to rail by 2050 (DEA 2014) ■ Reversal of public transport defection to ~ 2012 modal share of rail ■ TOD reduces motorised travel demand by 10% in 2050	■ Hybrid-ICE /ICE cost competitive vehicles ■ Late development of HFCV for Heavy Vehicles (e.g. Buses, Trucks) ■ 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/HFCV 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 freight road corridor migration to rail by 2050 ■ Reversal of public transport defection to ~ 2012 modal share of rail ■ TOD reduces motorised travel demand by 10% in 2050	■ EV/HFCV cost competitive by 2030 ■ Migration to rail in freight and passenger transport

While cognisant of South Africa's NDC pledge, 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 7.75Gt. McCall et al. (2019) had previously suggested that an economy-wide budget of 7.75 Gt was the lowest emissions threshold that the country could sustain without negative economic impacts. 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.

4.1 Exploring the technical feasibility of an ambitious transition

Growth Factors

The primary drivers of growth in transport services are GDP and population growth.

The South African population is currently estimated at ~57 million people and is projected to increase to 75 million by 2050 (UN 2019).

The economy is forecast to grow at approximately 3% per annum on average over the period 2020-2050. Economic growth between 2018 and 2022 is based on medium term projections from the National Treasury MTBPS (NT 2018a) and the International Monetary Fund (2018). Longer term growth projects are aligned to meet the Department of Energy's planning growth rate of ~3% to 2050 (DoE 2016)

These are captured, as represented in Figure 4, in the SATIM model. Densification and Transit Oriented Development (TOD) which would decouple the rate of demand for passenger motorised travel with population growth is an additional factor to consider. In this study, owing to a lack of local studies, the results of Pye and Daly (2015), based on a UK analysis, is adapted to provide a conservative assumption about a potential reduction in passenger motorised travel in 2050 for South Africa.

Fuel Supply

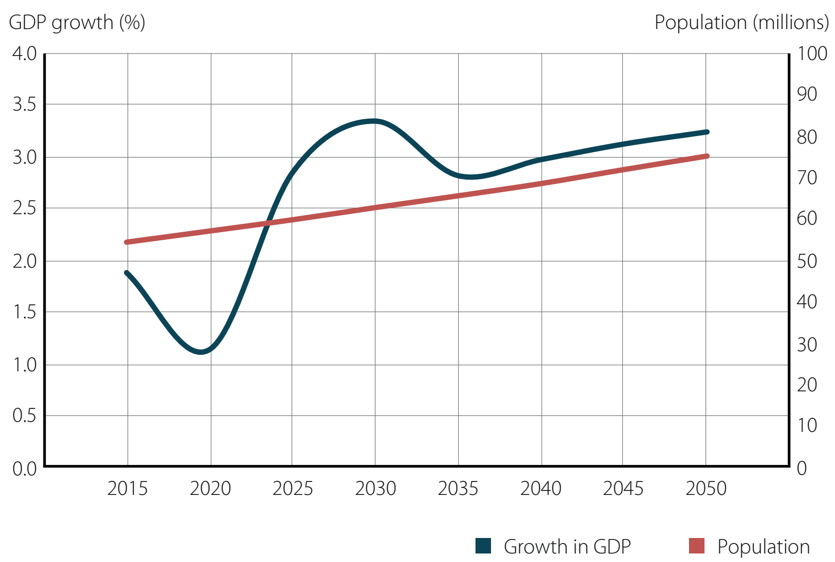
With a total production capacity of 718,000 barrels/day (oil equivalent) South Africa produces the majority of its liquid fuels from imported crude oil and domestic coal via liquefaction (SAPIA 2018).

A transition will have a dramatic impact on the domestic liquid fuels supply chain (KPMG 2017).

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, to become effective in 2017 and estimated to cost R41 billion (2015 Rands) (DoE 2011; SAPIA 2017). Its implementation has however reached an impasse with industry and government in disagreement regarding the responsibility for financing the refurbishment of the refineries. Nonetheless, in this model we assume that the CF2 regulations will be effectively implemented by 2030. Existing 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 included as an option rather than assumed as a fixed investment (Africa Oil and Power 2019). A median global crude oil price is modelled at US $80/barrel (2015 prices) over the period 2030-2050.

In addition, we assume that South Africa's existing coal-to-liquid (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 transport sector.

Figure 4: **Projected population and economic growth for South Africa**



Box 2: CTL Fuel Supply

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.

Vehicle Efficiency, Speed & Occupancy Factors

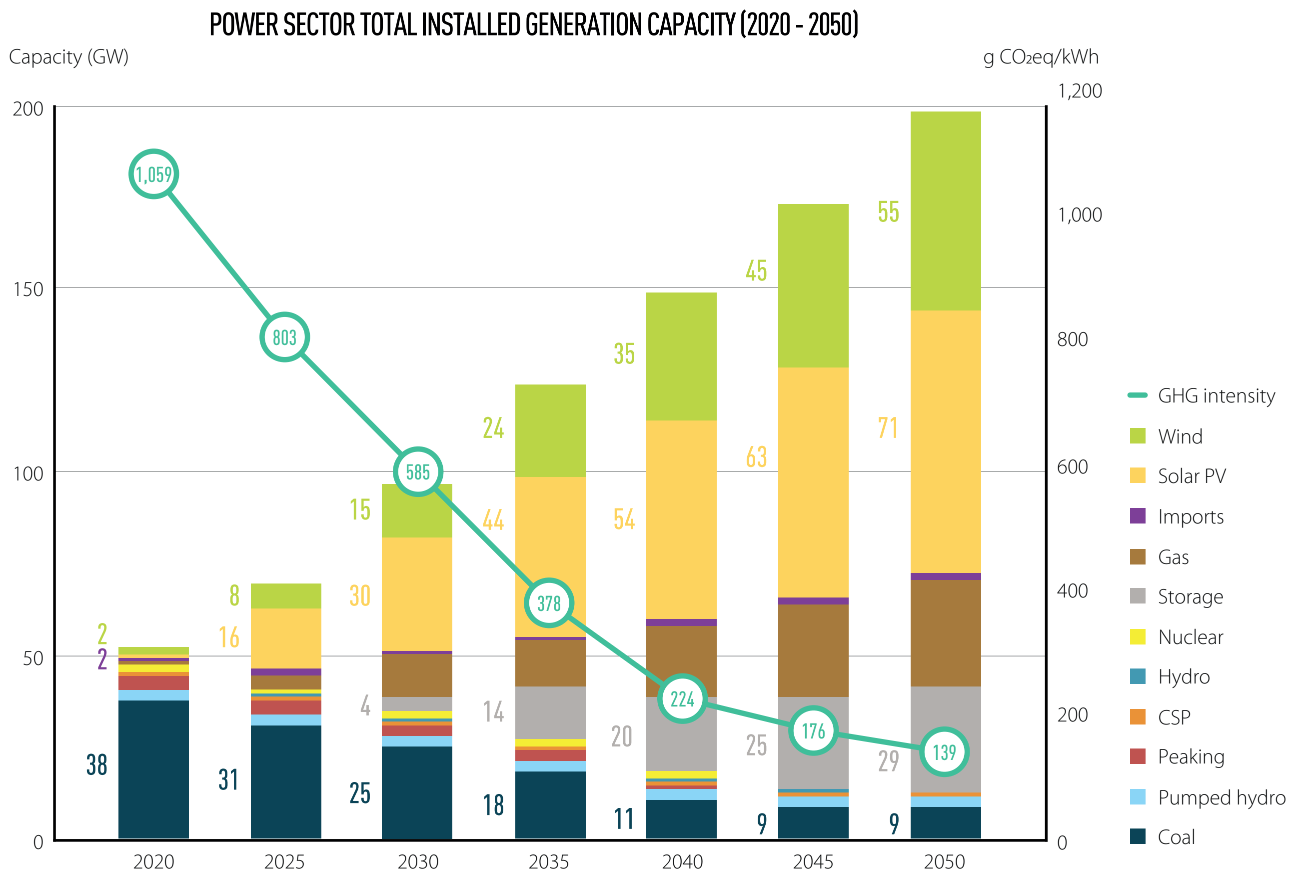
An increase in vehicle efficiency is an important mechanism to decrease emissions in the transport sector. However, we maintain conservative assumptions as reported in real world testing of road vehicles (IEA 2019). The model assumes, conservatively, an annual vehicle fuel efficiency improvement of 0.5% and 0.1% for public and freight road vehicles, respectively, as is modelled in the Integrated Energy Plan (DoE 2016). 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. SATIM, being a full-sector energy model, provides 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, as adapted from McCall et al. (2019): Minimum Emissions Standards requirements for the coal fleet are implemented from 2025; limits on the total new capacity of renewable energy 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 (Figure 5).

