wattnow

THE OFFICIAL PUBLICATION OF THE SOUTH AFRICAN INSTITUTE OF ELECTRICAL ENGINEERS

POWER

MAY 2024

SAIEE

CONTENTS

SAIEE @SAIEE SAIEE

Dear **watt**now reader

As South Africa grapples with its current electricity crisis challenges, there is hope for a brighter future. The country has abundant renewable energy resources, including wind, solar, and hydropower, that have the potential to provide a sustainable and reliable source of electricity for the nation.

In recent years, there has been a significant increase in the development of renewable energy projects in South Africa, with the government setting ambitious targets for installing renewable energy capacity. These projects can increase the country's power generation capacity, reduce its dependence on fossil fuels, and lower carbon emissions.

One key driver of this shift towards renewable energy is the decreasing cost of technologies such as solar panels and wind turbines, making them more competitive with traditional power sources. This has opened up new opportunities for investment in the renewable energy sector, creating jobs and stimulating economic growth in the country.

This issue features various articles, from discussing Energy in South Africa and the forecast for the next ten years to optimisation tools inspired by natural processes.

The June issue features Motors and Drives, and the deadline is 13 May. Please send any article/news contributions to minx@saiee.org.za

Herewith the May issue; enjoy the read!

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Pascal Motsoasele
2024/5 SAIEE President

April is my first month as president of the SAIEE for the 2024-25 term of office. It is a great honour to write to you, our members, and the entire wattnow magazine's readership. The president usually produces a monthly report to the Council. I hope to make this letter a regular monthly feature in our magazine and social media platforms to keep our members abreast of my monthly activities and promote open and transparent communication with you.

So please feel free to engage me as often as you can. Feel free to respond to my letter by writing to our managing editor, Ms Minx Avrabos, and I will endeavour to respond to all of you timeously. I'll ask her to publish your outreach message and my response so the wider membership may benefit from whatever we discuss. Deal?

For this inaugural letter, I wish to inform you of my activities for the first month of office:

- As stated during my inaugural address, I want to promote regular interaction between myself and our members. I am pleased to announce that the email address president@saiee.org.za is now operational. Kindly feel free to reach out to me.
- I have noted that the various centres have been holding their Centre AGMs during the month, and others have yet to happen. I endeavour to attend those that have not yet happened as I have registered as an attendee for those that will be held online.
- As mentioned previously, I will not conduct a presidential tour and give my inaugural presentation to the Centres. I will visit the Centres upon their request. This is done to optimise by leveraging our online resources to communicate my message since there is a recording on our YouTube channel, SAIEETV. Therefore, there is no need to repeat the talk at each Centre—I'd rather we redirect the funds to improve our outreach and marketing efforts.
- On 17th April 2024, I attended the Telecoms Section's monthly online meeting. We discussed the IEEE Wireless Africa Conference that will be held at the University of Pretoria on 17-18 October 2024. Members of the SAIEE Telecoms Section are part of the planning committee. We also discussed our possible role in the IEEE Globecomm conference from 8-12 December 2024 at the CTICC, Cape Town. At the end of the meeting, a riveting presentation on 6G networks of the future was given – I want to encourage all Sections and Chapters to promote technology debates and information sharing during their meetings. These are quite invaluable, I feel.
- On 18th April 2024, the Women in Engineering Chapter held its AGM online, and I was invited to say a few words. Our past president, Ms Sy Gourrah, gave the keynote address, giving a thoughtful presentation in line with the theme "Inspiring Engineering Inclusion." This was very fitting because she is the visionary and founder of that very Chapter. I am happy to report that Ms Matshedisho Phoshoko has ascended to the chairmanship of this Chapter; we wish her and her team all the best.
- On 19th April 2024 I attended the hybrid (i.e., online via MS Teams and in-person at the SAIEE Council Chambers) nuclear discussion titled "Symposium on Research, Development, and Innovation on Peaceful Uses of Nuclear Technology" organised by the Nuclear Chapter in collaboration with ASSAf, the Department of Science and Innovation, the University of Johannesburg, SANEDI, the South African Academy of Engineering, Wits University, SAICHE and SAIMechE. There was an in-principle agreement for further collaboration, and some MoUs will

be drafted by that end.

- On Saturday, 20th April 2024, I was invited by the Central Gauteng Centre to give a keynote address at their STEM outreach event in KwaThema, Springs, where I was met by 310 students from 4 different schools. I wish to congratulate the Centre on its collaboration efforts with other associations that encourage school kids' uptake of STEM subjects. It was a successful event – I saw banners from Unisa's Engineering Faculty, the National Science & Technology Forum (NSTF)'s Stimulator, the Pfuxani STEM Foundation, the Council for the Build Environment (CBE), Love Life, and others.
- On 23rd April 2024, I attended the SAIEE Corporate Forum meeting at the Council Chambers. Some of the corporate partners joined us online via MS Teams. I might need to take up golf, as some partners expressed interest in a Charity Gold Day event 😊. We also discussed our corporate social responsibility policies (e.g., bursaries, community outreach, STEM promotion at schools, student internship placements, mentorship, etc.) with them, and some MoUs (e.g., NECSA) are currently being developed.
- On 24th April 2024, I attended the Events & Marketing Committee meeting, where, among others, we discussed sourcing speakers for the Presidential Invitation Lecture and the Bernard Price Memorial Lecture. Please suggest names of suitable speakers, and we will try to approach them.
- On the 25th of April 2024, I attended the Centre Chairs meeting as an ex officio. It wasn't very reassuring to see that many Centres did not send a representative to the meeting, nor did they offer an apology for the meeting. My focus for the year is to stimulate Centre activity and interest. Towards this, I will be reaching out to the Centre Chairs directly during May. I want to have their voices heard and learn how best to serve them.
- On 30th April 2024, I will attend the KZN Centre's AGM presentations online. Their theme is "Building Eminence in the Engineering Profession", and they have a lineout of speakers advertised on our social media platforms.

We will hold our Council meeting online on Friday (3rd May 2024). The Honorary Treasurer (Prof Pat Naidoo) and I will be attending in person from our Council Chambers, as we will be meeting with our Auditors at SAIEE House earlier during the day. Everyone and anyone interested is welcome to join us; I believe in the open-door policy. Remember to invite me should you wish to visit your Centre.

Yours in service of the Institute. wn

PASCAL MOTSOASELE FSAIEE
PRESIDENT

Retirement Village visits SAIEE's Max Clarke Museum

Guests visit to the SAIEE Max Clarke Museum.

On the 15th of April in 2024, Bill Bergman, a Fellow of the South African Institute of Electrical Engineers (FSAIEE), took a group of residents from Rand Aid's Inyoni Creek Retirement Village to visit the Max Clarke Museum, which is run by the SAIEE. The group was treated to a delightful tea before they embarked on the museum tour, where they found the exhibits to be intriguing and beautifully presented.

From left: Bill Bergman and Prof Pat Naidoo at the handover of the AVO meter.

After the museum visit, the group gathered in the conference room to listen to Prof. Dr Pat Naidoo, the Past President of SAIEE. Prof. Naidoo spoke about the Institute's mission and activities and answered questions from the audience. A highlight of the afternoon was when Bill Bergman presented an antique AVO meter that was used by the South African Corp of Signals during World War II to add to the museum's collection.

After the visit, Mel Stamelman, a member of the Inyoni group, expressed gratitude to Pat Naidoo and Gerda Geyer for arranging such an enjoyable and informative visit to the SAIEE. The visit was a memorable experience that left the visitors with a better understanding of the Institute's work and its contribution to the field of electrical engineering. wn

Mel Stamelman, Inyoni Group.

Empowering minds

- NEMISA, CUT AND #SAIEEFSC JOIN FORCES IN DIGITAL LITERACY AND DATA SCIENCE TRAINING

Bloemfontein Facilitator for Digital Literacy and Data Science 101 and SAIEE Student chapter chairperson: Mr Mpho Oganne, Mrs Mpho Wittes, Mr Africa Dintwe, Mrs Diteboho Mokhohlane, Mr Thabo Letooane, Mrs Tshili Morobane and Mr Teboho Stols

Central University of Technology (CUT), Bloemfontein, trained 126 individuals from the community in the National Electronic Media Institute of South Africa's (NEMISA) Microsoft Digital Literacy and IBM Data Science 101 from March 25th to 28th, 2024. At the heart of this initiative was Mr Africa Dintwe, the Free State Colab Director for NEMISA.

Working under the guidance of Prof Masinde, the Acting Dean of the Faculty of Engineering, Built Environment, and Information Technology, Mr Dintwe orchestrated a comprehensive training program designed to meet the diverse needs and aspirations of the participants.

The training program received a boost of inspiration with the presence of esteemed guests from the South African Institute of Electrical Engineers (SAIEE) Free State Centre (FSC). Mr Lucky Mokalusi, the Chairperson of #SAIEEFSC, and Mr Thabo Letooane, the Student Chapter Chairperson, shared their insights and experiences to motivate and inspire aspiring learners. The main aim was to promote #SAIEEFSC, underscored by a commitment to nurturing talent and fostering innovation within the community.

On March 28th, participants received their certificates of completion. Their achievements are a testament to the power of collaboration and dedication in driving meaningful change within communities.

The success of this initiative is a testament to the strong partnership between NEMISA and CUT. Their shared commitment to education and innovation has enabled countless individuals to realise their full potential and contribute meaningfully to society.

In conclusion, the partnership among NEMISA, CUT, and #SAIEEFSC is a shining example of what can be achieved when organisations come together with a shared vision and purpose. Through education and empowerment, they are laying the foundation for a brighter, more inclusive future for all.

Schneider Electric Spark Your Interest in Electricity online course impacts more than a thousand youth.

Zanélle Dalglish
Global Leader: Training & Education
Schneider Electric

The free interactive online training course, Spark Your Interest in Electricity has since its launch, more than a year ago, seen approximately 1700 students from English-speaking Africa enrolling into the course and completing one or more sub courses. To date, the majority of enrolments have been from South Africa, Kenya and Nigeria.

The free interactive online training course, "Spark Your Interest in Electricity" has since its launch, more than a year ago, seen approximately 1700 students from English-speaking Africa enrolling into the course and completing one or more sub courses. To date, the majority of enrolments have been from South Africa, Kenya and Nigeria.

"The Spark Your Interest in Electricity" course, which was designed and launched in a partnership between Schneider Electric and multimedia giant Trace, is available on the Trace Academia app from both the Google Play (Android) and Apple iStore (iOS) platforms.

"Schneider Electric is leading the way when it comes to providing training to the youth. With the world becoming increasingly more digital and virtual, we've ensured that that our training approach keeps up with these evolving trends," says Zanélle Dalglish, Global Leader: Training & Education Affairs, who was instrumental in establishing this course with Trace Academia.

"The Spark Your Interest in Electricity course provides an introduction to electricity for NEET youth (Neither in Employment Education or Training) as well as anyone that is interested to understand the basics of electricity.

The course was designed and developed by a team of experts from South Africa that carefully designed the course curriculum to include the important modules required to Spark your Interest in Electricity," says Dalglish.

The "Spark Your Interest in Electricity" course has been developed in line with Trace Academia's criteria for course certification which includes a rigorous approval process and aims to provide a virtual hands-on training in the field of electricity.

It also serves as a precursor to encourages youth to take the next step; enrolling in an electricians or related course provided at various tertiary and vocational institutions.

To obtain a "Spark Your Interest in Electricity" certification, which serves as an introduction to electricity, students must complete the entire course syllabus which includes eight modules:

- Discover The Magic of Electricity,
- Electrical Sockets and Light Fittings.
- Connecting Wires.
- Principles Of Electricity.
- Discover Circuit Breakers.
- Understand Series and Parallel Circuits.
- What Are Electrical Hazards.
- What Is an Earth-Leakage Device?

"Our aim with the course material is to truly spark students' interest, laying the groundwork for future studies in the electrical trade. Module 1 of the course delves into the magic of electricity, including its formation, movement, and storage, while module 7, for example, provides insight into understanding series and parallel circuits which is fundamental to any electrical work," explains Avin Ramjeeth, Projects & Offer Manager at the Schneider Electric Academy. wn

CHIETA welcomes the Hydrogen Skills Research Report released by Minister Nzimande

Yershen Pillay
Chief Executive, CHIETA

The Chemical Industries Education and Training Authority (CHIETA) welcomed the release of a groundbreaking research report mapping the way forward for "Identification of Skills Needs for the Hydrogen Economy." The Chemical Industries Education and Training Authority (CHIETA) welcomed the release of a groundbreaking research report mapping the way forward for "Identification of Skills Needs for the Hydrogen Economy."

This report, prepared for the Department of Higher Education and Training's Labour Market Intelligence (LMI) Research Programme, addresses the critical skills requirements for South Africa's transition to a green hydrogen economy.

Speaking at the CSIR in Pretoria on Tuesday, 16 April, the Minister of Higher Education, Science Innovation, Dr Blade Nzimande, said the LMI, in response to the needs of the economy and the labour market, undertook a project to identify skills for the hydrogen economy. The hydrogen economy is expected to grow phenomenally in South Africa, and R319 million of the R1.4 trillion of the Just Energy Transition investment plan has already been targeted for this sector. The Minister said South Africa commands high respect from the International Labour Organisation (ILO), the European Union (EU), the World Bank and the OECD for the research conducted through the LMI projects.

"We are now moving towards supporting provincial level skills planning as well as industry-specific planning tailored to the specific needs and policy context of South Africa in the 21st Century," the Minister said.

The report identifies 138 new green hydrogen value chain roles, including engineers, technicians, tradespeople, specialists, and managerial and elementary-level occupations.

Seventy-seven occupations not reflected in the Organizing Framework for Occupations (OFO) were recognised, highlighting the need for additional skills and qualifications.

The global hydrogen economy is experiencing rapid growth, with green hydrogen playing a crucial role in developing a sustainable energy future. Green hydrogen enables the decarbonisation of hard-to-abate sectors such as heavy-duty transport, cement, steel, mining, refineries, chemicals, agriculture, and plastics.

Recognising the potential of green hydrogen, South Africa is driven to determine how to leverage this resource to aid its path to net-zero emissions and address poverty, unemployment, and inequality challenges.

In responding to the report, CHIETA will lead the establishment of a Centre of Specialisation for Green Hydrogen Skills to close the hydrogen skills gap and ensure South Africa has the 138 skills to grow the hydrogen economy. CHIETA, MQA, and TETA will collaborate to establish this multimillion-dollar centre by 2025.

The report identified the three SETAs as central to the growth of the green hydrogen economy.

The report added that 74 degree and diploma programs are required for the hydrogen economy, 50 of which are already offered in South African institutions. However, 24 additional programs are needed to thoroughly meet the sector's skills demands.

"This research report underscores the importance of proactive skills development to support South Africa's transition to a green hydrogen economy," said Yershen Pillay, CEO, CHIETA. wn

UAE power mix will continue to be dominated by thermal power in next decade, says GlobalData

With the discovery of more onshore hydrocarbon reserves, the United Arab Emirates (UAE) is aiming to become self-sufficient in gas supply by the year 2030. Currently, the country is dependent on gas imports for power plants and water desalination plants. As of 2023, thermal power generation comprised around 77.7% of the total power generation mix of the country. Due to the presence of large gas and oil reserves, thermal power will continue to dominate the power generation mix in the UAE during 2023-35, says GlobalData, a leading data and analytics company.

GlobalData's latest report, "UAE Power Market Size, Trends, Regulations, Competitive Landscape and Forecast, 2024-2035," reveals that the installed capacity share of thermal power in the UAE was around 80.4% in 2023, where gas-based thermal power capacity dominated the power capacity mix with a share of 80.2%.

Sudeshna Sarmah, Power Analyst at GlobalData, comments: "With the discovery of new hydrocarbon reserves, the UAE is planning to invest heavily in hydrocarbon infrastructure and seek to develop new production techniques. At present, the country is in the process of choosing new locations to set up new infrastructure and seeking unconventional methods for hydrocarbon production."

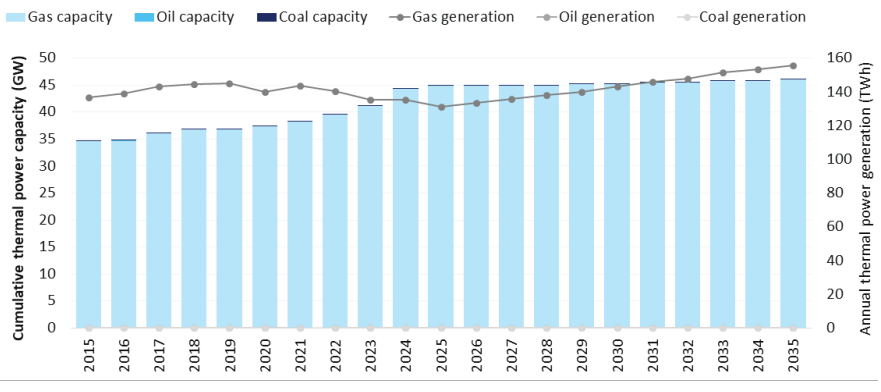
In 2023, gas was the dominant technology, contributing around 99.8% of thermal capacity. Oil and coal contributed around 0.1% each, respectively. By 2035, the cumulative thermal power capacity is expected to increase further to 46.1GW from 41.2GW in 2023, rising at a compound annual growth rate (CAGR) of 0.9% during the period. Annual generation from thermal power sources is estimated to rise from 135.5TWh in 2023 to 155.9TWh in 2035, increasing at a CAGR of 1.2%.

Sarmah adds: "Most of the increase in capacity is expected in gas-based thermal power rather than oil, whose capacity is expected to remain almost unchanged. Gas turbine manufacturers can benefit from this increase in gas-fired power capacity."

Sarmah concludes: "Since 1971, the UAE has relied on its large oil and natural gas resources to support its economy. Rapid economic and demographic growth over the past decade has pushed the UAE's electricity grid to its limits.

The UAE is planning to add nuclear, renewable, and coal–fired electricity generating capacity to accommodate rising demand. Despite the UAE's vast deserts, only small progress has been made in the direction of harnessing renewable energy resources." wn

Thermal Power Capacity and Generation, UAE, 2015-2035



GlobalData.

Source: GlobalData Power Intelligence Center

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Cape Town copes with power cuts

South Africans, especially in the Mother City and its vibrant CBD, display remarkable resilience and adaptability despite the country's power cuts. The Cape Town CBD have developed effective coping mechanisms, saved energy, and embraced renewables, which has been inspirational.

City centre resident and architect Brian Paul, who works from his home-based studio in an eight-storey residential complex just off Long St, and his wife Cecile, a Cape Town fashion designer, have kept power cuts from affecting their lifestyle and attitude.

"I use the stairs more now, even if the lift works. I see it as an opportunity to improve my fitness. Having grown up in Europe, walking up four or five flights is commonplace," Brian Paul says.

He adds that the power scarcity has also made them far more conscious about their electricity use. For example, keeping a geyser at boiling point for 24 hours for a 10-minute shower is "madness".

CCID ENERGY CAMPAIGN

It is precisely this thinking that the Cape Town Central City Improvement District's (CCID) "Switch on to Switching Off" campaign, now in its third month, seeks to encourage.

The initiative is a step-by-step guide recommending various actions stakeholders who own or rent property or work, live, or visit the CBD can take to save electricity.

These include energy audits to identify areas of high energy consumption, upgrading to LED lighting, optimising heating, ventilation, and air conditioning (HVAC) systems, promoting energy-saving behaviour, using energy-efficient office equipment, and installing renewable energy systems.

CCID Chairperson and CEO of Boxwood Property, Rob Kane, has praised Cape Town CBD stakeholders for embracing the campaign.

"We fully recognise the challenges they face due to the energy crisis, yet they have shown incredible spirit in helping to save power in the inner city," he says.

CITY INITIATIVES

Several City of Cape Town projects are starting to yield positive results, which have lifted residents' spirits.

In February, it was announced that since the start of the 2022/23 financial year, Cape Town businesses and households had earned more than R25.8 million under the City's Cash for Power programme.

The programme enables power sellers to earn credits against their total municipal bill and, in return, receive cash for power fed back into the grid.

Matthew Kempthorne, the chairperson of Sub-council 16, which includes the CBD, Atlantic Seaboard, and Paarden Eiland industrial area wards, says the City has been highly proactive.

"We were the first City in South Africa to allow small-scale embedded generation, where generators operate in parallel with the national grid. The City's Power Heroes initiative has also been highly successful."

This program involves installing smart meter devices that can be operated

remotely by the City's Network Control Centre to switch off non-essential loads like geysers and pool pumps when the network is constrained.

"We have also converted all traffic lights to LED, which is saving R14 million in electricity a year, and are retrofitting our streetlights," Kempthorne says.

Kempthorne and Paul agree that as "irritating" power cuts are, there is still plenty to love about South Africa and Cape Town, in particular.

"Unlike Europe, Cape Town's warm climate means we don't need central heating, whereas Europeans need a constant power supply for space and water heating," Paul says.

"Europe has power outages too – they just don't make the headlines!"

Read more about the CCID campaign here; download the digital booklet with eight energy-saving steps for businesses, landlords, and residents at https://bit.ly/49Qi7QX; and click here for the energy-saving poster. wn

OEM High-Pressure Transducer with Maximum Long-Term Stability

INSTROTECH, the local representative of KELLER, a Swiss-based market leader in the production of isolated pressure transducers and transmitters, is offering KELLER 10LHP (with the low-pressure variant 10L), the flagship OEM pressure transducer in the KELLER product portfolio and exemplifies the highest standards.

The KELLER 10L and 10LHP series are available in identical dimensions and cover pressures ranging from 0,1 to 1000 bar together. Both series are principal products in the KELLER OEM portfolio and offer an optimum solution for demanding applications.

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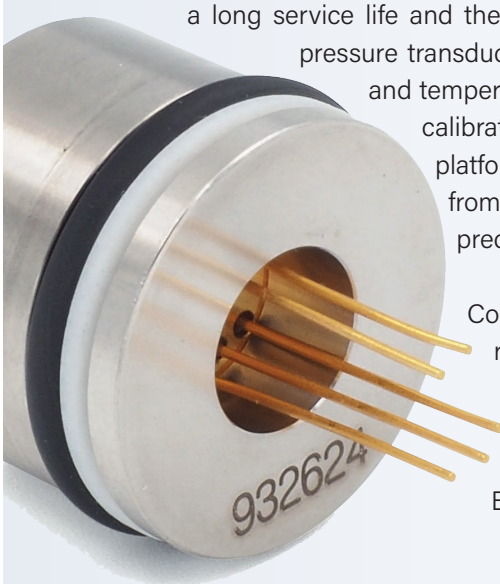
Dimensions	⌀ 19 mm x 15 mm
Temperature Range	-20…100 °C

The high-pressure transducers of the 10LHP series have a robust housing made of stainless steel, giving optimum long-term stability for a range of OEM applications. The metal diaphragm is welded on front-flush and gap-free, separating the silicon piezoresistive pressure sensor from the measuring medium. Every pressure transducer is measured over the entire pressure and temperature profile and is supplied with a detailed calibration sheet.

The 10LHP achieves maximum accuracy and long-term stability thanks to optimally matched, high-quality materials. The compact, robust design offers a long service life and the highest product quality. Every KELLER pressure transducer is measured over the entire pressure and temperature range and is supplied with detailed calibration data via KELLER's myCalibration platform. The OEM pressure transducer 10LHP from KELLER stands for the highest quality, precision, and durability. wn



Contact INSTROTECH, the local representative, for more information on KELLER's OEM High-Pressure Transducer with Maximum Long-Term Stability.

Email: sales@instrotech.co.za

Hitachi Energy and SP Energy Networks to boost renewable energy flow

Hitachi Energy has won an order from SP Energy Networks to design and deliver a first-of-its-kind power quality solution to balance the grid and boost the flow of renewable energy across the UK. The solution will enable SP Energy Networks, the electricity network operator for Central & Southern Scotland and Merseyside, Cheshire, North & Mid-Wales, and North Shropshire, to add more renewables to the grid and facilitate the phase-out of fossil fuels.

The project at SP Energy Networks' substation at Eccles consists of two sets of an SVC Light® STATCOM1 and a synchronous condenser controlled centrally by the MACH™ control system, connected at a common electrical node. This unique combination of technologies will maximise the future power system's potential while providing increased system resilience, thus supporting the increasing integration of renewables into the electricity grid.

Each STATCOM installation uses Hitachi Energy's advanced power electronics and technology-leading MACH2 control and protection solution to provide system strength and instantaneous voltage control and enable maximum power flow.

This technology, which entrusts a STATCOM to control a local synchronous condenser, is market-leading. It builds on an earlier collaboration between SP Energy Networks and Hitachi Energy on the network innovation competition project Phoenix, supported by Ofgem, the UK energy regulator.

"The innovative power quality solution will increase the transfer capacity across the UK by up to 280 MW by improving the transmission network's strength as more renewable generation is connected in Scotland," said Billy Moore, Senior Project Manager at SP Energy Networks." The criticality of technology such as this will become more important as we reduce the usage of fossil fuels."

"We are delighted to have co-created this innovative solution with SP Energy Networks, which will maintain grid stability and enable more clean electricity to flow through the system in the UK," said Marco Berardi, Head of Grid & Power Quality Solutions and Service business at Hitachi Energy. "This pioneering innovation is another addition to our ever-evolving portfolio of power quality solu-tions that help grid operators overcome the immediate and long-term challenges of the energy transition."

With the integration of more renewable energy into the grid and the move away from conventional power plants, transmission system operators face several challenges. In this project, the SVC Light STATCOM and synchronous condenser, combined with control, generate or absorb reactive power to adjust the grid voltage and maintain system resilience. wn

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Aluminium Alloy Junction Boxes are ideal for urban installations

Eldon Kruger
Marketing Director
Pratley

Pratley Aluminium Alloy Junction Boxes can be used in multiple applications for urban installations

Aluminium Alloy Electrical Junction Boxes from leading electrical termination manufacturer Pratley can be used in multiple applications in urban areas to distribute and connect cables. Some examples include connecting power supply cables to external buildings, swimming pool pumps, gate motors, outside lighting, or CCTV camera installations. "These handy junction boxes are also ideal for supplying power to outside lapas and patios," says Marketing Director Eldon Kruger.

Pratley also manufactures Aluminium Alloy Junction Boxes to supply main municipal power to houses, the most popular being the Pratley Aluminium Alloy Roof Connection Box and the Pratley Aluminium Alloy Foundation Box.

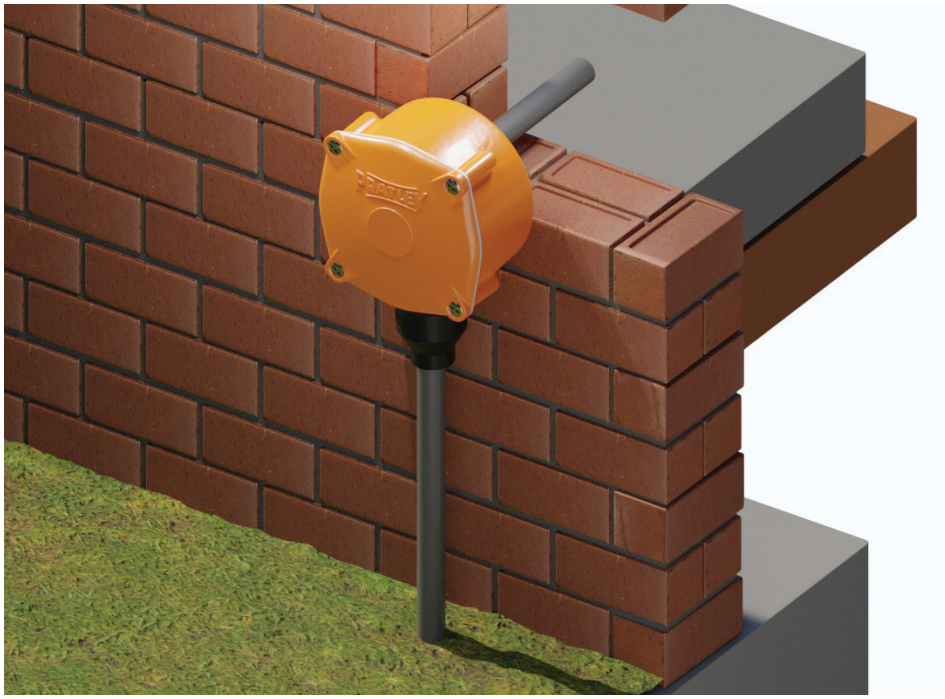
The Roof Connection Box is used where the municipal supply cables run overhead. The box is installed on the roof to form a connection point between the overhead cable and the supply to the main distribution board.

Another method of supplying municipal power to a house is using underground cables, and the Foundation Box is ideal for this. It is mounted on the outside wall of the house, just above the foundation, hence its name. The main power is connected inside the foundation box, from which the supply cable, in turn, is connected to the main distribution board inside the house.

The durability of the Pratley Aluminium Alloy Junction Boxes means they are often used to replace damaged, inferior-type plastic junction boxes. They are manufactured from a lightweight, strong, and impact-resistant aluminium alloy that is powder-coated to ensure corrosion resistance and longevity once installed.

Pratley Aluminium Alloy Conduit Box

"We recommend that any installation is carried out by qualified electricians or CCTV technicians," highlights Eldon. All junction boxes are tested in Pratley's in-house test laboratory, and third-party tested by the SABS are tested to be totally water- and dust-tight.



Pratley Aluminium Alloy Foundation Box mounted on the outside wall of a house above the foundation

Mains power is connected inside the Pratley Aluminium Alloy Foundation Box

Unlike some inferior imported junction boxes, Pratley Aluminium Alloy Junction Boxes do not deteriorate when exposed to sunlight and the elements, which means complete peace of mind for years after they are installed.

Pratley Aluminium Alloy Junction Boxes can be purchased prepopulated with rail-mounted terminals in various configurations and sizes. They feature built-in cable glands, making them the ideal 'turnkey' solution for many urban electrical connections. All Pratley junction boxes are suitable for armoured and unarmoured cables and can be factory-pre-fitted according to customer requirements.

"Our policy statement states that the performance of our products must exceed all others on the world market. The Pratley Aluminium Alloy Junction Box range is no exception to this statement," concludes Eldon.

For further information, visit our comprehensive website at www.pratleyelectrical.com or contact our Sales Office at (011) 955 2190 or email sales@pratley.co.za for assistance.

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UPS trade-in helps South African IT industry protect environment

A world without waste is possible. It only requires deliberate action, commitment, and critical mass to make it a reality. Intelligent power management technology manufacturer Eaton is offering a 15% rebate on trade-ins of older UPS systems and 20% rebate when purchasing warranty extensions and an additional 2% for PAP members to commercial uninterrupted power supply (UPS) users who purchase newer, superior models in its 'UPS Trade-In 2024' campaign aimed at reducing environmental chemical waste.

Customers using older technology can hand in their old UPS devices through their IT Distributors and receive a 15% discount when upgrading their current UPS.

"Communities and municipalities are grappling with growing pressure to provide adequate waste management services due to increased waste generation," says Jessica Masina, DPQ Field Product Marketing Manager at Eaton.

"As South Africans use more batteries for a variety of applications amidst an energy shortage, Eaton realised the need to improve recycling rates in the UPS systems that we develop.

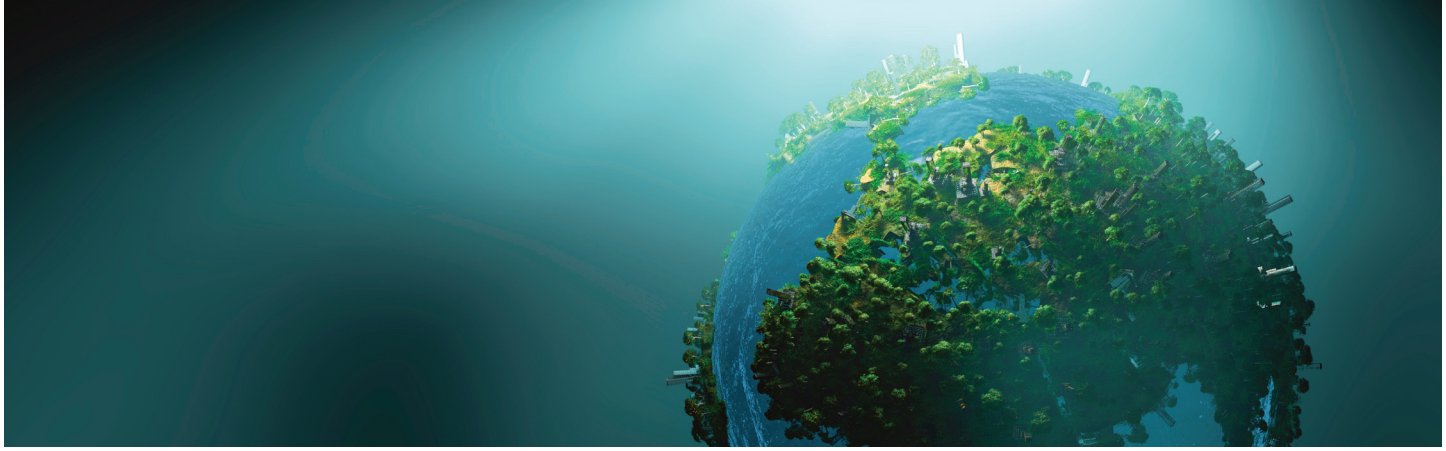
"As we support users in renewing their power storage and backup systems to be more sustainable in their operations, (we also want to contribute to a more sustainable and responsible IT upgrade) with the aim to significantly alleviate the impact of waste on the environment," Jesscia says. South Africa is experiencing a worsening waste challenge, producing almost 13 million tonnes of waste per annum. Around 90% of this waste ends up in landfills, with only 7,5% being recycled, according to the United Nations Environment Programme.

The Commonwealth Scientific and Industrial Research Organisation (CSIRO), an Australian public research body, considers battery recycling, particularly Lithium-ion batteries, to be a "serious waste problem".

With the increased use of renewable power and storage systems around the world for homes, businesses, and even vehicles, CSIRO projects the global market for lithium-ion batteries to increase tenfold between 2020 to 2030. In 2020, the market reached 250 Gigawatt hours (GWh), or 250 million kWh. The average South African household consumes around 4500 kWh.

There are several reasons why UPS battery recycling is significant. First and foremost, batteries contain toxic chemicals that can harm human life if not disposed of correctly. When thrown in landfills, these chemicals can leach into the soil and contaminate the water supply. By recycling UPS batteries, we can ensure that these toxic chemicals are disposed of properly, preventing them from causing harm.

While lead acid batteries (like those found in motor vehicles) are recycled at around 99%, lithium-ion batteries (used in toys, rechargeable home electronics, watches, electric vehicles, home, and



business power storage systems) are only recycled at around 5% due to the difficult and costly recycling process. The recycling process for lead-acid batteries involves crushing the batteries, submerging them in liquid, and then separating the lead and plastic components. Lithium-ion batteries, on the other hand, are recycled in large plants using a more complex process that involves dismantling and shredding the battery, then melting it down or dissolving it in acid.