The GHG emissions intensity[6] 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%.

Figure 5: **The SATIM cost-optimal expansion of the power sector**



6. 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.

4.2 Transport Transition Scenarios

The Spatial Planning and Modal Shift pathway results in a lower demand for passenger transport when compared to the Road Vehicle Emphasis pathway (Figure 6). 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. Also 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 (Figure 7).

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 also 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 8, 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. 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 ~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.

Figure 6: **Modal split of passenger-km demand by technology**

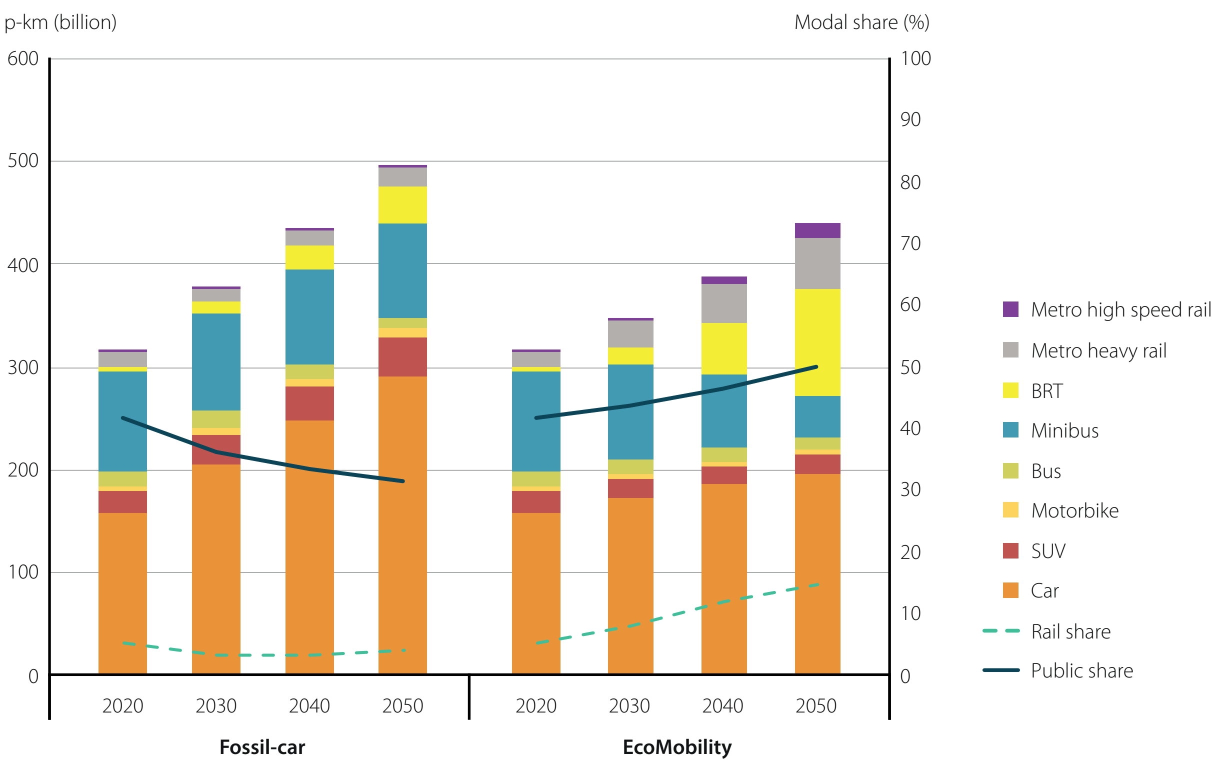


Figure 7: **Freight modal shares of tonne-km**

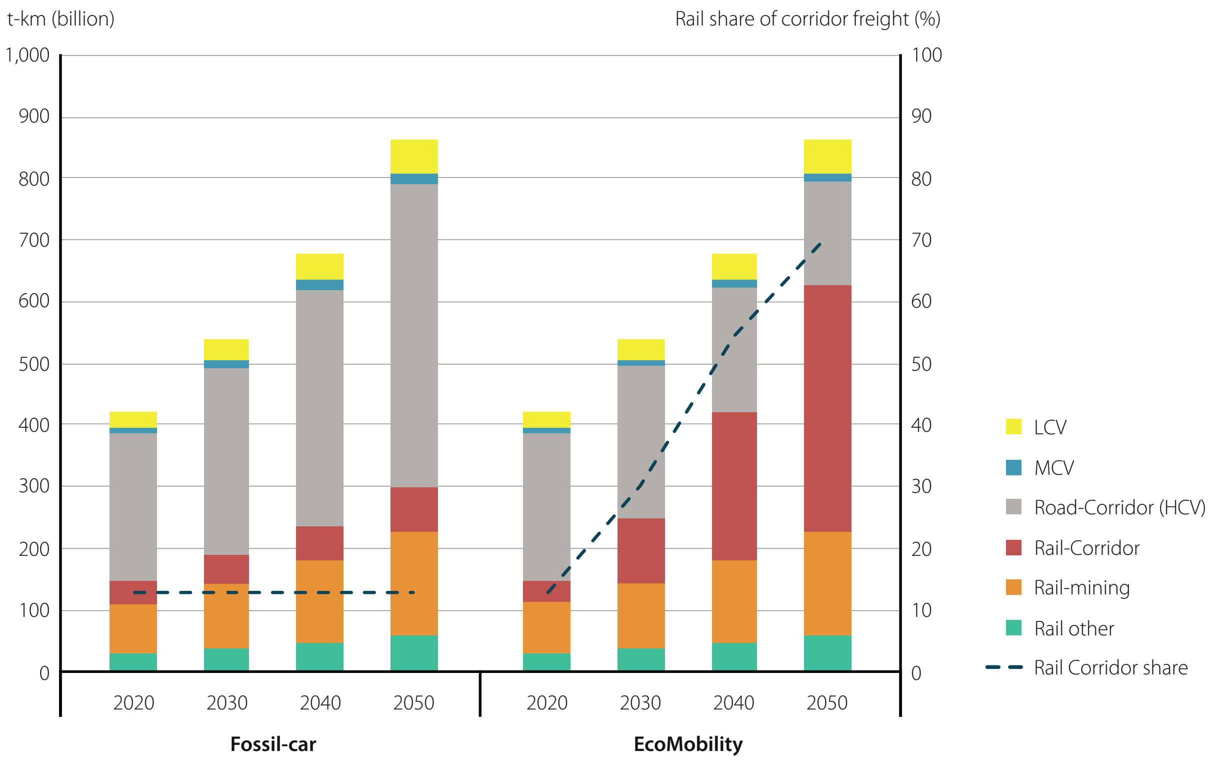
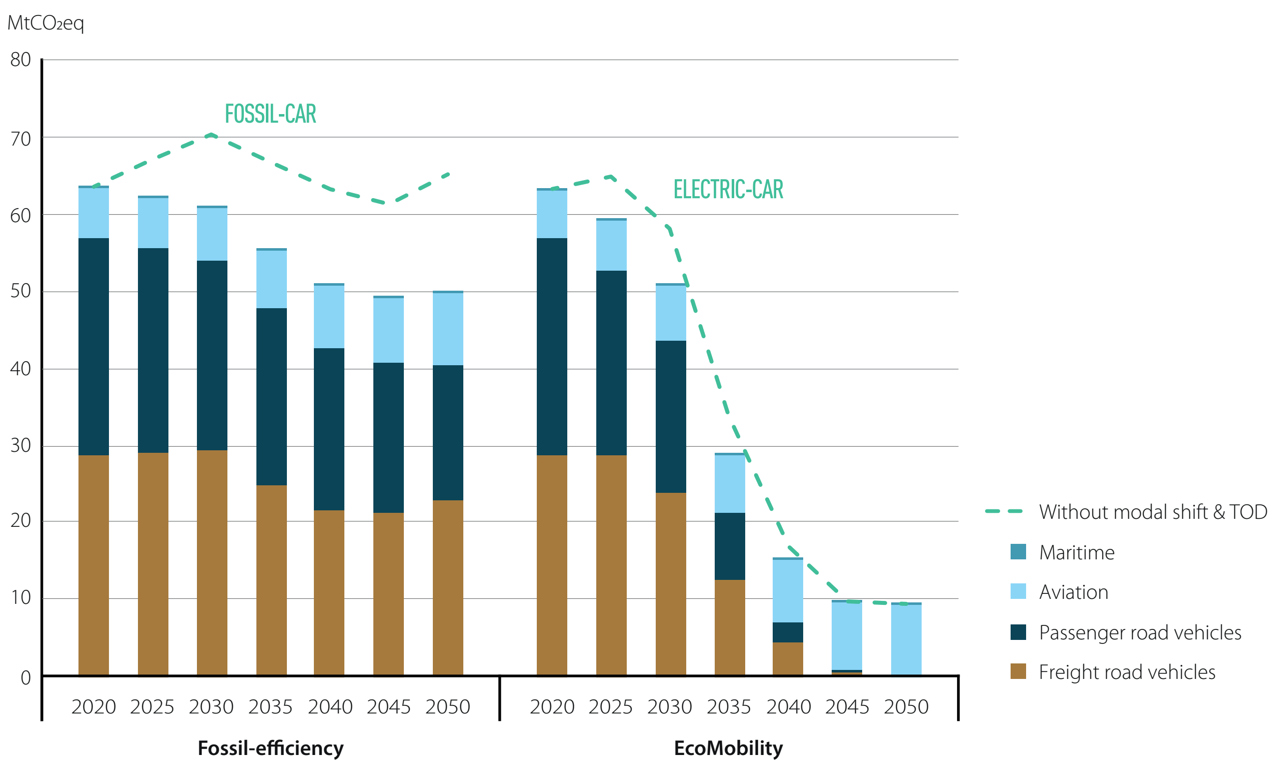