As the demand for UPS systems increase, so does the need to address the environmental impact of UPS battery disposal. Eaton's Trade-In Drive is designed to make the lives of IT managers easier by allowing them to buy a new best-in-class UPS while disposing of their old one in an environmentally responsible way.

By participating in this campaign, customers can enjoy the benefits of a well-performing UPS, including Value Proposition based on the campaign benefits:

- **Continuity of operations:** latest UPS systems provide reliable power backup, ensuring that business operations continue seamlessly, even during power outages.
- **Data protection**: safeguarding against data loss or corruption through safe system shutdown or switch to backup power during power disruptions.
- **Device protection:** mitigating the risk of damage to sensitive IT equipment by regulating power supply during voltage spikes or fluctuations.
- **Efficiency and compatibility:** newer UPS systems are more energy-efficient, reducing the energy costs. They also offer better compatibility with the existing IT infrastructure and come with improved features, such as better management software or improved power factor.
- **Expert Support:** throughout the process, customers receive support from experts who ensure a smooth transition and address any concerns.
- **Eco-Friendly Disposal:** for those opting for UPS replacement, contribute to environmental sustainability by responsibly disposing of old equipment through our eco-friendly practices.

"As the update of backup power systems ramp up globally and in South Africa, the public and private sectors will need to continue developing innovative recycling systems and incentives to help support the sustainability of natural resources, including mineral, water and soil quality and availability," Jessica says.

Beware of the fire risk posed by lithium-ion batteries

As renewable energy systems, including solar panels and battery energy storage systems (BESS), gain popularity, experts caution about the potential fire risks posed by lithium-ion batteries. Lithium-ion batteries are commonly used in energy storage systems, which pose unique fire hazards due to their flammable electrolytes, highlights ASP Fire CEO Michael van Niekerk.

Unlike traditional lead-acid batteries, lithium-ion batteries can undergo thermal runaway, leading to intense fires that are difficult to extinguish. The risk is compounded by the emission of flammable gases during thermal runaway that can result in explosions if ignited.

Van Niekerk stresses the importance of adequate safety measures, recommending the construction of two-hour fire-rated rooms to house lithium-ion batteries.

Proper ventilation and gas detection systems are essential to manage the off-gassing phenomenon associated with these batteries. In addition, fire dampers are recommended to contain potential fires within designated areas, minimising the risk of spreading to larger structures.

While large-scale energy storage systems, such as those installed by electricity utilities, may adopt different risk management strategies, van Niekerk underscores the importance of considering safety precautions in all installations. "The risks associated with improperly installed solar panels and batteries are significant in residential settings where DIY installations are common," he cautions.

In light of these concerns, ASP Fire stresses the need to consult a professional to design, install, and certify renewable energy systems. Proper integration and monitoring of components and adherence to safety standards significantly reduce the risk of fire incidents.

The growing interest in renewable energy solutions has prompted ASP Fire to collaborate with solar panel engineering firms, offering its expertise in fire safety design. "At a recent project in Sea Point, Cape Town, improper installation of batteries in a block of flats raised serious safety concerns. Our intervention as a fire safety professional helped rectify the situation, stressing the importance of seeking expert advice," concludes van Niekerk. wn

Vertiv Adds New Single-Phase, Global Voltage Output UPS Models to Fast-Growing Lithium-Ion Portfolio

Karsten Winther
President
Vertiv EMEA Region

Vertiv (NYSE: VRT), a global provider of critical digital infrastructure and continuity solutions, todayintroduced the extension of the Vertiv™ Liebert® GXT5 Lithium-Ion double-conversion, on-line uninterruptible power supply (UPS) system for 5kVA-10kVA Global Voltage (GV) (200V-240V; Default 230V) applications.

This expansion of the Liebert GXT5 Lithium-Ion line to 10kVA (from 1-3kVA) further rounds out the Vertiv portfolio of lithium-ion UPS systems and solutions for the edge of the network. Vertiv is now accepting orders for the new 5-10kVA GV models in Europe, Middle East and Africa (EMEA), and shipping from current inventories.

The Liebert GXT5 Lithium-Ion models are designed for the smaller spaces typical of the network edge, with a convertible rack/tower design and only a 3U (5kVA to 10kVA UPS) rack height. These GXT5 LI GV models include an integrated maintenance bypass cabinet preserving additional rack U-space. All Liebert GXT5 Lithium-Ion UPS systems come with a five-year limited warranty.

The higher power density of lithium-ion batteries enabled Vertiv to pack more runtime in less space compared to a typical UPS with valve-regulated lead acid (VRLA) batteries, and that runtime can be extended with up to eight external battery cabinets.

With improved performance at higher operating temperatures and longer life expectancy, the lithium-ion batteries in the Liebert GXT5 Lithium-Ion reduce the total cost of ownership by up to 50% compared to VRLA solutions.

In addition, lithium-ion batteries typically last eight to 10 years, compared to about three to five years for VRLA batteries, reducing or eliminating the cost and inconvenience of battery replacements during the life of the UPS.

"With this expanded offering, Vertiv is poised to capitalise on the expected rapid growth of lithium-ion batteries," stated Karsten Winther, president for Vertiv in the EMEA region.

"The Liebert GXT5 Lithium-Ion UPS offers compactness, versatility, and low-maintenance, presenting an efficient solution perfectly suited for remote sites with minimal onsite technical support."

According to Omdia, lithium-based battery adoption for UPS in data centres is expected to continue its fast growth and soon dominate the UPS battery market, reaching 65% of global revenue by 2030.

For more information on the Vertiv™ Liebert® GXT5 Lithium-Ion UPS family or other Vertiv power and cooling solutions, visit Vertiv.com. wn

The front view of the sleek Vertiv GXT5LI-5000MVRT3UXLN.

SAIEE Student Membership Fees waived until 31 August 2024!

The South African Institute of Electrical Engineers (SAIEE) is always looking at novel ways to grow the institute and to ensure sustainability.

OUR GROWTH COMES IN TWO FORMS:

1. From new members who are already in the field, and

2. From organic conversion from student members to members/associates.

Any organisation worth its salt knows that the most significant contribution to an institute comes from converting its student members into members. Being an SAIEE student member costs R205, payable annually.

IS THIS COST REASONABLE OR NOT?

As students at Higher Education Institutions (HEI), which constitute South Africa as either a University, University of Technology or TVET College, we know that tuition fees are expensive. This was evidenced by the 2018 student strike at Wits University, which resulted in the government resolving to offer free education through the National Student Financial Aid Scheme (NSFAS) scheme.

Typically, any social club or grouping must register at the HEI to be recognised, and after that comes the hard slog of recruiting other like-minded individuals to join the cause. In our instance, Electrical Engineering students should get involved with the HEI student chapter.

To date, there has been a vexing question about what a reasonable amount to charge for student membership is.

The SAIEE has decided on the following:

1. The SAIEE Student Membership fees remain current and will remain the same for the next five years.
2. The SAIEE Student Membership fees will be waived until 31 August 2024.
3. The waiver in point 2 above is communicated to student members as a discount for the recommended period.

For more information on SAIEE Student Membership, feel free to contact our dependable Membership Team via the following details:

Connie Makhalemele
T: 011-487-9045 or email
connie@saiee.org.za

Thandolwethu Lefutso
T: 011-487-9050 or email
thando@saiee.org.za

Alternatively, navigate to the SAIEE website Membership pages for more information: bit.ly/JoinSAIEE wn

JOIN SAIEE

- the gateway for a successful career

Make a difference today - join us!

The South African Institute of Electrical Engineers (SAIEE), founded in 1909, strives to provide leadership to all its engineering practitioner members in becoming more effective in providing and enhancing the quality of life of all communities in Southern Africa.

AS A STUDENT, YOU ARE THE FUTURE.

Any engineering student signing up between 1 March and 31 August 2024 will receive free membership for the year. Apply now!

Click here on how to become a member today!

SAIEE

For more info, email Dudu Madondo - reception@saiee.org.za

Exploring renewable energy career paths for youth in South Africa

A remarkable expansion is underway in South Africa's energy sector. The country increasingly embraces renewable energy sources, spurred by pragmatic considerations such as sustainability, economic competitiveness, and environmental responsibility. As South Africa strives to address global challenges like climate change and energy security, the renewable energy sector is brimming with exciting career paths for the next generation.

Here, Temporary Employment Services (TES) providers can play a vital role in bridging the gap between South Africa's young workforce and the renewable energy sector's growing labour needs. TES providers can empower young people to enter this rapidly growing industry by facilitating placements and participating in skills development partnerships with industry players.

The energy crisis - a catalyst for change

The urgency behind our transition to renewable energy is heightened by an ongoing energy crisis characterised by load shedding – deliberate, rolling power cuts implemented to manage electricity demand. This crisis highlights the need for a more sustainable, secure energy system, and renewable energy sources like solar and wind offer a viable solution that harnesses clean and abundant natural resources to power the nation.

THE PROMISE OF RENEWABLE ENERGY FOR EMPLOYMENT IN SOUTH AFRICA

Given that it is predicted that by 2029, at least 19.28% of all energy used will be from renewable sources, it is clear that this industry will keep growing, with the private sector actively leading the expansion. The surge in adoption indicates a shift towards sustainable practices and signifies a promising future for renewable energy in our country.

Positively, this growth in the renewable energy sector offers significant career prospects for the youth. This is particularly important in light of data released by Statistics South Africa in May 2023, showing that the total number of unemployed youth aged 15-34 years stands at a staggering 4.9 million, 46.5% of the country's employable population.

With roles spanning various disciplines such as engineering, project management, research and development, and policy advocacy, young individuals will be able to contribute to the design, installation, and maintenance of renewable energy systems, lead project initiatives, drive innovation, influence policy decisions, and even venture into entrepreneurship. This presents a dynamic and promising field for career growth and development, the ideal conduit for young people to shape a sustainable future for the nation actively.

A GROWING INDUSTRY FOR A GROWING WORKFORCE

Renewable energy offers opportunities beyond mere employment. For unskilled workers, it offers a gateway to gainful employment and provides valuable skills development opportunities. Construction projects associated with renewable energy infrastructure serve as learning platforms, imparting essential skills such as workplace safety practices, technical skills, and project management expertise. The decentralised nature of renewable energy projects means that opportunities are not limited to urban centres but extend to rural areas,

contributing to inclusive economic growth and development across the country.

CAREER POSSIBILITIES APLENTY IN RENEWABLE ENERGY

In terms of specific roles in high demand within the renewable energy industry, a spectrum of avenues is available to individuals with varying skill levels. The sector offers an unimaginable array of career paths, from health and safety personnel to engineers and semi-skilled and skilled electricians, civil works professionals, and project managers.

As the industry matures, there will be a growing need for workers in operations and maintenance roles, providing long-term employment prospects for young individuals who gain the necessary specialised skills.

Embracing renewable energy career paths offers young South Africans personal and professional growth opportunities. The sector's long-term stability ensures consistent employment opportunities, with specific renewable energy projects likely to span several decades. Being part of a flourishing industry presents a chance to be at the forefront of innovation and development, with ample room for career advancement and skill enhancement. Contributing to renewable energy initiatives also allows individuals to make a tangible impact on mitigating climate change and fostering a more sustainable future for future generations. This factor has proven to be necessary with the upcoming Gen Z workforce.

SHAPING THE WORKFORCE OF THE FUTURE

As an alternative to traditional career pathways, Temporary Employment Services (TES) providers and outsourcing firms can play a crucial role in facilitating entry into the renewable energy sector for the younger workforce. TES providers specialise in sourcing, recruiting, and managing temporary or contract workers, offering flexibility and scalability to businesses needing labour. By partnering with TES providers, the sector can access a pool of talented individuals with diverse skill sets, bridging any skill gaps and accelerating project timelines. TES arrangements allow individuals to gain valuable hands-on experience in the industry, building their resumes and enhancing their employability in the long term.

In this way, TES providers can serve as a strategic resource for both employers and young professionals looking to embark on a career in renewable energy and, in the long run, the transition to renewable energy provides the ideal opportunity for our youth to contribute meaningfully to the country's sustainable development.

As the sector continues to grow and evolve, embarking on renewable energy career paths offers young individuals the chance to be part of a transformative journey towards a greener, more prosperous future. wn

The SAIEE CUT Student Chapter supported local orphanage

On April 13, 2024, the SAIEE Central University of Technology (CUT) Student Chapter visited the "KAMOHAU IN NEED CHILDCARE CENTRE" orphanage in Bloemfontein as part of their community engagement program. The orphanage hosts 29 children, 7 of whom are disabled. It has been in operation for 12 years and shelters neglected, orphaned and children from child-headed families.

The student chapter visited this orphanage previously and realised the dire conditions of their shelter's lighting and plug-wiring. As a result, they committed to returning and assisting with re-wiring their home to make it safer for the kids and those caring for them.

Mr Tebang Phali (CUT SAIEE Student Chapter Guardian) secured funding from "Intelligent Electronic Systems Design", which was needed to purchase the materials required for the proposed wiring project.

In collaboration with "MANGO-BE Power Solutions", an electrical design and installation company based in Bloemfontein, the SAIEE Student Chapter commenced with their re-wiring task in the early hours of the day, where they started by removing all the existing wiring, plugs and lights.

With the assistance and guidance of "MANGO-BE Power Solutions" employees and Mr Phali, the students then worked on wiring the lights, putting in place the plugs, and replacing and wiring the two new distribution boards. The work continued until midnight as the students booked only one day to complete the job.

The student chapter also received assistance from the SAIEE Free State Centre, which provided funding for food and refreshments while at work. The student chapter would like to express its appreciation to the centre for its support and look forward to working with them on many other projects.

SAIEE CUT Student Chapter, as an academic organisation at Central University of Technology, Free State, would also like to thank the university, the student governance and the CUT vehicle park for their role and assistance in making this project possible.

Thank you to all our sponsors:

- SAIEE Free State Centre
- Central University of Technology
- Intelligent Electronic System Design
- MANGO-BE Power Solutions. wn

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Why Join Us

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Our bursaries are for candidates who have completed a first-year study for a degree or diploma in Electrical, Electronic or Computer Engineering at an accredited South African tertiary institution.

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Our Purpose

To enhance the practice of electrical engineering in South Africa and the stature of our members through knowledge, networking, influence, education and communication.

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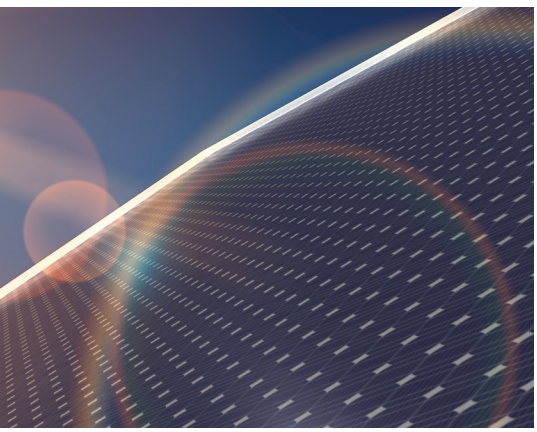
Local Solar panel manufacturing

A CATALYST FOR SUSTAINABLE ECONOMIC GROWTH



As South Africans – we are indeed a resilient bunch! We bounce back quickly and most often block off the source of our despair. But for how long can this continue? For how long can we pretend that unemployment is not a real problem?

By: Mr Viren Gosai
General Manager
ARTsolar

For how long can we remain optimistic about the recovery of our National Grid? How long can we look the other way while cheap, imported products are "dumped" in our Country? We can commence the building process only after we get serious about addressing these issues. One such catalyst is local solar panel manufacturing! Why? Embracing local PV manufacturing contributes to sustainable energy production and serves as a catalyst for building robust and resilient economies. If we can build within, we don't need to look outside!

In recent years, the push towards renewable energy has become vital in addressing climate change and energy security concerns. One key aspect of this transition is developing and supporting local solar panel (photovoltaic "PV") manufacturing and its related value chains.

Real Sustainable Local Job Creation and True Economic Diversification

"Killing two birds with one stone" applies so aptly to our solution: Making locals support our National Grid and alleviating the massive unemployment we face! Real, skilled jobs are created across various sectors, from research and development to manufacturing, installation, and maintenance. This sector further supports diversifying the economy by contributing to various "feed-in" industries like component manufacturing and various support services industries, e.g., HVAC, SHEQ, logistics and professional consulting. These jobs provide income for workers and stimulate economic growth by circulating money within local communities. This is precisely what South Africa desperately needs!

GLOBAL TECHNOLOGY TRANSFER AND LOCAL INNOVATION

The global leaders in PV manufacturing are China, India, and the USA. The rest of us follow the trends and depend on global supply chain pricing. Due to the commodity-based nature of the products, price sensitivity becomes a vast determinant in selection. Hence, as South African manufacturers, we are dependent on global supply chains and strategic partnerships to comply with local Financial Institutions' incessant need for a "Tier 1" solar panel. Incidentally, various new rating agencies using models such as the Altman Z-Score ratings are now being publicised to escalate the superiority of global brands.

All of which essentially seek to utilise historical financial results to determine the probability of future existence. Essentially, will these companies be around to service the 30-year warranty? So, there is no indication of quality, responsible procurement, technical ability, or environmental impact. But to comply, we must! Hence, as local manufacturers, we painstakingly subject ourselves to various global audits

to obtain international certifications, guaranteeing our product-making process carries the global brand.