Figure 8: **Emissions from the transport sector**



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 (Figure 9). 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 electric vehicles. 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 (see *Impacts on Fuel Demand, Power Sector and Refineries*)

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 10 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.

Figure 9: **The impact of modal switching on direct transport emissions**

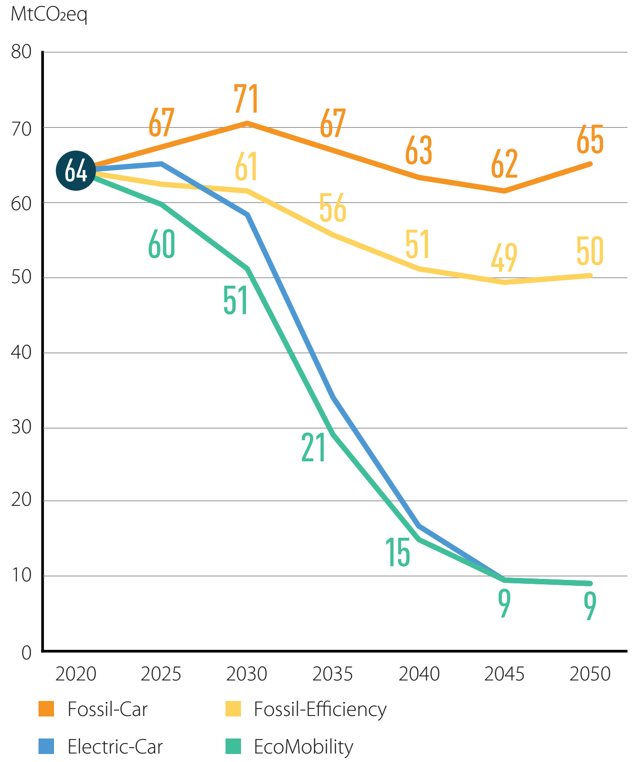
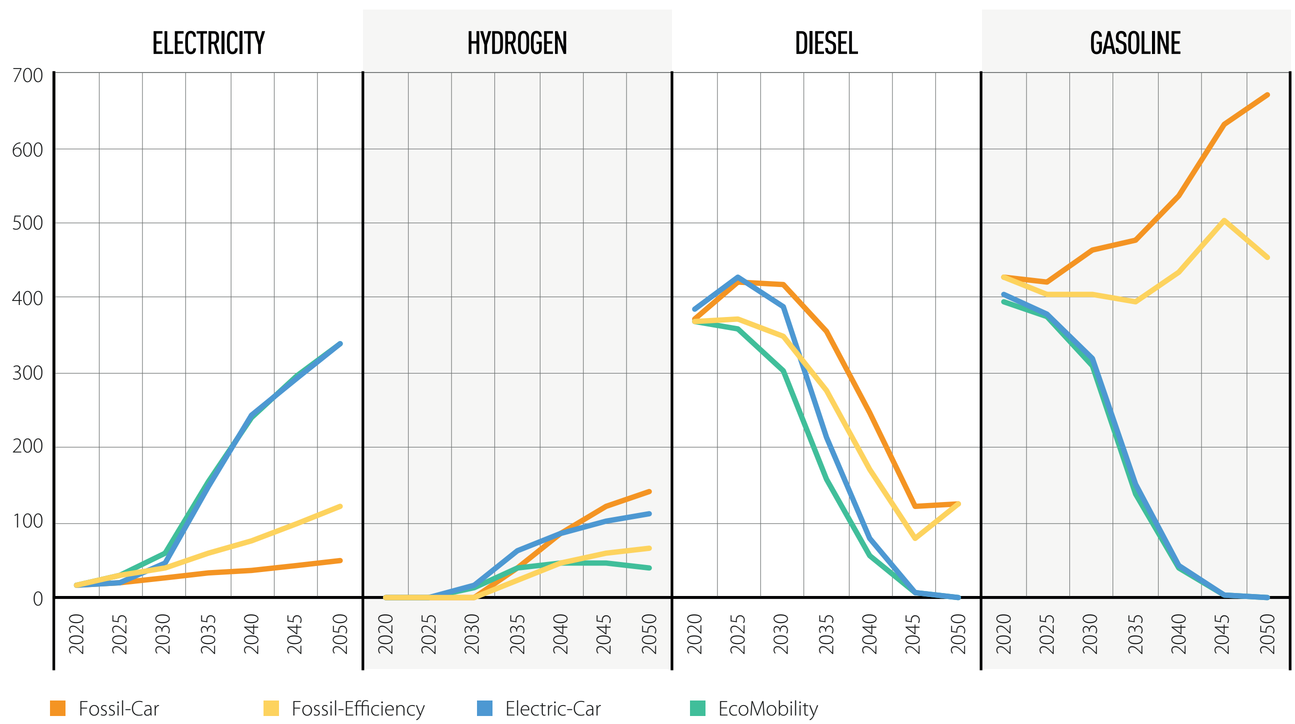


Figure 10: **Transport fuels**



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 11 and 12, respectively. A domestic EV market has the potential to be fully electrified in 2050, whereas a non-EV market would have a preference for Hybrid-ICE vehicles in the private fleet, as well as hydrogen in the public fleet.