It's not all bad, though. This process promotes global technology transfer and local innovation. As companies adapt to meet local demands, they drive improvements in production processes, leading to more efficient and cost-effective solar technologies. This not only enhances the country's technological capabilities but also positions it competitively in the global renewable energy market.

So, local manufacturers CAN make a globally certified and relevant product!

BUILDING SOUTH AFRICA THROUGH REAL COMMUNITY DEVELOPMENT

The benefits of local PV manufacturing extend to positive community development, which in turn ultimately enhances national economic resilience. Creating authentic, sustainable job opportunities and supporting local education and training programs enhances the overall quality of life in communities and, in effect, our country as a whole. One job feeds at least four people in South Africa. Hence, a 340 MW manufacturing plant can directly support 1100 people. Furthermore, a thriving local PV manufacturing sector builds resilience to global supply chain disruptions, ensuring a stable and reliable source of renewable energy technology within the country. Moreover, local manufacturing aligns with environmental sustainability goals by reducing carbon emissions associated with transportation and promoting cleaner energy production.

If the global lockdowns have not opened our eyes, then nothing will! We need to build local industries and move away from global dependence. Africa needs African solutions. Do not pay the rest of the world to take our resources in exchange for "hand-me-downs." We are doing it right now but in pockets across various sectors. We need to extend this patriotic passion to more Industries.

IS THERE HOPE?

Most certainly, there is hope! India has recently successfully revitalised its local PV manufacturing sector through targeted policy interventions, such as the Domestic Content Requirement (DCR) under the National Solar Mission. India has witnessed significant growth in PV manufacturing capacity and job creation by mandating a percentage of locally sourced components for solar projects.

The EU has also introduced robust local content policies to promote domestic sourcing in renewable energy projects, including solar PV manufacturing. These policies aim to strengthen local supply chains and support the growth of a competitive and sustainable clean energy sector within the EU. This is after many local PV manufacturers closed due to the oversupply of cheap imports, which made local manufacturing unsustainable.

The USA's Inflation Reduction Act (IRA) incentivises domestic production across industries, including renewable energy. Through tax incentives, subsidies, and regulatory reforms, the IRA stimulates economic activity and reduces reliance on imported goods, fostering domestic manufacturing capabilities. So, three major global regions managed to rescue and revitalise their local PV manufacturing sector. With our already world-leading localisation policies, South Africa has the heritage, but we need help with implementation. We ring-fence and enforce as and when! Policing compliance is another issue as, too often, faces are turned when conditions are suitable.

We need strict enforcement and further incentive programmes that cater to local sourcing of solar components, providing financial support for domestic manufacturers, and fostering collaboration between industry stakeholders. South Africa can strengthen its renewable energy value chain and enhance competitiveness.

If this fails, we have ourselves to blame! The evidence is there; we must stop bowing to the money and take a firm stance that local solar panel manufacturing catalyses sustainable economic growth! wn

Energy In South Africa

Over the following ten years, South Africa's total power capacity is expected to expand by just under 4GW according to Fitch Connect forecast. According to the predictions, the vast majority of this capacity will come from non-hydro renewable sources, which will increase from a 9.3% share of total power generation in 2023 to 17.0% by 2032. This growth will be fueled by the Renewable Independent Power Producer Programme and the lifting of the license cap, which will enable more private sector participation in the power sector.

The thermal energy production in South Africa is expected to decline from 200.1 TWh in 2023 to 188.0 TWh in 2032.

The Just Energy Transition Partnership's plans to decommission and repurpose outdated coal-fired power plants to lower the market's high level of emissions and the persistent underperformance of the country's existing thermal capacity are mostly the reason for this.

By 2032, the government is planning to shut down seven coal-fired power facilities, but until more specifics are known about when and how this will occur, not much can be said.

CURRENT STATUS

In South Africa, approximately 85% or 42,000 MW, of the nation's electricity is generated via coal-fired power stations. Despite environmental concerns, coal will continue to provide most of South Africa's power for the next decade, although the share from renewables will increase. Non-hydro renewables are predicted to develop faster than the market, with 8.7 GW of additional renewable energy capacity planned to be installed between 2023 and 2032.

Solar energy will be the primary driver of this expansion because the government relaxed the standards for local content in solar modules to speed up the implementation of solar projects. The market's primary downside concern is ongoing power outages (load shedding), differences throughout the policy, intra-party disputes, and political threats.

STATE OWNED UTILITY

Eskom, the vertically integrated, state-owned power company, generates approximately 95 per cent of the electricity used in South Africa and a substantial share of the electricity generated on the African continent. The utility ranks in the top 20 utilities worldwide by generation capacity and is Africa's biggest power producer.

Approximately 95% of the electricity used in South Africa and 45% of the electricity used in Africa is produced by Eskom. About 45% of all end users in South Africa receive their power straight from the firm, with the remaining 55% being resold by redistributors (including municipalities). Meeting the rising demand for energy and ensuring economic growth is Eskom's central issue. Additionally, the business trades electricity with SADC member nations and purchases electricity from them. Future participation in African markets outside of South Africa (i.e., the rest of Africa and the SADC markets linked to the South African grid) is restricted to initiatives directly supporting secure supplies for South Africa.

GOVERNMENT INTERVENTION

The South African government in 2019 announced plans to unbundle Eskom into three separate entities responsible for generation, transmission, and distribution. This move was prompted by an urgent need to address the utility's significant debt levels while South Africa's National Treasury is drafting a measure to handle

the USD23 billion debt load of the struggling national utility. The National Transmission Company South Africa (NTC) has been granted permission by the National Energy Regulator of South Africa (NERSA) to operate a transmission system inside the territorial limits of South Africa starting in July 2023. Eskom, a South African electrical utility firm, has welcomed the NERSA action since it represents a crucial step in legally separating the transmission business.

REIPPPP

Despite Eskom's debt challenges, South Africa operates a highly successful Renewable Energy Independent Power Producer Procurement Programme (REIPPPP) for utility-scale transactions. Over 6,000 MW of generation capacity across various technologies, primarily in wind and solar, have been granted to bidders because of the renewables program, which is considered a model for other African nations. The Renewable Independent Power Producer Programme (REIPPP) aims to add more megawatts to the nation's electricity grid through private sector investment in renewable energy sources like wind, biomass, and small hydro. To address the recent load-shedding crisis, the President announced that the IPP Office would double the procurement of the average 2,600 MW renewable power per annum in 2022 and scrap the licensing cap threshold previously set at 100 MW.

SOUTH AFRICA INTEGRATED RESOURCE PLAN (IRP)

Policy: The South African Government's National Development Plan (NDP) is the blueprint for infrastructure development to 2030. The NDP lays out a framework for future power generation in South Africa, while energy policies in South Africa are driven primarily by the Department of Mineral Resources and Energy's (DMRE) Integrated Resource Plan (IRP). The IRP is DMRE's estimate of electricity demand growth, what energy generation types should be procured to meet that demand, and the generation capacity, timing, and cost. The IRP is an electricity infrastructure development plan based on the least-cost electricity supply and demand balance, considering the security of supply and the environment (minimising harmful emissions and water usage).

The IRP envisages a total addition to electricity capacity of 29,500 MW by 2030, led by renewables (notably 14,400 MW from wind and 6,000 MW from solar photovoltaic).

As a result, the government announced a procurement package in September 2020, representing a significant acceleration of the goals in South Africa's latest Integrated Resource Plan. This was the government's way of trying to respond to the problem of persistent electricity shortages in the country by announcing a new phase of power-generation procurement totalling a projected 11,813 MW.

The bulk of the new capacity will be distributed as follows:

- Renewables (6,800 MW)
- Gas (3,000 MW)
- Coal (1,500 MW)
- Pumped storage (513 MW)

All projects will be undertaken by independent power producers (IPPs), with output sold to Eskom. Ambitiously, the authorities aimed for the new capacity to be in place by 2022, but there have been delays in putting some projects into financial close. This is primarily due to some companies that won bids based on prices that changed significantly due to COVID-19, which affected the supply chain for manufacturing.

COAL

Coal has traditionally dominated the energy supply sector in South Africa. About 80 per cent of South Africa's primary energy needs are provided by coal. By 2032, South Africa is projected to continue generating most of its electricity from traditional thermal power sources, primarily coal-fired generation. The projections are supported by South Africa's plentiful supply of cheap coal, which assures a low-cost fuel source for electricity generation.

Furthermore, according to BMI projections, South Africa's thermal power generation will likely fall to 188.0 TWh in 2032 from an estimated 200.1 TWh in 2023. The planned phase-out of ageing units at coal-fired power plants across the nation and a drop in efficiency for many power plants are the leading causes of this decline.

It is anticipated that a yearly average of 99.3% of thermal output will continue to come from coal-fired electricity. The 4.8 GW Medupi and 4.8 GW Kusile projects, expected to eclipse any upcoming investments in gas-fired power, are to blame for coal's continued dominance.

Therefore, South Africa is less likely to be able to find the volumes of gas needed to lessen its reliance on coal considerably. With the options currently available, particularly the potential for gas imports from Mozambique, gas-fired power is not anticipated to play a more significant role in South Africa's power industry in the future, providing that enough infrastructure is created.

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The IRP plans to decommission just over 10,000 MW of coal-fired power plants by 2030 and replace them with a mixture of renewables and gas.

LEGAL ISSUES

It was reported in May 2022 that Unit 4, damaged in a generator explosion, will be brought online after hydrogen (used to cool the shaft) mixed with air instead of carbon dioxide during a purging process, will be brought online in August 2024. Eskom said it will fix design flaws as it repairs the unit. Meanwhile, units 5 and 6 at the power station operate at partial loads to meet emissions license requirements.

Eskom will implement fixes and repairs to these units during routine maintenance shutdowns to bring them to full load. The government has also stated that the Kusile power plant will be online by 2023. In December 2020, the Pretoria High Court overturned the environmental approval of the planned 1.2 GW Thabametsi coal-fired power plant after successful appeals by environmental groups. This followed arguments that the power plant would have been one of the most polluting power stations in the world. At the same time, environmental groups are lobbying for the planned Khanyisa coal power project to be cancelled. This poses a downside risk for future thermal power projects planned for South Africa.

EMISSIONS

South African state-owned utility Eskom stated in November 2020 that it was planning to reach carbon neutrality by 2050. Under its Just Energy Transition program, this is intended to move away from coal power. While this target is nearly three decades away, there's reasonable doubt on the prospects of success given Eskom's continued high reliance on coal power, considering that they are also still constructing the Medupi and Kusile coal power plants of over 4GW each. Eskom received a delay from the Department of Forestry, Fisheries, and the Environment (DFFE) by the Minimum Emission Standards (MES) relating to the levels of sulphur dioxide (SO2) emission at Kusile Power Station.

Eskom was also given a revised Atmospheric Emission License (AEL) to Kusile Power Station to reflect this postponed decision by the Nkangala District Municipality. Eskom will be able to run the three units without using the Flue Gas Desulphurization (FGD) plant, which is outfitted with emission-abatement technology for SO2, for a period of up to 31 March 2025, while the flue gas ducts in the permanent stack are being repaired, thanks to the postponement granted on 5 June 2023 and the licenses issued on 13 June 2023. By December 2024, all duct repairs in the permanent stack will be finished. This occurred after the Unit 1 flue gas duct failed on 22 October 2022.

RENEWABLE ENERGY

Government Initiative: Renewable energy is increasingly regarded as an attractive power source in the country. To diversify its energy mix and attract more IPPs to the sector, South Africa has developed a renewable energy independent power producer program, the Renewable Energy Independent Power Producer Procurement Program (REIPPPP), which has proven successful in bringing renewable energy projects to commercial operation. REIPPPP has procured 6.4 GW from 112 IPPs across seven bid windows.

After numerous rounds under REIPPPP, the program has seen a significant decline in costs by approximately 55 per cent for wind (ZAR 1.51 to ZAR 0.62 per kWh) and 76 per cent (ZAR 3.65 to ZAR 0.62 per kWh) for solar PV, which makes the technologies cost-competitive with new-build coal. Furthermore, renewable power sources account for just under 3% of South Africa's national electricity supply, from a zero baseline in 2010.

Investment: The program has leveraged approximately $135.6 billion in investment across South Africa, and projects include wind, solar (both PV and concentrating solar power), small hydro, landfill gas, and biogas as energy sources. Of this, 25.8 per cent is from foreign financiers and investors across the globe. To date, the United States is the largest source of foreign direct investment (FDI) in the renewables space, and several U.S. companies have shown strong interest in this program and have participated in tenders issued by the South African Department of Energy.

Financing: At the request of the South African government, the World Bank Group authorised the $497 million Eskom Just Energy Transition Project (EJETP) in November 2022. To decommission the 56-year-old Komati coal-fired power station, repurpose the project area with renewable energy and batteries, and create jobs for workers and communities, it will support its public energy provider, Eskom. If the project is successful, it might serve as a model for a fair energy transition in South Africa and beyond. The Canadian Clean Energy and Forest Climate Facility (CCEFCF), a $47.5 million concessional loan, a $10 million grant, and a $439.5 million loan from the World Bank contribute to the project's funding.

Opportunities: According to

research house BMI, non-hydropower renewables will be South Africa's fastest-growing electricity generation source between 2019 and 2028. Struggling thermal capacity at Eskom and the government's commitment to REIPPPP contracts suggest good growth opportunities. Wind power will be the primary source, accounting for 60 per cent of renewables output by 2028. The significant presence of the coal power sector means renewables' contribution to total electricity output will remain below 10 per cent during this time.

GAS GENERATION

While a large portion of the planned generation is based on renewables, a key issue has been the move towards natural gas as a fuel source. Currently, efforts are being made to develop west-coast offshore gas and explore shale gas reserves. The aim is to have liquefied natural gas (LNG) infrastructure to power combined-cycle turbines.

Although the country has vast untapped shale resources, estimated to generate up to 130,000 GWh of electricity per year according to South Africa's National Planning Commission, exploiting the country's shale gas deposits will still require the development of an adequate policy and regulatory framework in addition to the necessary physical infrastructure needed to transport and process any output that is eventually produced.

Looking further to 2030, a mix of shale gas and imported LNG could be a growing part of the power generation mix. Studies on shale gas potential in South Africa's Karoo Basin also indicate that total shale potential could be up to 30 times less than initially estimated, which, though still a sizeable amount, would weaken the investment case for domestic gas extraction. However, the environmental implications surrounding future extraction in the Karoo are controversial and would likely face resistance from environmental groups.

The South African Department of Energy is tasked with procuring 3,126 MW of power from gas in 2019–2025. This will be the baseload and mid-merit energy generation capacity needed from gas-fired power generation to contribute to energy security. The Department's "Gas IPP Program" has been initiated through the IPP Office. At present, the IPP Office is concentrating on the LNG-to-Power IPP Program. The demand for natural gas is expected to expand by an average of 5.2 per cent per year in 2021-30, boosted by government efforts to encourage its use and reduce reliance on coal. Under the IRP, gas-fired generating capacity is projected to rise by 3,000 MW.

The switch from diesel to gas particularly applies to domestic Ibhubesi gas field developments. Sunbird Energy is developing this field and is set to feed a 1,350MW power plant at Ankerlig, which currently runs on diesel. Eskom released an RFP in May 2024 for the supply, delivery and off-loading of Propane Gas via road tanker to Ankerlig and Gourikwa Power Station. The propane will be supplied to the respective sites on an "as and when required" basis for five years, with optional storage space for 10,000 kg of propane near the power stations.

NUCLEAR

Nuclear power accounts for just over 6% of South Africa's electricity output. Eskom operates the country's only nuclear plant at Koeberg, near Cape Town. Two reactors completed in the 1980s have a combined generating capacity of 1,830 MW. Although the two units at Koeberg were planned for closure in 2024 (Unit 1) and 2025 (Unit 2), upgrades to the reactors have extended their lifetimes to 2045 and 2047, respectively.

The IRP launched in 2019 appeared agnostic on the need for additional nuclear-power capacity; however, in May 2020, it was announced that the procurement of 2,500 MW of new nuclear capacity was being considered. Minister G. Mantashe states this could take the form of small modular reactor (SMR) projects led by private companies and consortia. In June 2020, the Department of Mineral Resources and Energy published a Request for Information (RFI) to potential investors—the first preparatory step on what is likely to be a long road to securing additional nuclear capacity under the Nuclear New Build Program (NNBP).

Following this, Eskom submitted a Nuclear Installation Site License (NISL) application to NNR for the site, with public hearings on a proposed Thyspunt Nuclear Installation Site License (NISL) held in the surrounding towns of Jeffrey's Bay and St Francis Bay in late 2021. The government reportedly aims to have the procurement process for the NNBP to be complete by 2024.

ENERGY SERVICES

According to Green Cape's Energy Services 2021 "energy services" (ES) Market Intelligence Report, the rising electricity prices, national energy insecurity, dropping technology costs, supportive energy policies, and incentives are prompting consumers to explore alternative energy options, driving the growth of the Energy Services (ES) market in South Africa, and creating a thriving value chain. To address this, the government amended the electricity generation regulations, and following

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that, the President announced in June 2021 that "the amended regulations will exempt generation projects up to 100 MW in size, from the NERSA licensing requirement, whether or not they are connected to the grid. This will remove a significant obstacle from investment in embedded generation projects,". He also pointed out that businesses that generate their own electricity will be allowed to wheel electricity to the grid, "subject to wheeling charges and connection agreements with Eskom and relevant municipalities".

The national embedded generation market for installations, operation, and maintenance of rooftop solar PV has grown in the past 12 months. Local solar PV data suggests an installed capacity increase by as much as ~110 MW throughout South Africa (possibly as high as 250 MW).