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 12), with a combination of rail and buses (including and BRT) displacing minibus taxis by 2050 (Figure 13).

Figure 11: **Private passenger road vehicles by population and technology**

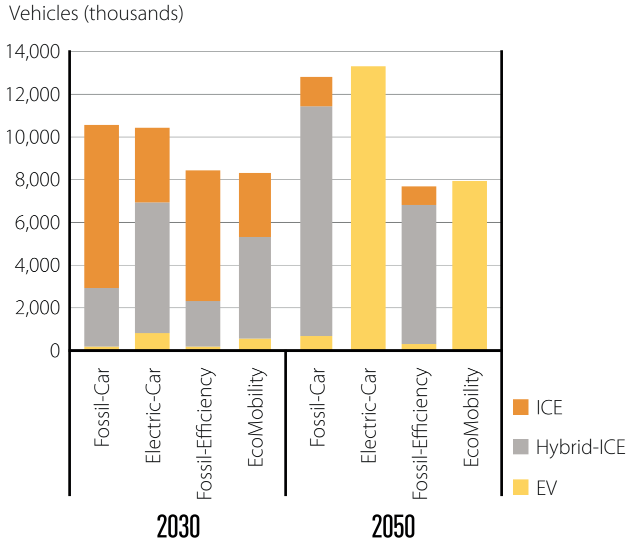


Figure 12: **Public transport road vehicles by population and technology**

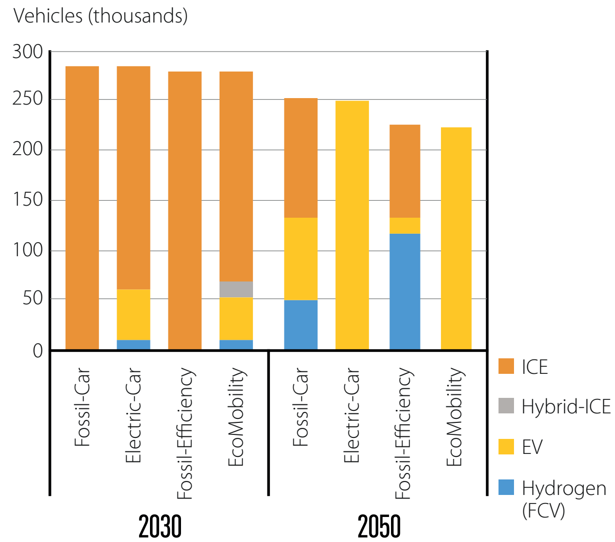
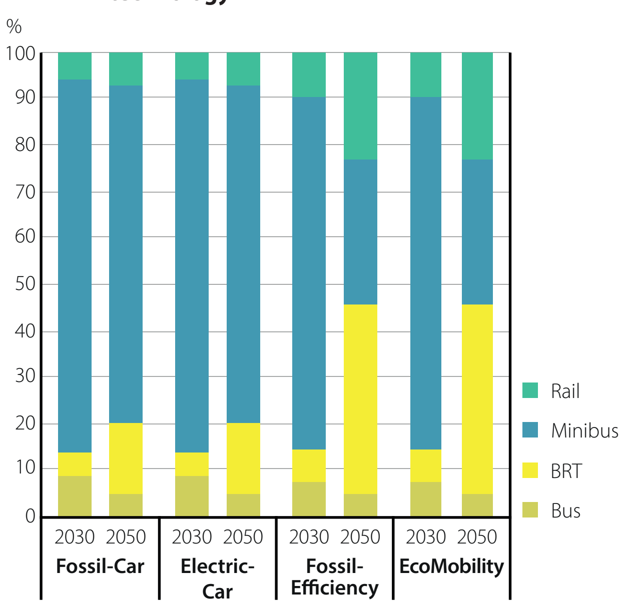


Figure 13: **Modal composition of public transport by technology**



Fuel Switching in Freight Transport

In the freight sector, the EV pathways result in the full electrification of LCVs and small to medium trucks in 2050. Merven et al. (2019) and Ahjum et al. (2019) 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 IEA (2017) reports that freight services are correlated to economic growth, which as seen in Figure 14, 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 product. 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 10, beyond which local refineries can supply would subsequently require imported product. The decline in diesel consumption is largely due to the switch to fuel-cells 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.

In terms of technology utilisation, as shown in Table 4, 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 EcoMobility scenario, the LCV fleet is electrified accounting for 96% of v-km driven in 2050 with fuel-cell heavy vehicles comprising 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 7. This is also evident when comparing the Fossil-Efficiency and Fossil-Car scenarios in Table 4.

Figure 14: **Freight transport road vehicles by population and technology**

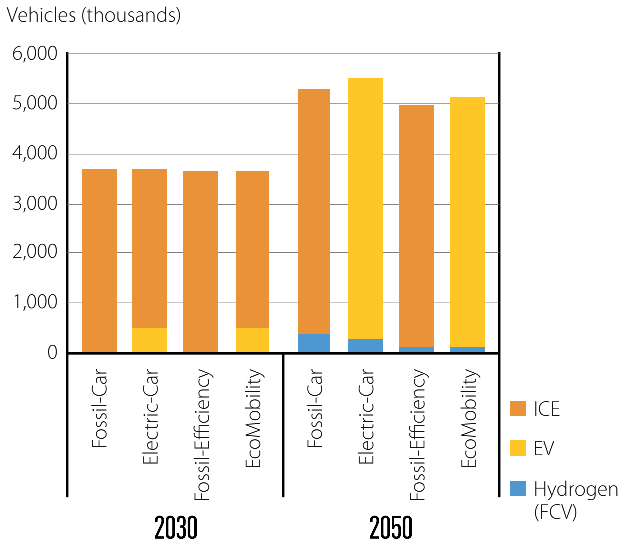
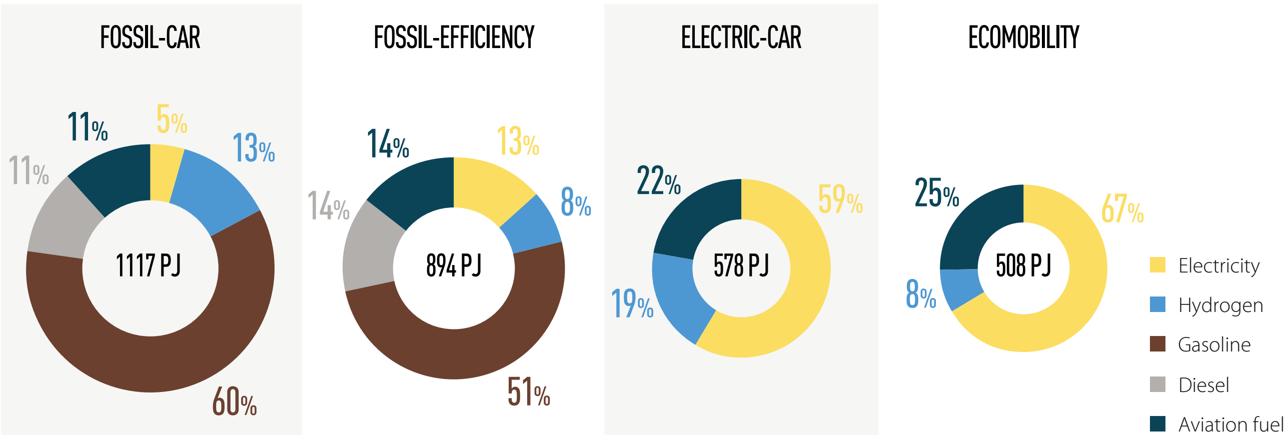


Table 4 **Share of freight vehicle-km by fuel type**

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

Figure 15: **Total transport energy consumption and fuel composition in 2050 for the scenarios**



Impacts on Fuel Demand

In the EcoMobility 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%) (Figure 15). Aviation fuel accounts for the remaining 25% and comprise the bulk of emissions in 2050 (Figure 8).

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 near doubles by 2050. Nevertheless, electric drivetrains, owing to their higher well-to-tank efficiencies, in tandem with modal switching confer greater savings in 2050.

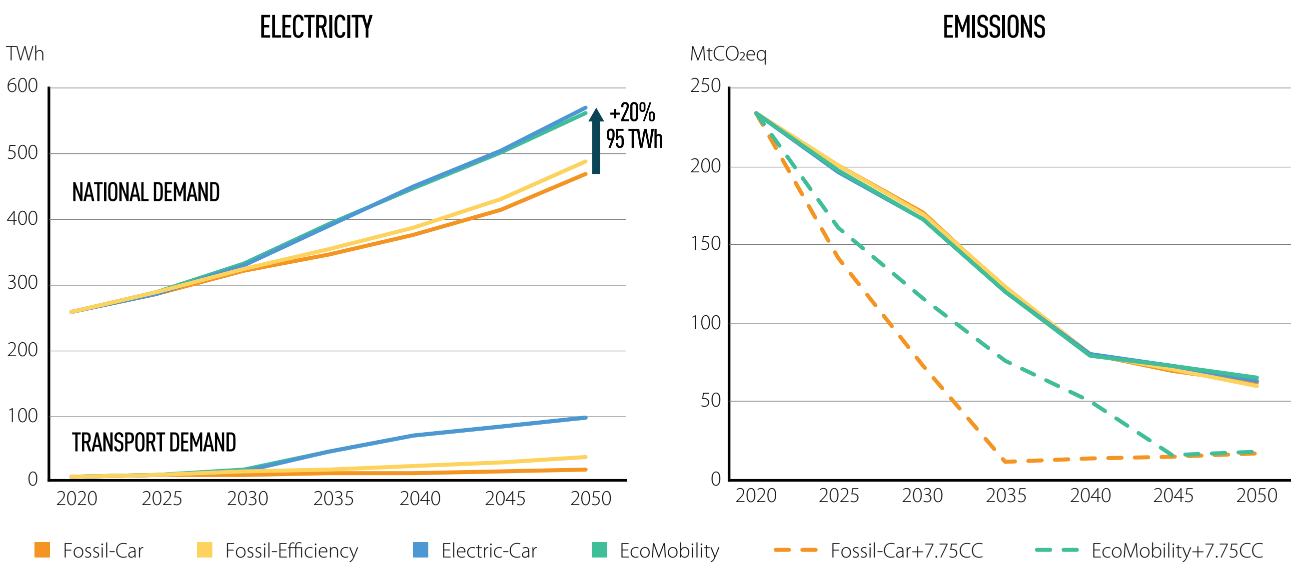
Marine vessel fuel usage is negligible at 0.1 PJ for both cases.

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 EcoMobility scenario (Figure 16a). 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 16b). 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 16b, 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

Figure 16: **Power sector: a) electricity supply; and b) associated GHG emissions (including a 7.75 Gt Carbon Cap case)**



for the EcoMobility scenario would persist until 2045. In the Fossil-Car scenario, a 7.75 Gt carbon budget requires earlier decarbonisation whereas in the EcoMobility scenario, due to the deployment of zero-(GHG) emissions vehicles, additional carbon space is allocated in the budget allowing for an extended decarbonisation period. Effectively, the EcoMobility 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.

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 (Figure 17). In 2030, without an 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

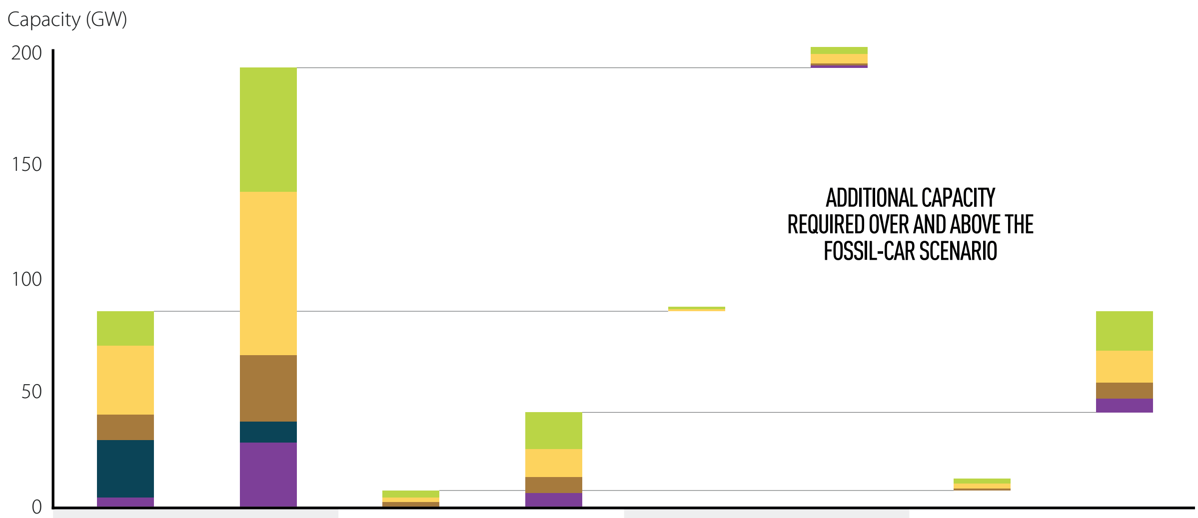
The existing coal-to-liquids (CTL) facility primarily consumes coal. Although the coal feedstock is supplemented with natural gas, the amount of gas that is able to displace coal is limited by plant design. The total CTL capacity in South Africa is approximately 150,000 barrels of oil equivalent per day, or roughly 246 PJ per annum. Of the total output, 83% is liquid fuels (i.e. jet fuel or kerosene, gasoline and diesel) with the balance consisting of other commodities (e.g. 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 would see it retire at the earliest by 2040. Supplying close to 30% of annual transport fuel, it is responsible for a much higher carbon footprint in the South African fuel supply chain when compared to Europe (Table 5).

Table 5 **Comparison of embedded CO_2eq for diesel and petrol for South Africa and Europe.**

Fuel	Country	Well-to-Tank	Well-to-Wheel
		kg CO_2/litre	
Diesel	South Africa*	1.5	4.3
	Europe**	0.6	3.2
Petrol	South Africa	2.6	5.2
	Europe	0.5	2.9

* SATIM model (excludes emissions associated with crude-oil extraction);
** EN16258, Kamdar (2019)

Figure 17: **The total power sector capacity required for the Fossil-Car scenario: displayed with the additional capacity required for the other scenarios**



	2030	2050	2030	2050	2030	2050	2030	2050
	Fossil-Car		EcoMobility		Fossil-Efficiency		Electric-Car	
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