The total annual available market could continue to grow at this rate to a saturation point of ~500 MW installed annually on an ongoing basis. This market could reach 7.5 GW of installed capacity by 2035. The commercial and industrial (C&I) sector has been leading investments in this sector, with ~70 per cent of new rooftop solar PV installations nationally in this sector.

The rapid uptake of solar PV over the past three years has surprised national regulators. It has highlighted the need for new national policies and regulations to guide and regulate the solar PV market. At a local level, there will also be a need for policy and regulation to govern the safe uptake of solar PV.

Municipalities will need the support of the national energy regulator and national and provincial governments to do this. Progress has already been made at a municipal level, with 35 municipalities across South Africa introducing rules and regulations allowing scale-embedded generation (SSEG) to connect to and receive feedback on the municipal electrical grid. Of these, 21 municipalities in the Western Cape are allowing SSEG, of which 15 have National Energy Regulator of South Africa (NERSA)-approved tariffs in place. With increasing demand for embedded generation, the South African energy storage market is expected to grow to ZAR14.5 billion by 2035, becoming a keystone of the future energy services market. This will create opportunities for investors, manufacturers, suppliers, and energy end-users in the energy storage value chain.

Energy efficiency also presents a significant opportunity to investors and businesses in all sectors. The annual available market currently stands at ZAR3 billion and will reach an estimated ZAR21 billion by 2035.

ELECTRICITY DISTRIBUTION

Ageing network infrastructure remains a concern for the distribution network as it compounds the supply and limits South Africa's ability to expand electricity access. The South African Department of Mineral Resources and Energy has completed a study to estimate the backlog, and work is currently underway to determine the most effective way to fund the rehabilitation of these networks and assets going forward. Eskom estimates it will need 8,000 km of transmission infrastructure by 2030 to bring more renewable energy online.

BANKABILITY OF UTILITY

Eskom has had severe cash problems, which has raised questions about its long-term financial viability. The debt owed by the business was ZAR400.0bn (USD 21.8 bn) as of February 2023. The company's financial situation is especially worrying in light of the long-term prospects for South Africa's fast-growing renewables sector, which has benefited from the government's effective auction-based regulatory structure. Developers of renewable energy, primarily foreign corporations, have signed power purchase agreements with Eskom for the electricity produced by their projects in anticipation that Eskom will uphold these agreements as reliable and enforceable. Investors seeking stable profits are likely to steer clear of any threat to the long-term viability of these arrangements.

Public Enterprises Minister Pravin Gordhan has confirmed that Eskom's business model is up for discussion as the government seeks to reduce the utility's fiscal risk and reposition the state-owned enterprise (SOE) for future sustainability.

Discussions could enhance Eskom's revenue in the short term through higher sales and, controversially, tariff increases. Yet further tariff increases (which have increased by over 300 per cent for some consumers in the past eight years) could spur more consumers to find ways of using less electricity, possibly even through full or partial defection from the grid.

The National Energy Regulator of South Africa (NERSA) has also warned of a "utility death spiral," whereby the price elasticity of industrial demand is emerging as a primary driver of the lack of demand. This has exacerbated a "vicious cycle" in which increasing electricity prices drive declining sales, resulting in the utility having to recover the same cost base from a shrinking customer base.

U.S. INITIATIVES

Power Africa: Launched in 2013, Power Africa is a market-driven, U.S. Government-led public-private partnership to double access to electricity in Sub-Saharan Africa. It also serves as a one-stop shop for private sector entities seeking tools and resources to facilitate doing business in Africa's power sector. In 2016, the Electrify Africa Act unanimously passed both houses of Congress. It was signed into law, institutionalising Power Africa and establishing two goals: to add 20,000 MW of generation capacity and expand electricity access to 50 million people in Sub-Saharan Africa by 2020. In bringing together more than 140 of the world's top companies, development institutions, and financial entities, Power Africa employs a transaction-centered approach to directly address critical constraints to project development and investment in the power sector. These interventions aim to mitigate investment risk and accelerate financial close by facilitating project bankability and providing technical and transaction support to engage with host-government counterparts.

Power Africa in South Africa: This interagency team is working to support the country's effort to introduce large-scale renewable energy and natural gas (for power and other uses) into the economy while assisting the government in strengthening and expanding the regulatory framework. Additionally, Power Africa provides transaction advisory support to municipalities, developers, and finance partners.

SUB-SECTOR BEST PROSPECTS

Products and services with immediate need or potential in South Africa include:

- Renewable Energy Independent Power Producer Procurement Program (REIPPPP)
- Energy Services
- Energy Efficiency and Demand-Side Management (DSM) Technologies
- Oil/Gas, LNG Provision, Exploration Equipment, Extraction, Pipeline, and Fuel Conversion
- Transmission and Distribution Equipment
- New Plant Equipment and related systems.
- Process Automation and Systems Control Equipment.
- Off-grid solutions.

The State of African Energy Outlook 2024

The energy situation in South Africa is vital not only for the country itself but also for the entire African continent. The country has been facing ongoing challenges in the energy sector, and it is crucial for stakeholders to have a clear understanding of the energy outlook in South Africa by 2024.

South Africa has been relying heavily on coal-fired power plants to meet its energy needs, leading to issues such as air pollution and carbon emissions. However, in recent years, the country has made efforts to increase its renewable energy capacity. The government aims to source 30% of its energy from renewable sources by 2025.

Despite these efforts, South Africa still faces challenges in the energy sector, with load-shedding becoming common due to the lack of reliable power supply. This has caused economic losses and frustration among citizens. To address these issues, the government has emphasized the need for increased investment in energy infrastructure and the adoption of new technologies to improve energy efficiency.

One report that sheds light on the state of energy in South Africa is the "African Energy Chamber 2024 Outlook Report". This report provides insights into the energy landscape in the country and the continent. The report highlights the potential for growth in the energy sector in Africa, with opportunities for investment in renewable energy projects and the development of a more sustainable energy system.

KEY HIGHLIGHTS

- 2023 – 2024 free cash flow and government take evolution in Africa expected to stay relatively flat after steep drop from 2022 to 2023
- Flat free cash flow generation between 2023 – 2024 attributed to stable commodity prices and flattish investment profile in the continent
- National Oil Companies (NOCs) and international oil majors lead the way in free cash flow generation for 2023–2024
- 2023 – 2024 annual government take expected to see a 25% drop from 2022 levels but still well over the pandemic period
- 2024 global oil + condensates output expected to be marginally higher than 2023 with Middle East and the Americas driving majority of short-term supply
- Growing road transport and Petrochemical sectors estimated to be the main demand drivers over the next 18 months
- Average stock change or demand vs supply balance over 2H-2023 is expected to be about 2.15 million bpd while 2024 is expected to be much tighter with difference reduced down to about 1 million bpd
- African Organization of the Petroleum Exporting Countries (OPEC) member nations are expected to be the key drivers of Africa's oil + condensates 2023 – 2024 output
- NOCs and majors form the main company segments in terms of working interest liquids production
- Production declines and outages in major OPEC members have led to 100% compliance to OPEC cuts become a compulsion rather than being a choice

- Various production disruptions, both planned and unplanned, are estimated to result in production losses of close to 215,000 bpd over 2023
- OPEC member nations' contribution to African output estimated to remain dominant even in the long-term
- Global gas supply expected to be driven mainly by North America, Middle East, Asia and Russia
- Global gas and liquified natural gas (LNG) demand expected to outrun the supply from currently producing fields and balance largely dependent on newer projects and currently undeveloped discoveries
- Africa joins the top four gas producers to round off the top five LNG exporters globally
- North Africa expected to pump majority of the natural gas supplies while West Africa expected to drive the LNG flows from Africa
- Global upstream spending potential going strong despite industry sentiment of underinvestment
- Potential greenfield spending in the United States, Africa, Asia and Middle East expected to drive a quarter of the overall spending through 2023 – 2030
- Liquid supply potential relatively lower than previous outlook and gas potential marginally higher
- Brent 2023 – 2024 outlook higher than previously estimated
- NOCs and majors – key driving forces behind Africa' short-term supplies, hydrocarbon potential, medium-term production and spending
- Total CAPEX over 2023 – 2030 expected to remain the same as last outlook with differences in timeline of spending
- North and West Africa expected to drive bulk of the cumulative as wells as annual spending through the period
- Liquids remain the key focus and equal split between onshore and offshore spending expected
- Majority of the spending, especially through the second half of the decade, expected to come from currently pre-FEED discoveries
- Nigeria, Libya, Algeria, Angola and Mozambique – the top five spenders over the period & NOCs and majors
- estimated to incur two-thirds of the total CAPEX
- Actual CAPEX spending forecast closer to "Mean" scenario which models the global warming cap at 2°C
- Drilling and rig demand on the rise till 2024 before assuming a declining trend
- Majority of the rig demand robust with only about 32% based on contingent volumes
- Healthy levels of exploration drilling expected over 2023 – 2025 with Algeria, Egypt, Namibia and Nigeria driving majority of the activity
- 11 high impact wells (HIWs) to be drilled in the next 15 months
- 177 blocks up for grabs as licensing rounds across Africa with to-be-awarded status expected to close in the next 18 months
- Liquids portfolios and majority producing assets driving mergers and acquisitions (M&A) activity so far in 2023
- Africa's hydrocarbon extraction emissions in the "mid-range" when compared to other regions, but natural gas flaring emissions intensity the highest globally
- Limiting natural gas flaring and utilization and/or monetization of produced natural gas – key to Africa's upstream sector's betterment
- Post COP27 exploration acreage awards – Africa accounting for 30% of the global offshore acreage awarded
- Africa expected to have the least potential greenfield spending probability - the ratio between actual spending and potential spending
- Total exploration spend over 2015 – 2025 and discovered volumes over 2019 – 2023 – South America double of that of Africa
- Africa's overall electricity access rates – significantly lower than global levels and even worse in rural Sub-Saharan Africa
-
- Majority of projects to improve the regional power capacity currently at concept stage
- Renewables capacity to be driven majorly by solar and onshore wind capacity, with hydrogen taking the growth further during the 2030s
- Onshore wind and solar expected to drive three-fourths of the total renewables capacity in Africa through to 2040, and along with hydrogen capacity drive over 95% of the capacity through 2030s
- Egypt, Morocco, Mauritania and South Africa – key regional renewables capacity drivers
- Natural gas to play a role in Africa's power mix even in 2050
- European banks, with a negative CAGR in fossil fuel financing in the past few years and strict climate policies, are more prone to fund green projects over upstream projects.

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1 INDUSTRY REVIEW

1.1 Positive free cash flows expected globally in the short-term

2023 – 2024 free cash flow and government take evolution in Africa expected to stay relatively flat after steep drop from 2022 to 2023

Flat free cash flow generation between 2023 – 2024 attributed to stable commodity prices and flattish investment profile in the continent

National Oil Companies (NOCs) and international oil majors lead the way in free cash flow generation for 2023 – 2024

2023 – 2024 annual government take expected to see a 25% drop from 2022 levels but still well over the pandemic period

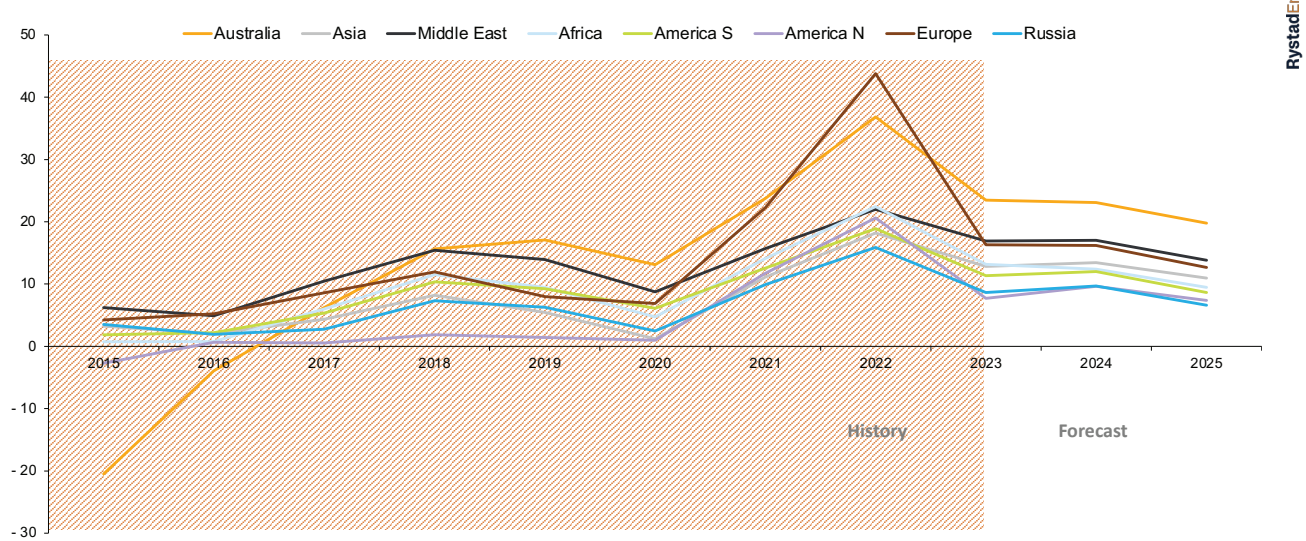
COVID-19 wreaked global havoc and shook the oil and gas industry with oil products' demand seeing drastic drop and oil prices seeing record lows. Post the pandemic, 2022 proved to be yet another extraordinary year for the oil and gas industry as Russian aggression on Ukraine snowballed into multiple decisions taken across the industry and across the globe which are expected to leave a long-term impact. The European Union (EU) decided to cut hydrocarbon import ties with Russia in opposition to the attack on Ukraine; the volatile market led to major players revisiting their investment strategies; and most importantly, the global discussion around energy transition and climate increased beyond any point in the past with gradual upstream investment cuts and simultaneous increased focus on renewables becoming the crux of looking at future of energy industry as a whole.

2022 saw the pandemic impact lessening and Brent surpassing the US$90 per barrel mark leading to an initial 2022 average price assumption of US$70 per barrel. However, the Russia – Ukraine conflict eventually led Brent reaching US$139 per barrel in intraday trading and eventually settling at close to US$100 per barrel average for 2022. Since then, while markets settled down relatively and actions from various players led to Brent dropping down to sub US$85 per barrel mark and expected to stay relatively flat around that mark for the years 2023 – 2024. The free cash flow generation for the years is a mere reflection of this with operators seeing lesser free cash flows driven by lesser revenues due to lesser average oil prices. An observation of the trend of global free cash flow generated per barrel of oil equivalent (boe) suggests all continents are expected to generate positive free cash flows going forward.

This is in line with the upstream cost cuts expected going forward in the short-term. It is to be noted that the higher investment activities in Australia and United States (US) were responsible for the negative cash flows in the period from 2012 to 2015, however major investments in the past and delayed sanctioning activity have returned the continents to a positive free cash flow position. Australia is expected to generate maximum free cash flows with a significant margin in the short-term, around US$20 – US$23 per boe over the period 2023 – 2025. As the next investment cycle starts, free cash flow generation is expected to decline gradually in the short-term.

Industry review

Upstream FCF evolution per continent (USD/boe nominal)



Source: Rystad Energy UCube

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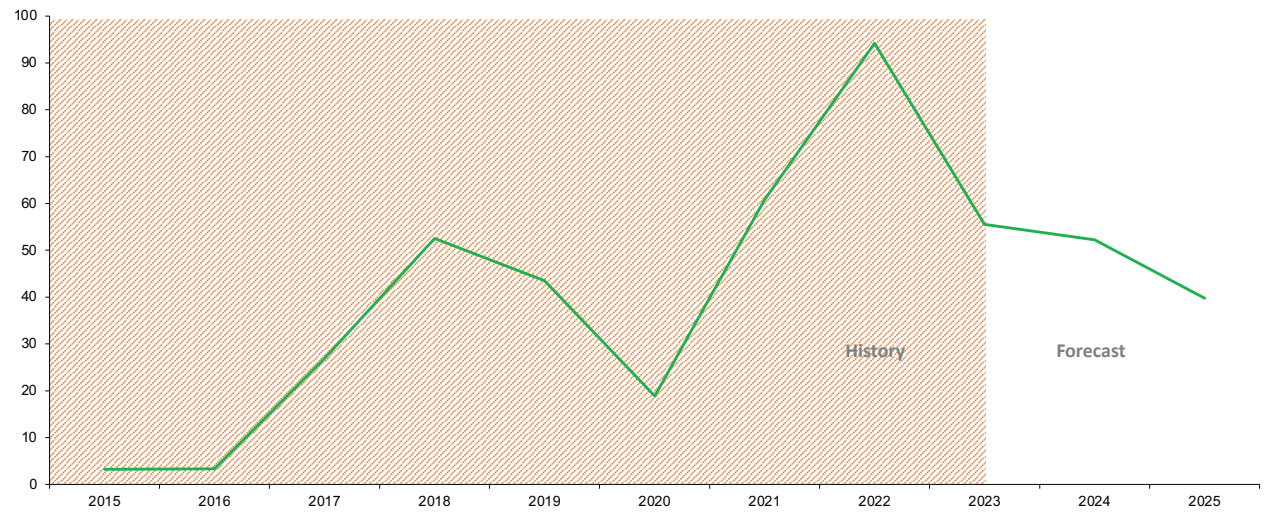
1.2 Africa short-term free cash flow evolution in line with global trend

Africa is more in line with other continents with respect to the free cash flows evolution in the short-term and all the African projects are expected to generate a cumulative free cash flows of around US$55 billion in 2023, roughly in line with the pre-pandemic levels of 2018. The bounce back from the pandemic shockwave of 2020 has led to free cash flow generation increase from 2020 lows of under US$20 billion to close to US$95 billion in 2022. The oil price drop and upstream spending strategy revisions have resulted in 2023 levels drop down to around US$55 billion and 2024 expected to stay at relatively flat at just over US$52 billion. 2022 seems to have recorded the highest free cash flow in the first half of this decade with 2025 dropping further down to about US$40 billion

The top 10 companies for the years 2023 – 2024 in terms of free cash flow generation in Africa comprise of a group of NOCs like Algeria's Sonatrach, NOC (Libya) and Nigeria's Nigerian National Petroleum Corporation Limited (NNPC Ltd.) and Angola's Sonangol; and majors like Eni, TotalEnergies, ExxonMobil, Chevron, Shell, BP and Azule Energy (Eni – BP joint venture (JV) in Angola). While recovery in production is the key driver behind Libya's NOC being one of the top free cash flow generators in Africa, stakes in most producing blocks in Algeria or partnering with majors on multiple producing blocks in Nigeria and Angola are the drivers behind these countries' respective NOCs stand in the list of Top 10 free cash flow generators in Africa. Commodity prices is the key reason behind majors generating high free cash flows and their fluctuating respective standings in the top 10.