5 CONCLUSION

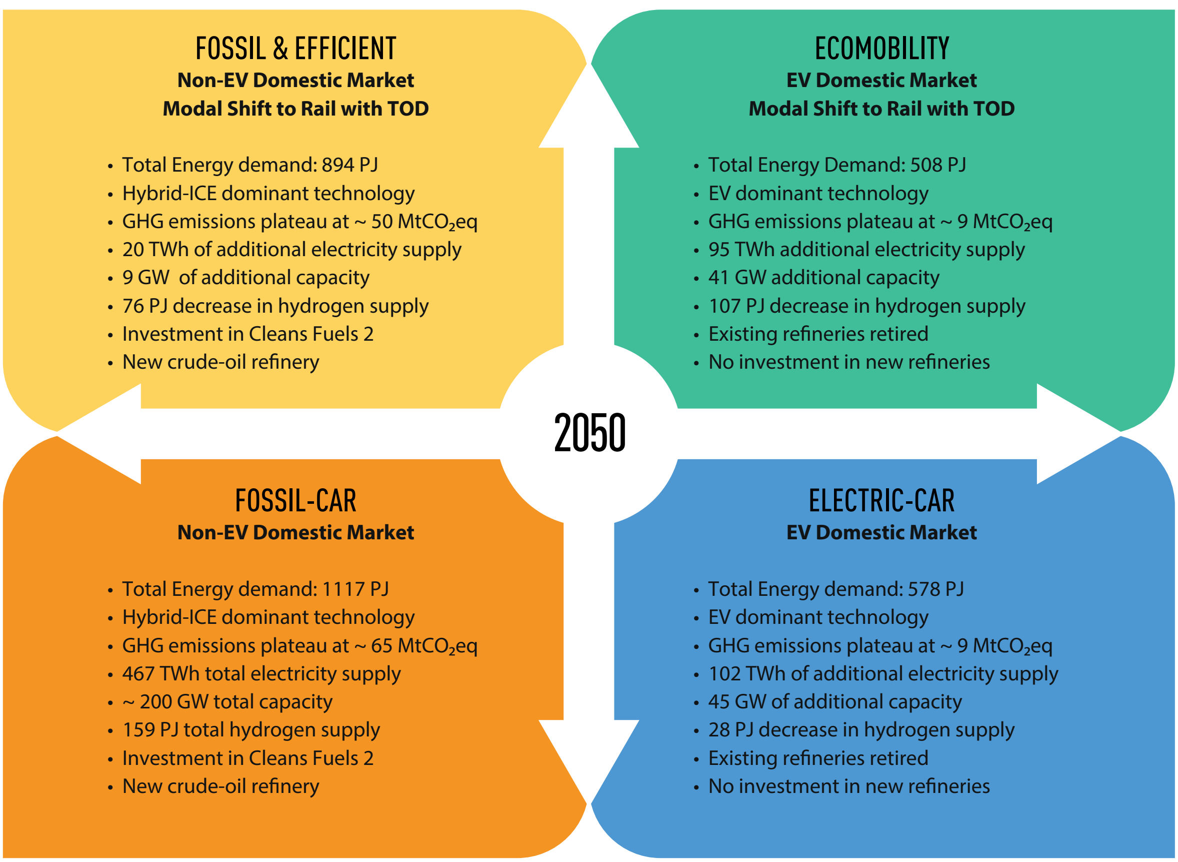
A full sector representation of the South African economy in a least cost modelling framework (SATIM) was utilised to assess the resultant economy-wide energy and GHG emissions for the transport sector towards 2050. Assuming an average annual economic growth rate of 3% over the period (2020-2050) with population reaching 75 million in 2050, four scenarios were modelled. The scenarios contrasted policy choices about vehicle technology (Fossil-Car vs Electric-Car) and urban planning with respect to modal shifting in passenger road transport and freight; as well as transit oriented development (Fossil-Efficiency vs EcoMobility). The scenarios as they compare for GHG emissions and energy demand are summarised in Figure 21.

Given the current levels of energy demand and emissions of the 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; 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 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 EcoMobility 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 $MtCO_2eq$.

Figure 21: **Key outcomes in 2050 for the transport scenarios**



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 8 depicts transport emissions for the Fossil-Efficiency and EcoMobility 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.

The future of the domestic 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. 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 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 18).

In contrast, both the Electric-Car and EcoMobility 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 17). 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 16).

Although the emissions for the EcoMobility 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.

McCall et al. (2019) suggested a 7.75 Gt carbon budget represents a lower threshold to decarbonising the economy without negative economic consequences. If such an emissions constraint is applied to the analysis, both EV scenarios would result in increased emissions from the power sector until 2045 compared to the fossil fuel scenarios (Figure 16). This however suggests that EVs, a zero GHG emitting technology, facilitates an extended period of decarbonisation of the power sector by extending the operation of the existing coal plants and deferring early investment in renewable energy.

The future of the CTL facility post 2040 is contentious given the high CO_2 emissions intensity of its operation. Similar in magnitude to total transport sector emissions, its retirement reduces refinery emissions from 53-56 $MtCO_2eq$ in 2035 to 13-6 $MtCO_2eq$ in 2040 (Figure 19).

Future aviation fuel demand could account for 11% -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.

Hydrogen as a transport fuel mainly replaces diesel in the corridor freight fleet. The level of hydrogen demand is dependent on both the choice of road vehicle technology and modal shift (Figure 18). 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 19).

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.

In accordance with the Green Transport Strategy's (GTS) vision of a resource efficient transport system, 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. However, in this study, incentivising the adoption of alternative vehicle technologies is shown to be the prime lever with which to satisfy the GTS mission "to substantially reduce GHG emissions and other environmental impacts from the transport sector". Specifically, the electrification of transport in tandem with a low-carbon power sector offer the most benefit. A preference for EVs would exceed the GTS mitigation benchmark. Furthermore, in light of continued technological innovation, the analysis indicates that the transport sector is able to contribute an order of magnitude higher to emissions reductions if policy encourages the adoption of economic and resource efficient technological alternatives, and behavioural changes towards public transport. wn

APPENDIX A: MODELLING TRANSPORT WITH THE SOUTH AFRICA TIMES (SATIM) MODEL

SATIM is a least-cost optimisation model which incorporates a technology rich representation of the economy. The economy wide energy supply chain for energy services demanded across all economic sectors is optimised for the least system cost: i.e. lowest cost to the economy. SATIM is calibrated to a national energy balance and the optimisation is predicated on assumptions about future technology costs and energy prices (Figure 22).

Within SATIM, the transport model is composed of a number of sub-models, a schematic representation of which is illustrated in Figure 23.

The vehicle parc model (Figure 24) - described by Stone et al. (2018) - is used to establish the characteristics of the vehicles in operation from 2000–2014 for South Africa. The vehicle categories analysed include private, public and freight vehicles.

The vehicle kilometres model captures distance demand for freight and passenger. Freight vehicle kilometres are derived from an economic model, which provides a GDP growth forecast and demand for freight services in ton-km. Vehicle kilometres are then calculated from load factor estimates for each vehicle type.

Estimating passenger travel demand is more complex and is based on local estimates and inferences from international literature of travel time by income group, vehicle speeds for public and private vehicles, and occupancy (Figure 25).

Modal shares for road and rail for both freight and passenger transport are derived from local literature with future shares exogenously expressed. Behavioural determinants which would encourage households to preference public transport are not modelled, but are instead expressed as exogenous factors based on local historic trends. A reduction in passenger kilometres (p-km) due to urban densification and transit oriented design (TOD) is not explicitly captured in the modelling but inferred from similar international modelling analyses (Pye and Daly 2015).

Aviation and maritime transport are incorporated as aggregate fuel demands with no technology representation: demand is correlated to projected GDP growth.