Industry review

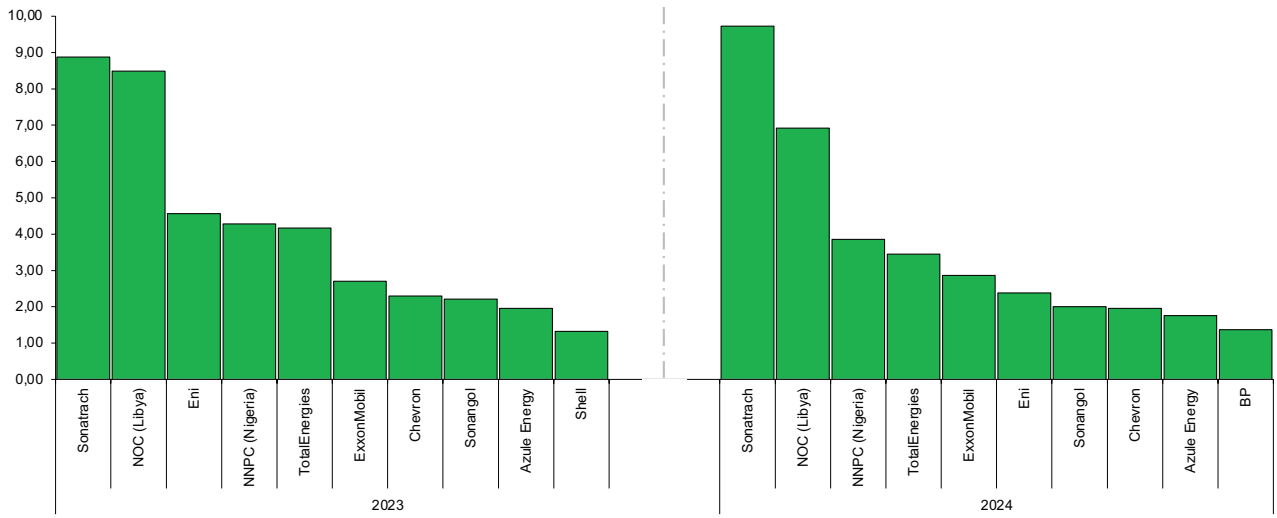
Upstream FCF evolution and forecast to 2025, Africa (Billion USD)



Source: Rystad Energy UCube

Industry review

Top 10 companies by 2023 and 2024 FCF in Africa (Billion USD)



RystadEnergy

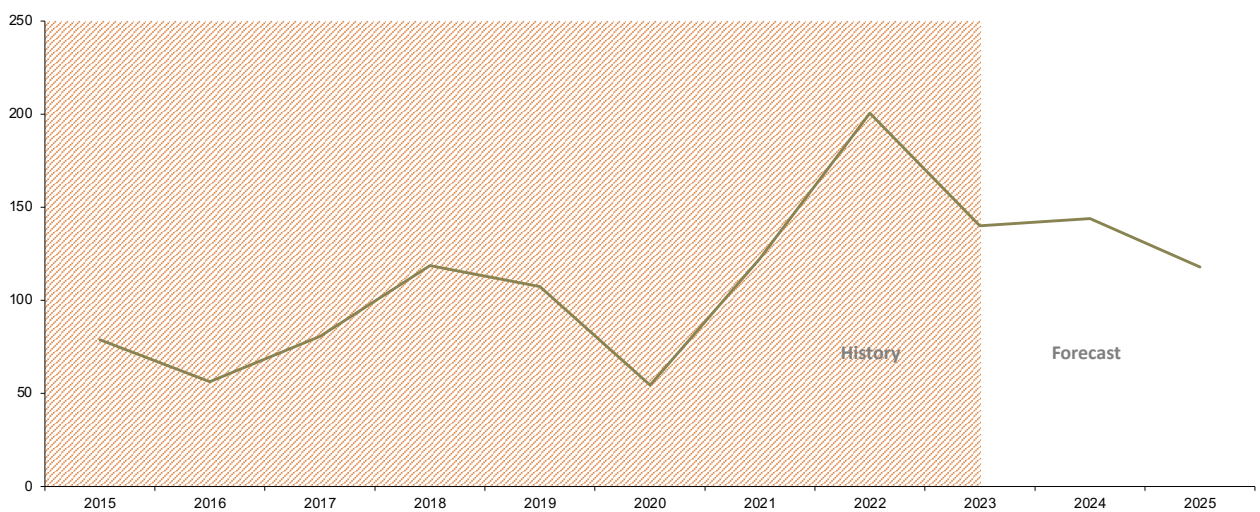
Source: Rystad Energy UCube

1.3 2023 government take in Africa at 75% of 2022 levels

Government take includes various tax parameters such as royalties, profit oil and other taxes paid to the government on an asset level as well as on corporate level by the operators. The government take can vary on different parameters such as production, profitability and commodity prices etc., depending on the fiscal regimes of the respective countries. Higher revenues mean higher taxes and hence, higher government take. As such, as higher commodity prices have resulted in higher revenues and in turn higher government take in 2022, lower and relatively flat oil prices mean relatively lower and flat upstream revenues for the years 2023 – 2024 and in turn lower and flat government take for both the years. While government take in Africa exceeded US$200 billion in 2022, it is expected to be around US$140 billion – US$ 145 billion over the years 2023 – 2024. It is to be noted this is still higher than the volatile market period past 2014 price crash and the volatile market during the global pandemic.

Industry review

Government take evolution and forecast to 2025, Africa (Billion USD)



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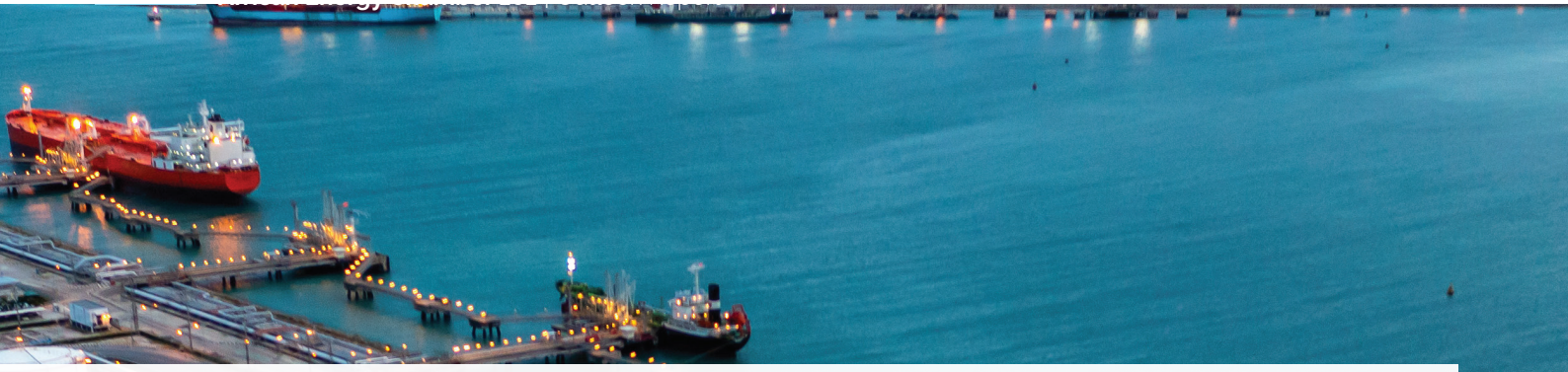


2 OIL MARKETS REVIEW

2024 global oil + condensates output expected to be marginally higher than 2023 with Middle East and the Americas driving majority of short-term supply

Growing road transport and Petrochemical sectors estimated to be the main demand drivers over the next 18 months

Average stock change or demand vs supply balance over 2H-2023 is expected to be about 2.15 million bpd while 2024 is expected to be much tighter with difference reduced down to about 1 million bpd

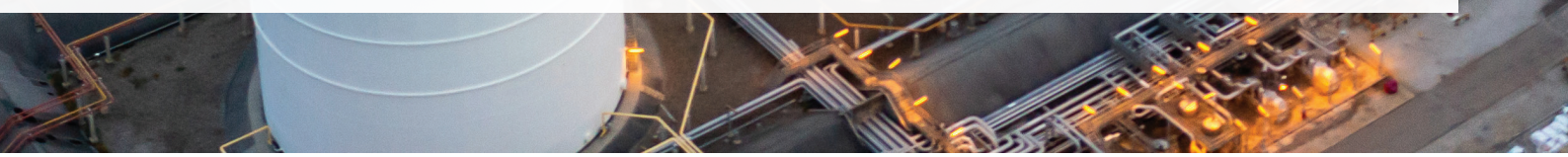
African Organization of the Petroleum Exporting Countries (OPEC) member nations are expected to be the key drivers of Africa's oil + condensates 2023 – 2024 output

NOCs and majors form the main company segments in terms of working interest liquids production

Production declines and outages in major OPEC members have led to 100% compliance to OPEC cuts become a compulsion rather than being a choice

Various production disruptions, both planned and unplanned, are estimated to result in production losses of close to 215,000 bpd over 2023

OPEC member nations' contribution to African output estimated to remain dominant even in the long-term



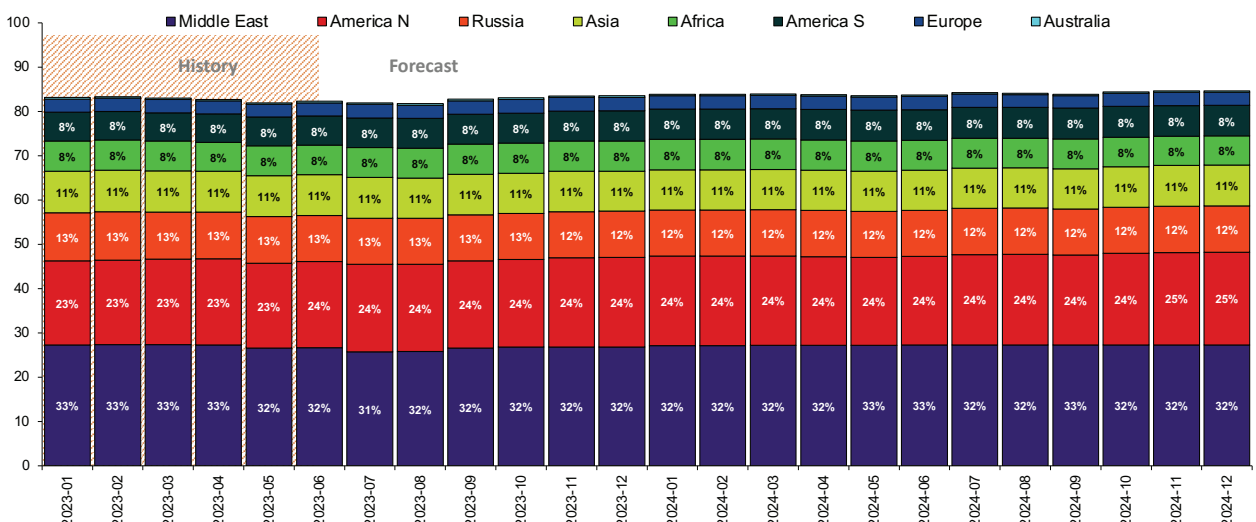
2.1 Global short-term liquids supply: Driven by Middle East and the United States

2023 saw various key drivers like the OPEC supply cuts, Saudi Arabia's individual pledge on the cut extension and renewed optimism around the Chinese stimulus and demand that can impact the global liquids (oil + condensates) output in the short-term. Overall, 2023 global average supply is estimated to reach about 82.75 million barrels per day (bpd). Middle East, a region as a whole, and the US are expected to drive over half the output with Middle East adding up to 32% and North America pumping 24% of the annual volume.

The outlook for 2024 is a slightly higher output of just over 84 million bpd, a 1.6% year-on-year (YoY) increase over 2023. Middle East and North American Shale are expected to drive over 55% of the total output for 2024 as well. 2023 – 2024 oil + condensates output from Middle East and North America is expected at 26.76 million bpd – 27.26 million bpd and 19.56 million bpd – 20.32 million bpd respectively. The Americas, both north and south combined, are expected to see a marginal 4% growth in output YoY while Middle East is expected to see an even smaller 2% YoY growth over 2023 output. Africa 2023 – 2024 output is expected to stay relatively flat at about 6.77 million bpd. The YoY increase driven by Middle East and the Americas is offset by marginal decline in output from the rest of the world – Russia, Asia, Europe and Australia.

Oil markets review

Global short-term crude + condensates supply (Million barrels per day)



Source: Rystad Oil Market Cube

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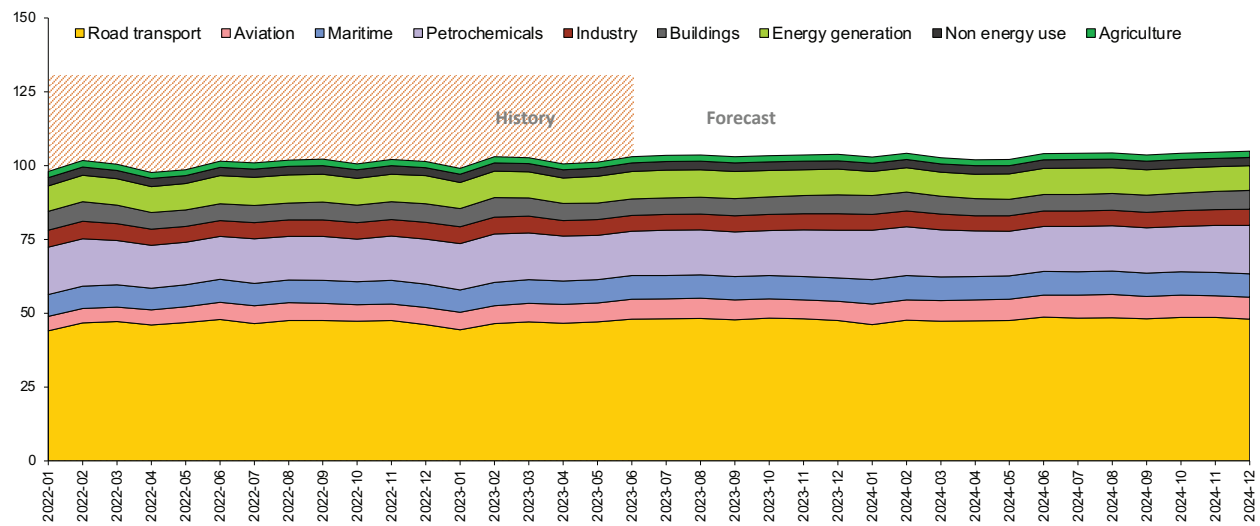
2.2 Global liquids demand – supply balances

Global liquids demand, which saw record distortions during the pandemic era, has seen a relatively "calm" times post that and remainder of 2023 and 2024 is expected to stay balanced and relatively flat. As pandemic restrictions become a thing of the past, road transport and aviation driven liquids product demand constitute to over half the global demand in the next 18 months. Asia, mainly China, and the US drive over 60% of the global road transport + aviation led products demand over second half of 2023 and full year 2024. Industrial demand, mainly petrochemical industry driven, is expected to the second key market driver for global demand over the period. Region-wise, pet-chem sector in the Middle East alongside Asia and the US is expected to be the largest globally in terms of drawing liquids demand. Significant demand is also likely to be driven by energy generation initiatives like power.

Despite the subdued economic activity in China and Europe over the second quarter in 2023, the demand did not see a severe dip. Over the second half of 2023, easing macroeconomic pressures, such as the tightening of US monetary policy, should encourage a more optimistic market outlook. The start of summer in the Northern Hemisphere has sparked a surge in crude oil demand, driven by record-breaking temperatures and increased travel, particularly impacting consumption of road and, notably, aviation fuels.

Oil markets review

Global products demand, split by sector (Million barrels per day)

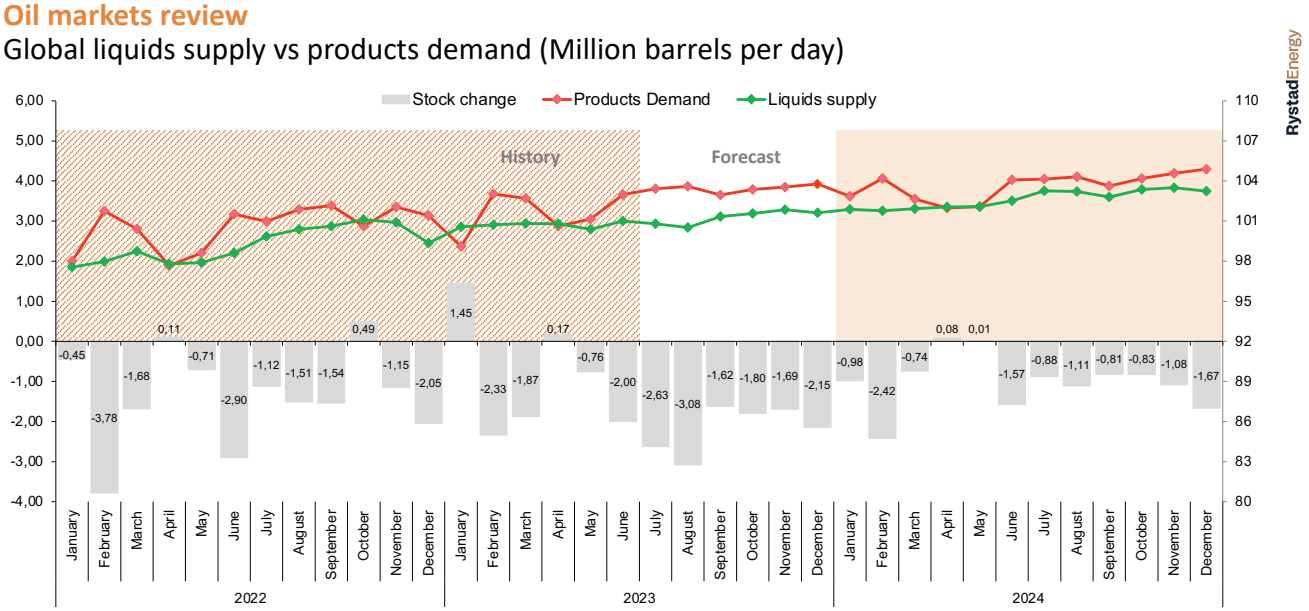


Source: Rystad Oil Market Cube

Meanwhile, Saudi Arabia has extended its voluntary 1 million bpd cuts into August. Potential for further extensions to help balance the forthcoming market deficits cannot be ruled out. Alongside this, a decrease in Russian exports is being observed since April 2023 due to intensified local refinery activity, despite considerable reductions in government subsidies. Looking ahead, average product demand over Q3–2023 is expected to increase to over 103.3 million bpd, while supply is predicted at close to 101 million bpd. This disparity would cause a significant 2.44 million bpd deficit in this period. Q4–2023 is expected to be a less intense quarter, with demand estimated at 103.6 million bpd and supply expected to rise to 101.7 million bpd, leading to a relatively lesser deficit of 1.88 million bpd, which would cause substantial stock draws by the end of the year. Regionally, North America's summer refinery season is set to peak in August with an output of 19.5 million bpd, primarily driven by robust US demand and strong refinery margins. This would result in a modest net export margin of 200 thousand bpd in August, recovering to 1.4 million bpd in Q4–2023. Simultaneously, Saudi Arabia's cutbacks will reduce the Middle East's total net surplus to 16.5 million bpd in Q3, with declining Russian exports adding more strain, particularly on the APAC market, which is projected to experience deficits of 24.7 million bpd in Q3–2023, escalating to 25.4 million in the final quarter.

Oil markets review

Global liquids supply vs products demand (Million barrels per day)



Source: Rystad Oil Market Cube

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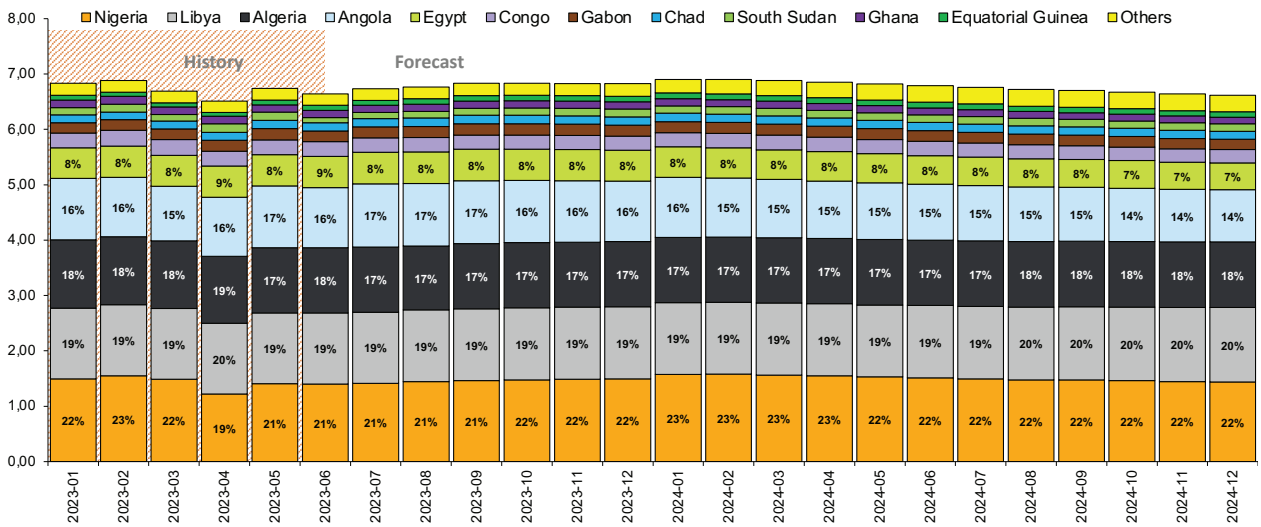
2.3 Africa short-term supply: 2024 expected to see gradual month-on-month decline

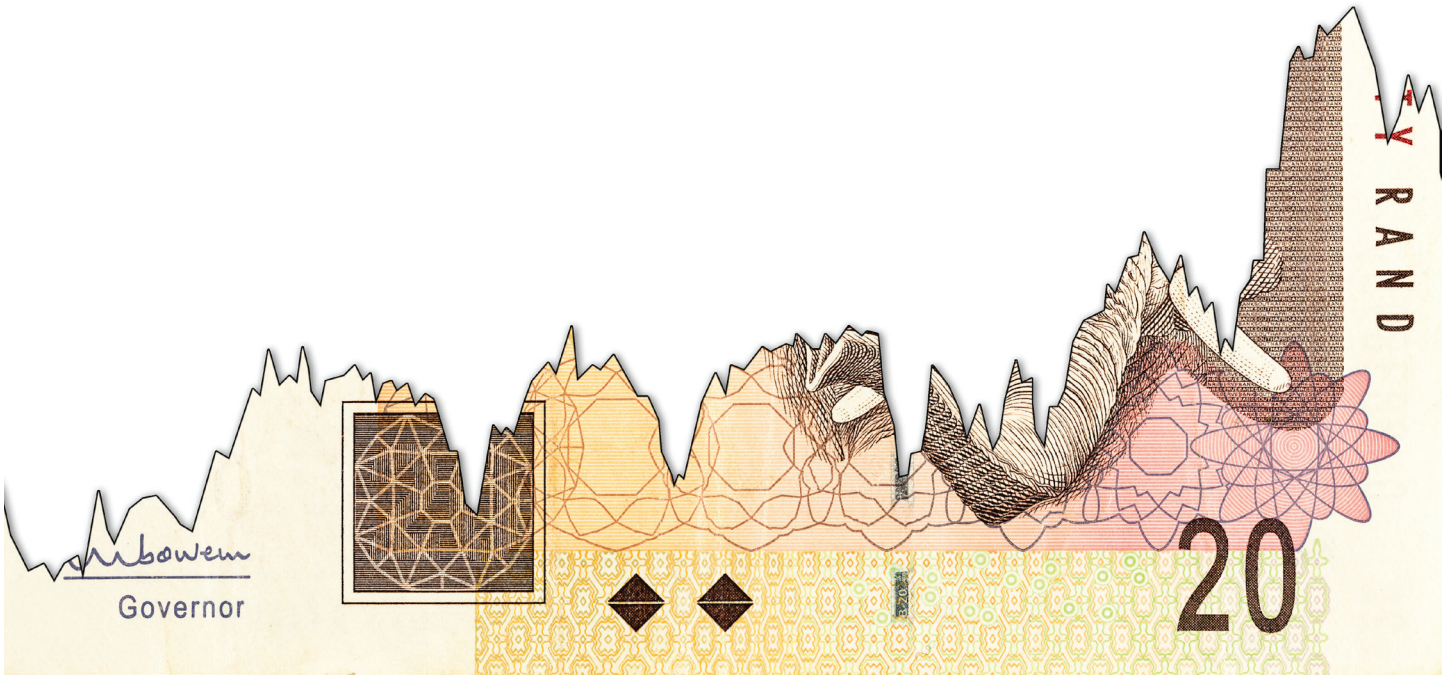
While global outlook for oil production in 2024 is expected to be marginal growth, Africa is expected to stay relatively flat at about 6.77 million bpd average over both the years 2023 – 2024. Africa monthly contribution to global output over the two years is also expected to stay flat at about 8% of the total volumes. However, month-on-month (MoM) production outlook for Africa over 2024 is expected to be a gradual marginal decline from about 6.9 million bpd in January 2024 to about 6.62 million bpd in December 2024. The OPEC member nations in Africa alongside Egypt, Chad and Ghana are expected to be the key drivers of the oil + condensates output from Africa over the two years. OPEC members – Nigeria, Libya, Algeria and Angola comprise of the top four producers in Africa for both the years with outputs of 1.45 million bpd, 1.29 million bpd, 1.19 million bpd and 1.1 million bpd respectively for the year 2023 and 1.51 million bpd, 1.31 million bpd, 1.18 million bpd and 1.01 million bpd respectively for the year 2024. While these four countries' oil + condensates flows add up to two-third of the total output for both the years, Nigeria alone is expected to contribute just over a fifth of the total annual volume and the other three producers are expected to flow just under a fifth of the annual average. Egypt – expected to round off the top five producers in Africa over both the years – is estimated to flow about 560,000 bpd and 520,000 bpd for the years 2023 and 2024 respectively. Libya, currently seeing strong recovery from its civil war lows, is expected to see MoM growth in 2024 along with its neighbour Algeria. Nigeria, rocked by production outages in 2023, is expected to see gradual recovery in 2023 but

Oil markets review

Short-term crude + condensates supply, Africa (Million barrels per day)



Source: Rystad Oil Market Cube

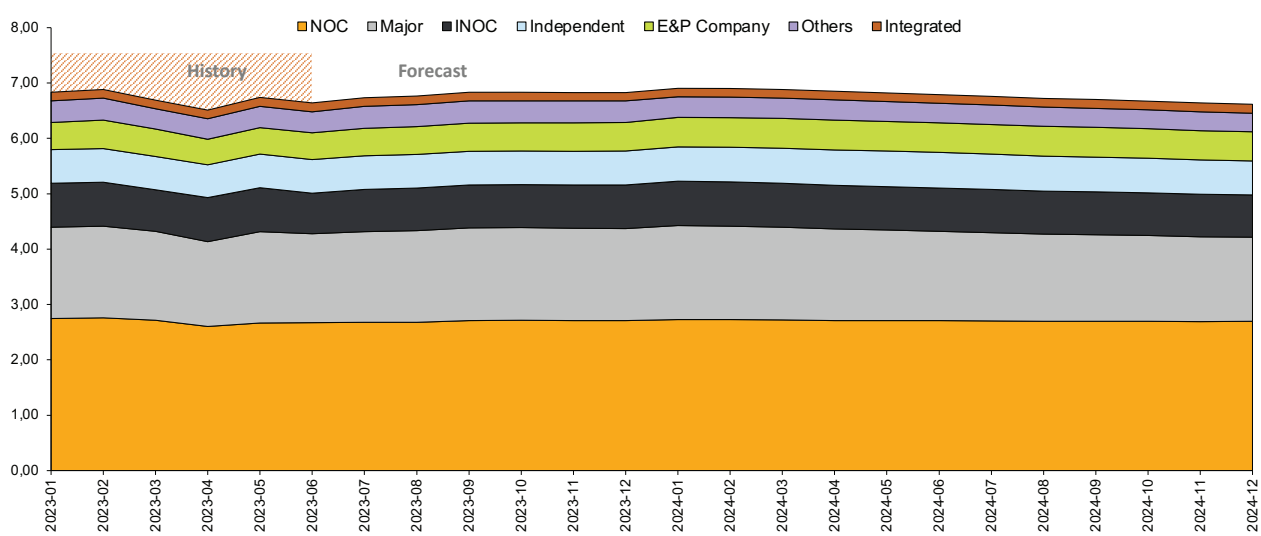


gradual decline in 2024. The remaining two producers from the top five are also estimated to see a gradual MoM decline in 2024.

In terms of leading producers of oil and condensates in Africa in the short-term, it is the NOCs, either by being the primary stakeholders like in the case of Algeria or as JV partners (with majors) like in the case of Nigeria, that are expected to lead the way with their working interest stake of the total volumes. 40% of the total oil + condensates supply from Africa in 2023 – 2024 is expected to come from NOCs' stakes in the producing fields. International oil majors like Shell Plc, TotalEnergies, Eni (all three independently or as a JV like Shell Petroleum Development Company (SPDC) in Nigeria), BP (again independently and as Azule Energy (BP – Eni JV in Angola), Chevron and ExxonMobil form the second largest company segment in terms of short-term liquids production in all of Africa. National Oil Companies with International presence (INOCs) like Norway's Equinor complete the top three segments and together NOCs, majors and INOCs are expected to constitute to three-fourths of the total liquids output in Africa in the short-term. Independents like Tullow Oil which has dominating presence in Ghana and Exploration and Production companies (E&Ps) form the next two large company segments.

Oil markets review

Short-term crude + condensates supply, split by company segment, Africa (Million barrels per day)



Source: Rystad Oil Market Cube

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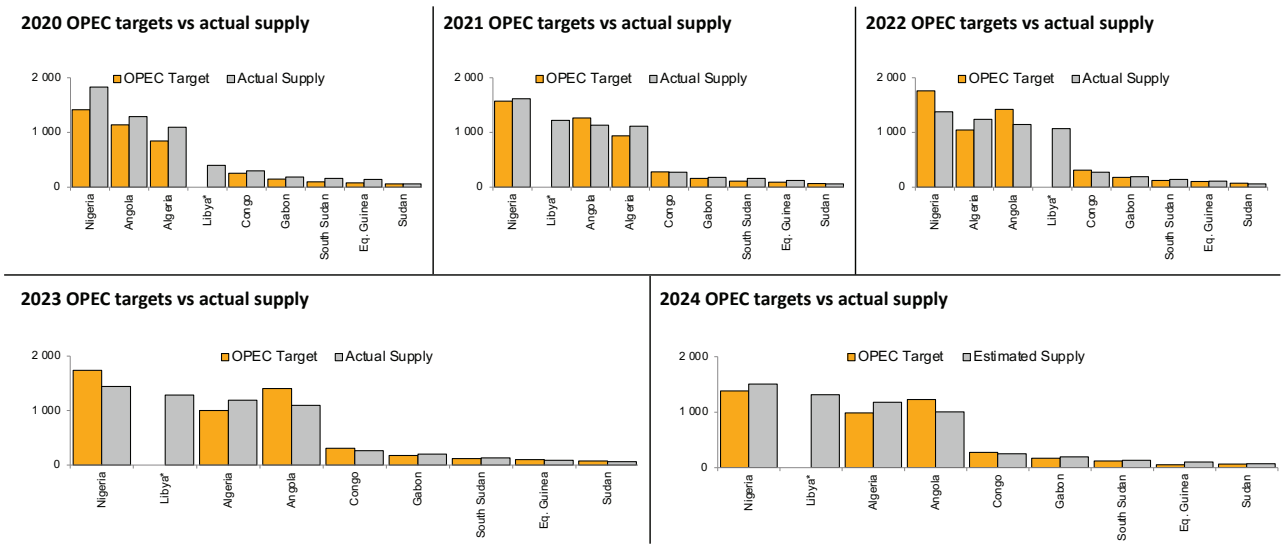
2.4 Disruptions to OPEC members' flows can dent the continent's output severely

OPEC member nations in Africa were, are and are expected to remain the key producers of liquids in the continent. The membership of OPEC cartel ensures a petroleum exporting country status but also comes with certain regulations, especially in times of market turmoil. These regulations sometimes involve regulatory supply or production cuts where the member nations are given production quotas and are expected to voluntarily cut down their output within these cuts. These cuts are prescribed by the cartel to control the supply – demand balance globally and to control a volatile market situation or irregularly high or low global oil prices. The member nations are expected to adhere to these cuts so that the cartel maintains its control on the global markets as opposed to losing the market share and control to North American Shale. Historically, the compliance of Africa's member nations to OPEC supply regulations or quotas or cuts has been on the lower side. These countries always had a higher production capacity than the quota and produced higher even at times of YoY production decline. However, the situation has now reversed, especially with the two largest producers of Africa – Nigeria and Angola. Even when the world as a whole and upstream sector both were dealt a lethal blow in the form of the global pandemic, Nigeria and Angola's actual output for the year 2020 outran the production quota by 30% and 15% respectively. 2021 also saw Nigeria's liquids production marginally exceed the production cap. However, production outages caused by pipeline sabotages, militant attacks and subsequent force majeures imposed by the operators that have historically crippled production in Nigeria, combined with

Oil markets review

OPEC members' production targets vs actual supply, Africa (Thousand barrels per day)