Figure 22: **Overview of the Energy Systems Model (SATIM)**

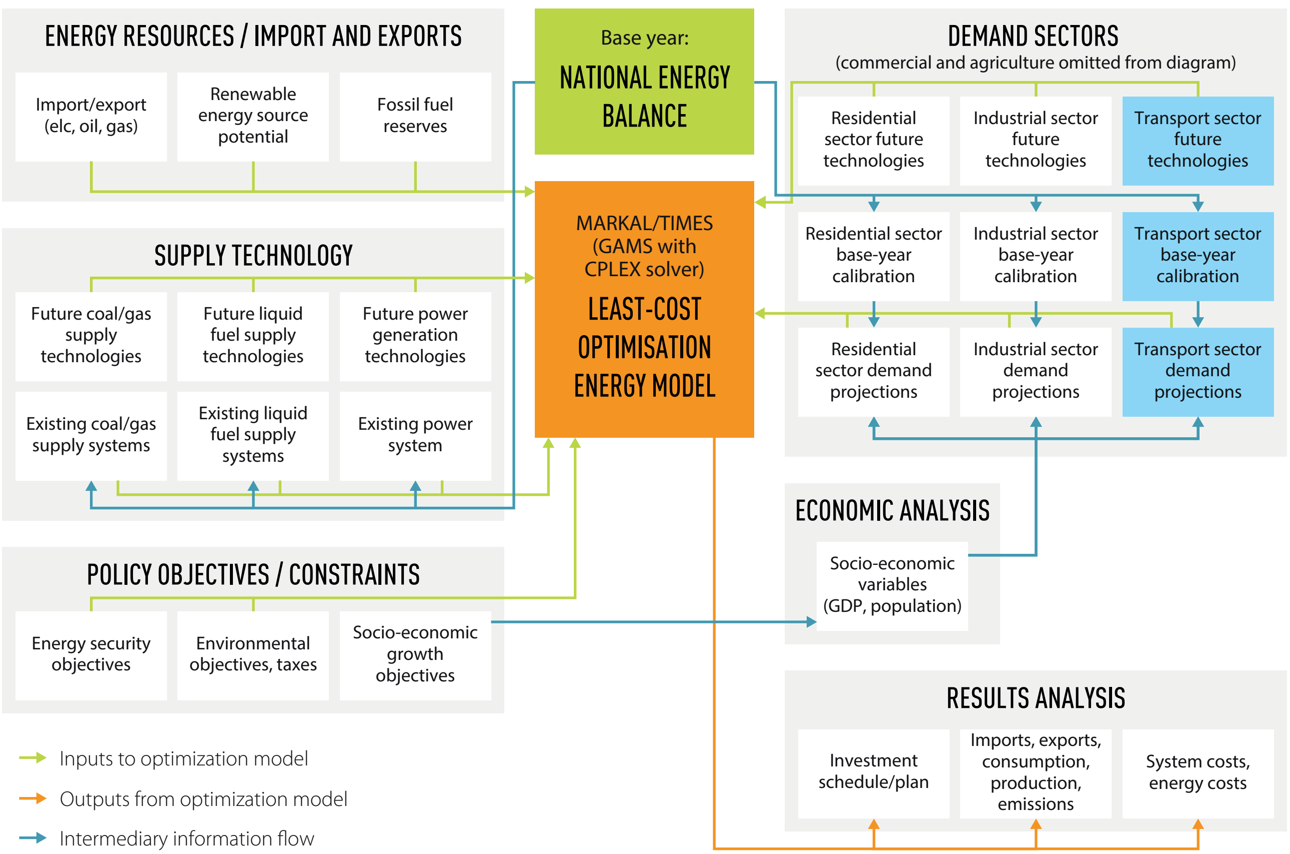


Figure 23: **A schematic of the SATIM transport model**

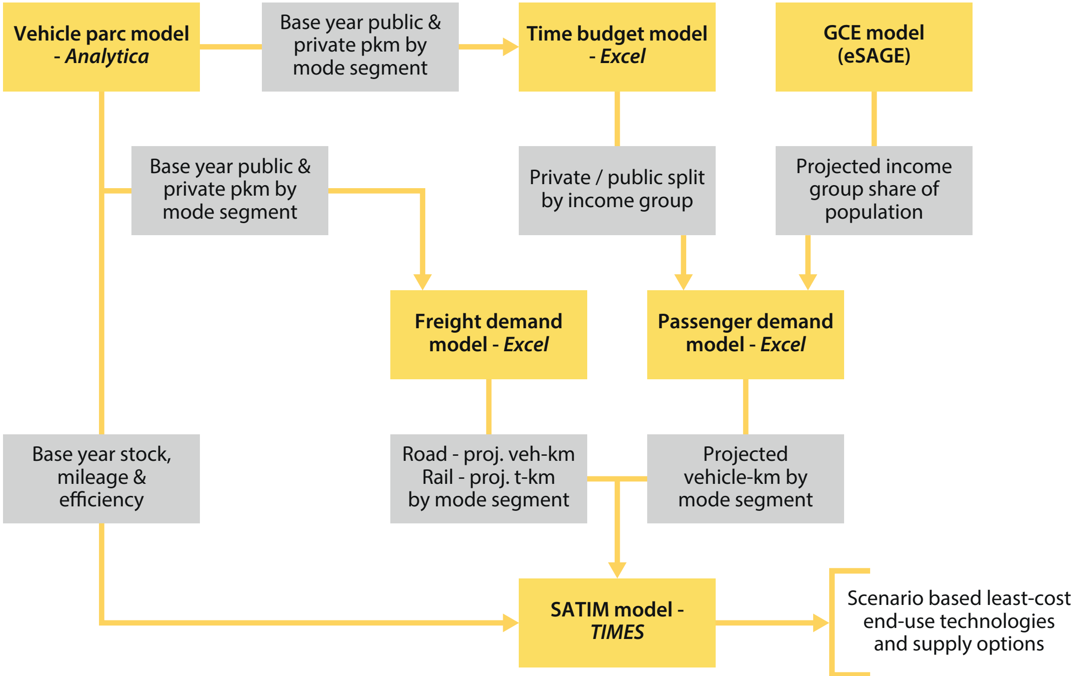


Figure 24: **Vehicle parc and fuel calibration in SATIM**

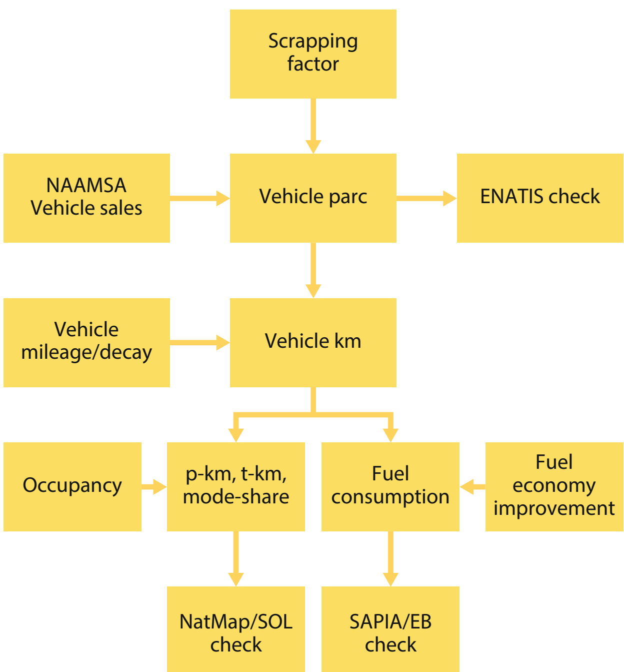
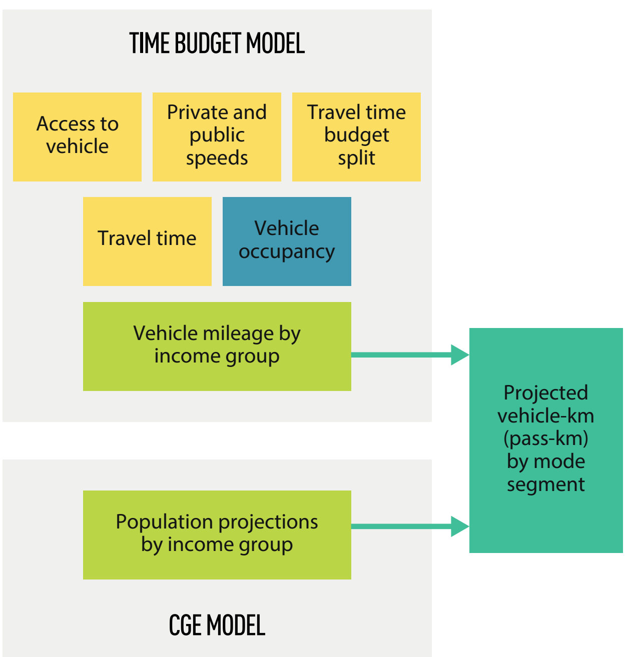


Figure 25: **Summary of the Passenger Demand Model**



The vehicle parc was estimated utilising public vehicle sales and national registration data. Scrapping factors are derived from Weibull distributions, which were determined for each vehicle class to reconcile registry data. Vehicle mileage decay (which is required for vintaging the vehicle parc) and fuel economy and occupancy factors (load factors for freight t-kms) were estimated from the literature, as local data on these factors is limited.

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MEMBERSHIP FEES EFFECTIVE 1 DECEMBER 2020

The Council meeting held on 2 October 2020 approved subscription & entrance fees as from 01 December 2020 as per schedule indicated below.

PLEASE NOTE: In terms of Bylaw 3.2, annual subscriptions are due on 1st December 2020

MEMBERSHIP FEES CAN BE PAID IN MONTHLY RECURRING PAYMENTS

Council agreed to a discount for fees paid before 31 March 2021. Members are therefore encouraged to pay promptly to minimize increase.

Grade of Membership	Annual Subscriptions paid before 31 March 2021		Annual Subscriptions paid after 31 March 2021		New Members FEES * see Notes 1 & 4 below.	
	RSA incl VAT (R)	Outside RSA excl VAT (R)	RSA incl VAT (R)	Outside RSA excl VAT (R)	RSA incl VAT (R)	Outside RSA excl VAT (R)
Student	151	131	181	157	181	157
After 6 yrs study	1 570	1 090	1 884	1 308	1 884	1 308
Associate	1 570	1 090	1 884	1 308	1 884	1 308
Member	1 735	1 205	2 082	1 445	2 082	1 445
after 6 years	2 027	1 407	2 433	1 689	2 433	1 689
after 10 years	2 122	1 472	2 546	1 766	2 546	1 766
Senior Member	2 122	1 472	2 546	1 766	2 546	1 766
after 6yrs/age 40	2 300	1 595	2 759	1 914	2 759	1 914
Fellow	2 300	1 595	2 759	1 914	2 759	1 914
Retired Member (By-law B3.7.1)	975	675	1 170	810	n/a	n/a
Retired Member (By-law B3.7.3)	nil	nil	nil	nil	n/a	n/a

1. The fee for all new applications is R3010.00 which includes an entrance fee of R928.00. On election to the applicable grade of membership, the new member's account will be adjusted accordingly and refunds/additional payments made on request. Entrance fee for Students is free and new Student applicants require payment of R181.00.

2. Transfer fee to a higher grade is R504.00 for all grades of membership (except Student within 3 months of qualifying).

3. Members are encouraged to transfer to a higher grade when they qualify. It will be noted that the fees of Member and Senior Member grades after 10 and 6 years respectively are equal to the fees at the next higher grade.

4. Members elected after May 2021 pay a reduced subscription fee.

5. By-law B3.7.1 reads “Where a member in the age group of 55 to 70 years has retired from substantive employment in the engineering profession, such member may make written application to Council for recognition as a retired person and a reduced membership fee".

6. By-law B3.7.3 reads “any member complying with the conditions of B3.7.1 but who has been a member of the Institute for not less than 25 consecutive years, shall be exempt from the payment of further subscriptions.” Members who comply with the requirements of By-Law B3.7.3 may make written application to Council for exemption from paying subscriptions".

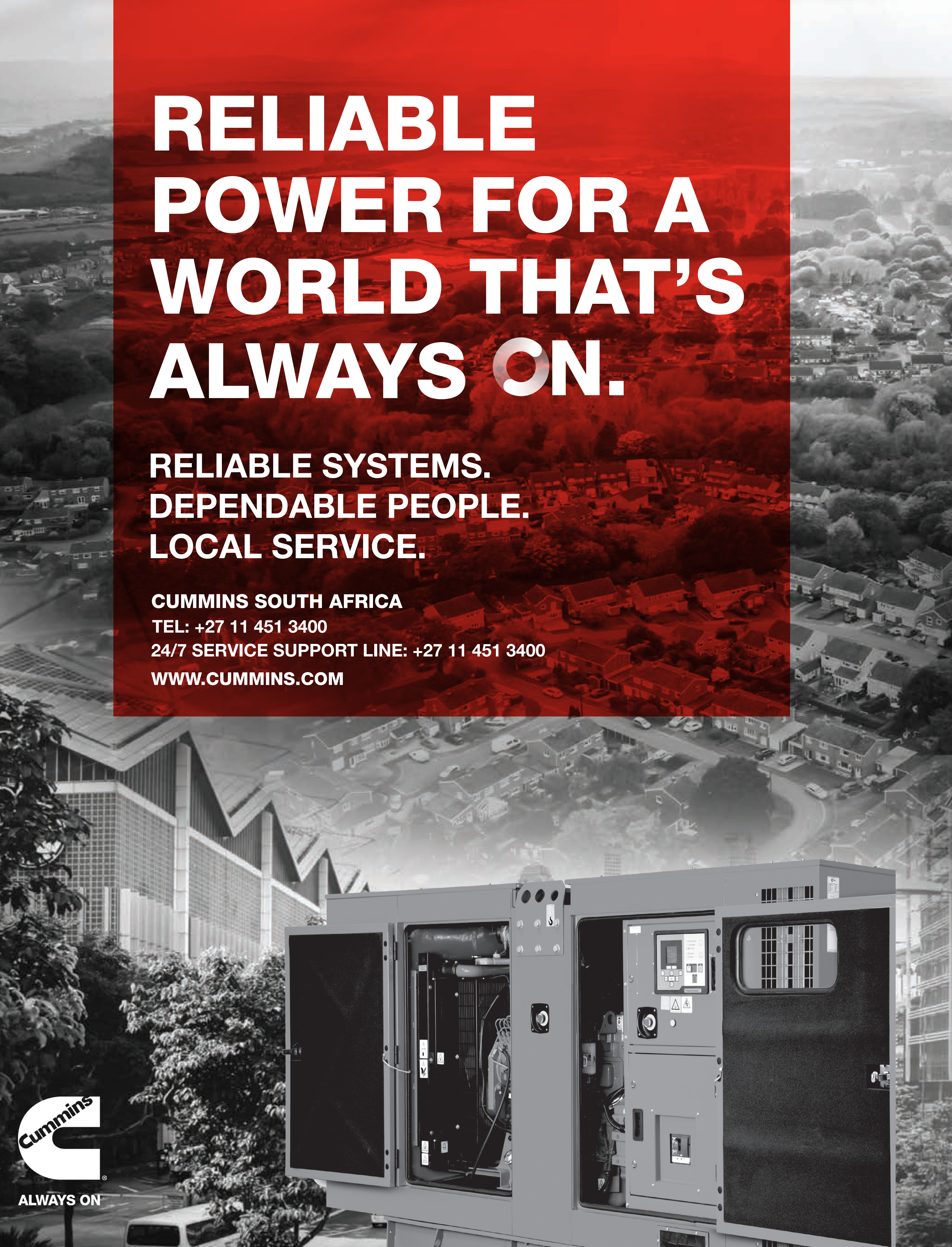
7. By-law B3.9 reads “any member in good standing who has been a member for fifty (50) consecutive years shall be exempt from the payment of further subscriptions.”

8. Members not in good standing by failing to pay their subscriptions by end of June of each year will, subject to Council decree, be struck-off the SAIEE membership role.

9. Members in good standing and no longer in substantive employment and do not receive payment or salary for work done may apply to Council for a reduction in their annual subscriptions.

10. The members monthly magazine ("wattnow") is available on line and members who require a hard copy may acquire same on request and for a nominal fee subject to minimum uptake numbers.

11. Members who wish to pay their membership fees in recurring payments should activate the payments on their banking portal. Members will receive the early bird discount only if their fees are fully paid by 31 March 2021.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