RystadEnergy

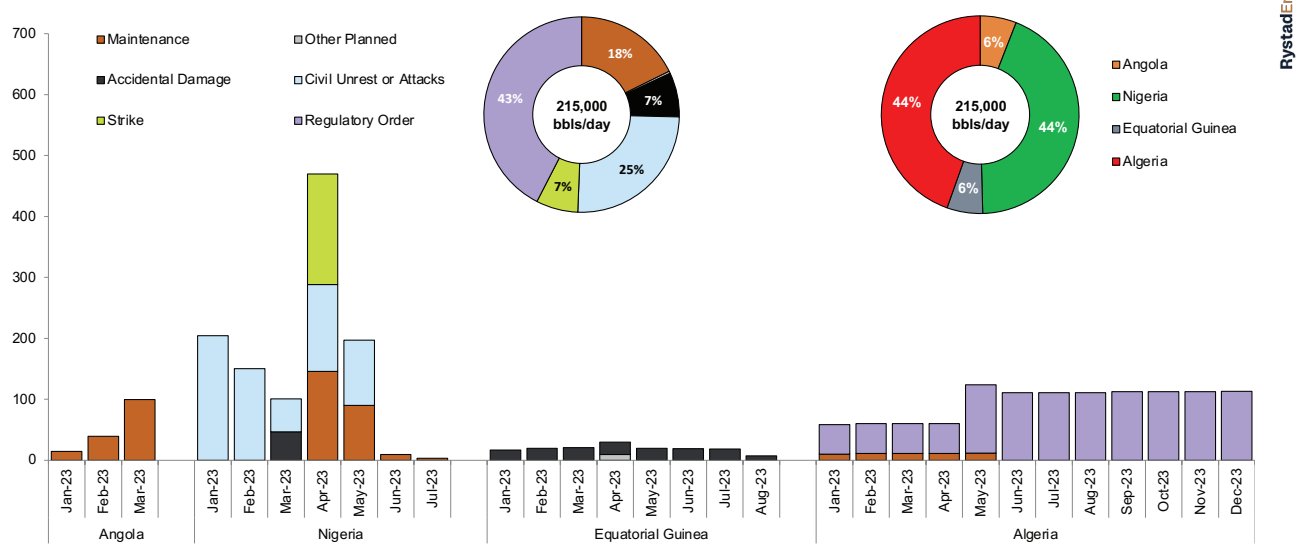
Source: Rystad Oil Market Cube

natural decline of legacy fields and lack of new start-ups have altogether led to Nigeria's output falling short of the production quota and hence showing 100% compliance to OPEC cuts for the years 2022 – 2023. Angola, which saw a cluster of floating production storage and offloading vessels (FPSOs) come online together, entered a terminal decline phase with these projects falling off plateau together and no new developments kicking off; and this put Africa's second largest oil producer also come short of OPEC production caps for the third year in a row.

Overall production outages over 2023 driven by various factors – both planned and unplanned are an average 215,000 bpd. While planned outages like Algeria's adherence to OPEC cuts in 2023 and maintenance activities majorly in Angola and Nigeria are estimated to drive close to 60% of these production disruptions in Africa in 2023, unplanned outages like accidental damages to infrastructure, strikes by unions and civil unrest, and attacks on infrastructure are expected to account for the remaining 40% of the total production outages, provided no such accidents happen going forward over the fourth quarter. In terms of countries driving production outages, two countries – Algeria with its planned regulatory cuts and, Nigeria with its unplanned outages and maintenance activities – are estimated to cause close to 90% of the total supply lost due to production disruptions. Remainder of the production outages have come from Angola and Equatorial Guinea where the cumulative volumes lost are an estimated 25,000 bpd average over 2023.

Oil markets review

Africa 2023 production outages (Thousand barrels per day)



Source: Rystad Oil Market Cube

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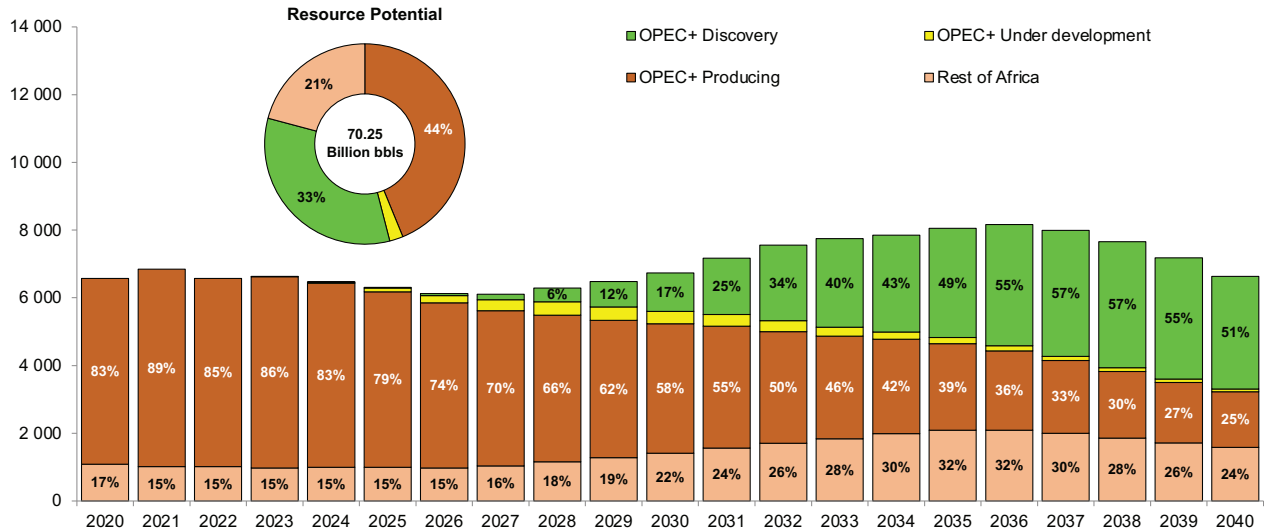
The production outages or an ongoing possibility of such accidents/attacks happening on projects in Africa's OPEC countries need to be looked at critically as these nations are not expected to flow majority liquids supplies in the short month-on-month (MoM) term but also are estimated to drive bulk of the production in the long-term as well. The current producing projects from OPEC countries in Africa are estimated to hold an estimated 44% of the total liquids reserves potential of over 70 billion barrels (bbls). An additional 33% is estimated to be the undeveloped discoveries in these countries and 2% from the currently under-development projects. As opposed to this, only just over a fifth of the total potential is from the non-OPEC African counterparts. The significant impact on the production can be seen from the fact that African OPEC countries are estimated to drive about 85% and close to 80% of Africa's total oil + condensates for the years 2023 and 2025 respectively. While the non-OPEC counterparts' contribution is estimated to increase from a mere 15% share in 2023 to close to a quarter of the output by 2030, the dominance from OPEC countries is expected to continue even after the legacy producing projects decline as the newer fields have the potential to take up the role as effectively adding over 50% of the output through the second half of 2030s. As such, the respective administrations of these countries should hold safe and inviting business environment and investment-attractive fiscal terms to keep their individual as well as Africa's oil flows robust.

Oil markets review

Africa long-term oil + condensates long-term forecast (Thousand barrels per day)



Source: Rystad Oil Market Cube

3 GAS MARKETS REVIEW

Global gas supply expected to be driven mainly by North America, Middle East, Asia and Russia

Global gas and liquified natural gas (LNG) demand expected to outrun the supply from currently producing fields and balance largely dependent on newer projects and currently undeveloped discoveries

Africa joins the top four gas producers to round off the top five LNG exporters globally

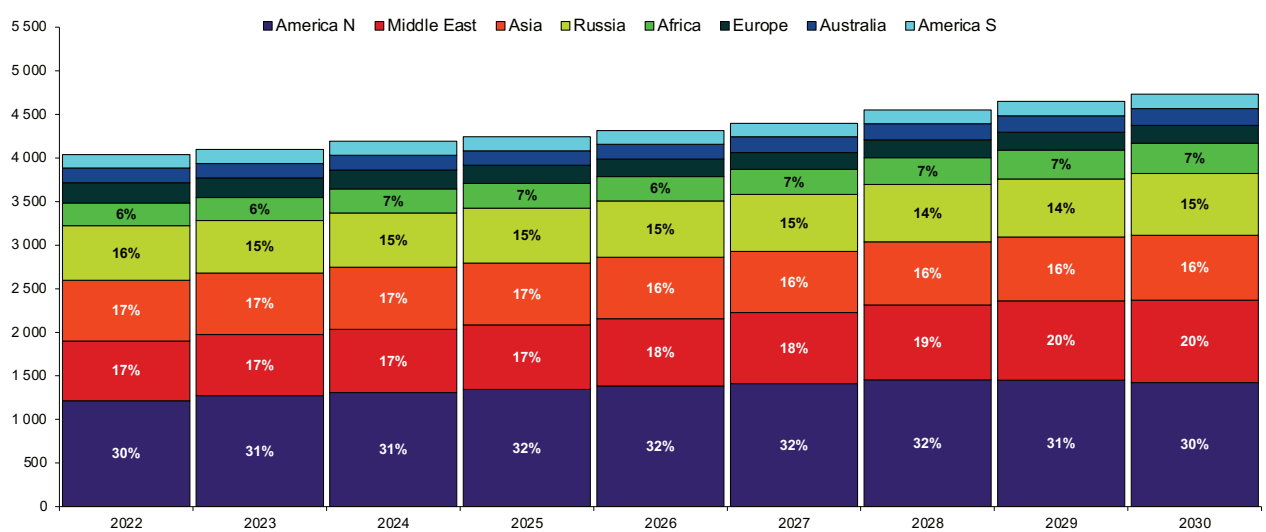
North Africa expected to pump majority of the natural gas supplies while West Africa expected to drive the LNG flows from Africa

3.1 Global gas supply potential estimated to see gradual growth through the decade

Global natural gas supply evolution through this decade is estimated to see gradual YoY growth from about 4,100 billion cubic metres (Bcm) in 2023 to about 4,250 Bcm in 2025 – a growth of 3.5% over 2023, and further to 4,730 Bcm in 2030 – a growth of 11% over 2025 levels and 15% over 2023 levels. The forecast reflects an average 2% YoY growth from 2023 to 2030. The growth potential was expected to be far higher but the volatility and chaos, caused by the Russian aggression on Ukraine, led to lower forecast especially from Russia. The volumes are expected to be largely driven by the US, Middle East, Asia and Russia. While the US, on average, is estimated to drive over 30% of the global natural gas output through the period, the top four producing regions together are expected to flow over 80% of the total supplies. Individually, the estimated average YoY growth is expected to be the highest in Middle East and Africa, with a 4% annual growth. All other regions, barring Europe, are expected to see a positive annual growth over the period. Europe is the only region which is expected to see decline in production from about 225 Bcm in 2023 to just over 200 Bcm in 2030.

Gas markets review

Global natural gas supply split by continent, forecast to 2030 (Billion cubic meters)



RystadEnergy

Source: Rystad Energy UCube

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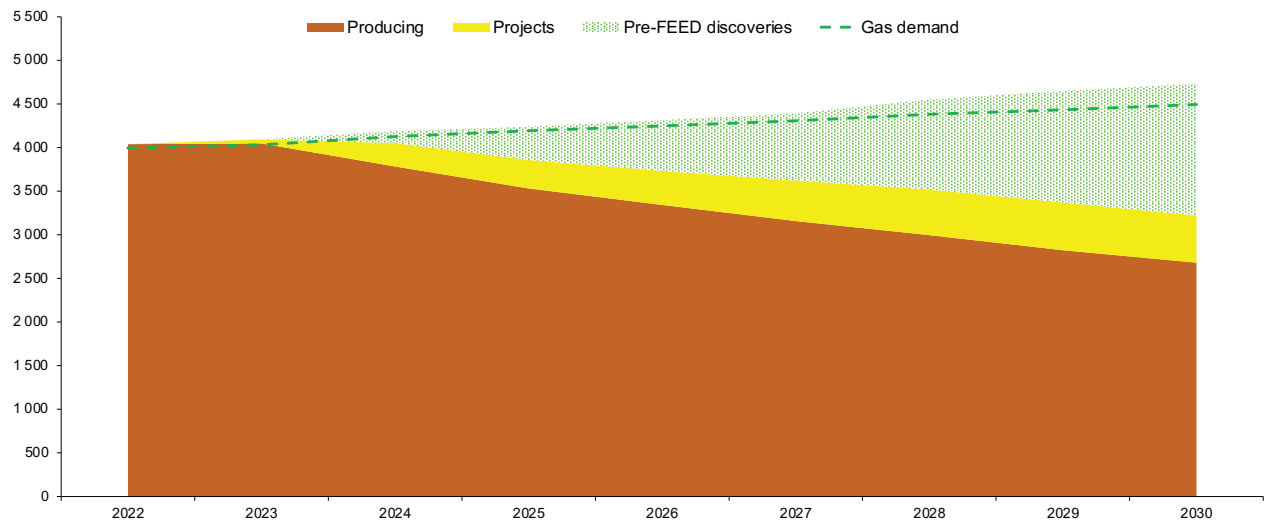
Potential global natural gas supply forecast might be showing a YoY growing trend, but the share of production from the currently producing fields is expected to decrease from just over 90% in 2024 to a little over 55% in 2030. Over the same period, the demand is expected to ramp up from about 4,030 Bcm in 2023 to almost 4,500 in 2030. Also, supply from the producing fields is expected to fulfil just over 90% of the demand in 2024. But this is estimated to decrease to under 60% by 2030. Considering the fact that the production from legacy fields is declining as opposed to the growing demand, the gap between demand and supply can only be closed by supply from the currently under development projects and undeveloped discoveries. The supply potential, including the expected supply from the currently undeveloped discoveries, is estimated to exceed the demand. But if the development timelines of these projects get postponed or if these projects get downsized, the supply can fall short of the demand.

One positive indicator for natural gas developments is that the upstream operators are now revising their strategies and aligning their future investments more in line with energy transition, and natural gas is being looked at as transition fuel. As such, these developments can be expected to get approved and come online in the currently estimated timelines.

Gas markets review

Global natural gas supply vs demand, forecast to 2030 (Billion cubic meters)



Source: Rystad Energy UCube; Rystad Energy GasMarketCube

Source: Rystad Energy UCube; Rystad Energy GasMarketCube

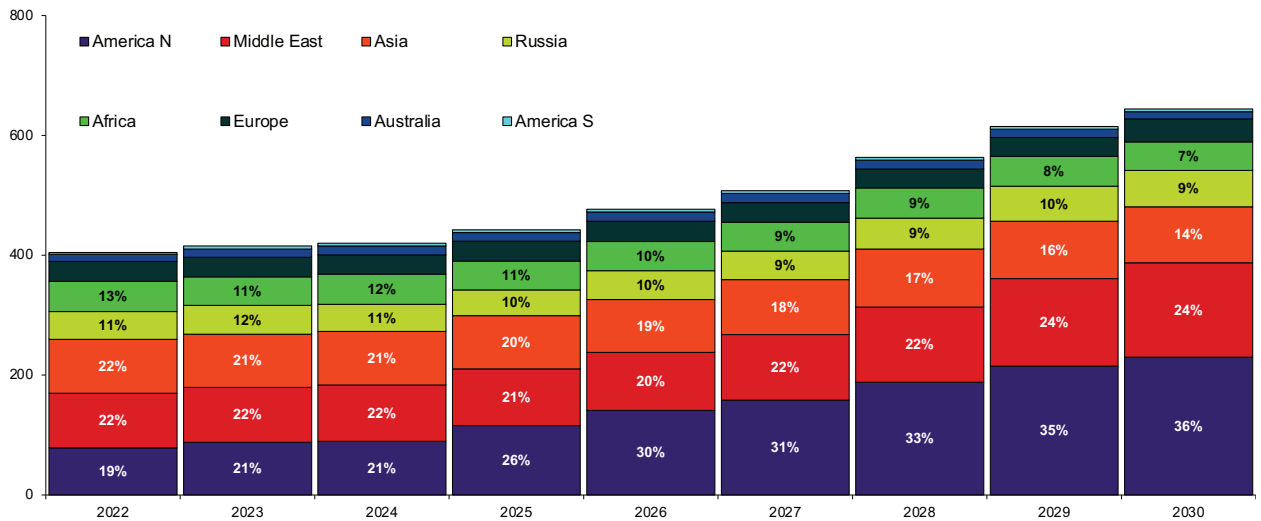
3.2 Global LNG flows estimated to see an average 8% YoY growth in late 2020s

As opposed to the overall natural gas supply potential, LNG export potential, supported by growing liquefaction capacity globally and driven by resilient demand especially in Asia and Europe, is expected to see a steeper growth of about 7% over the period 2023 – 2030 and a marginally higher 8% over late 2020s. LNG projects in the US which have been finding takers from the European markets and projects in the Middle East like the Qatar LNG which have been signing service contracts for accelerated development make these regions the top LNG exporters globally through this decade.

Multiple LNG developments in these regions have already had their respective final investment decision (FID) taken or are expected to see their FID happen soon. Many of these developments are estimated to come online and start exporting cargoes within the 2020s and as such are expected to see YoY growth in their respective LNG exports. US LNG exports are estimated to grow from about 88 million tonnes per annum (MMtpa) in 2023 to 115 MMtpa in 2025 and double to 230 MMtpa by 2030. LNG exports from the Middle East are expected to increase from just over 90 MMtpa in 2023 to almost 160 MMtpa by 2030. This level of growth from the US

Gas markets review

Global LNG supply split by continent, forecast to 2030 (Million tonnes per annum)



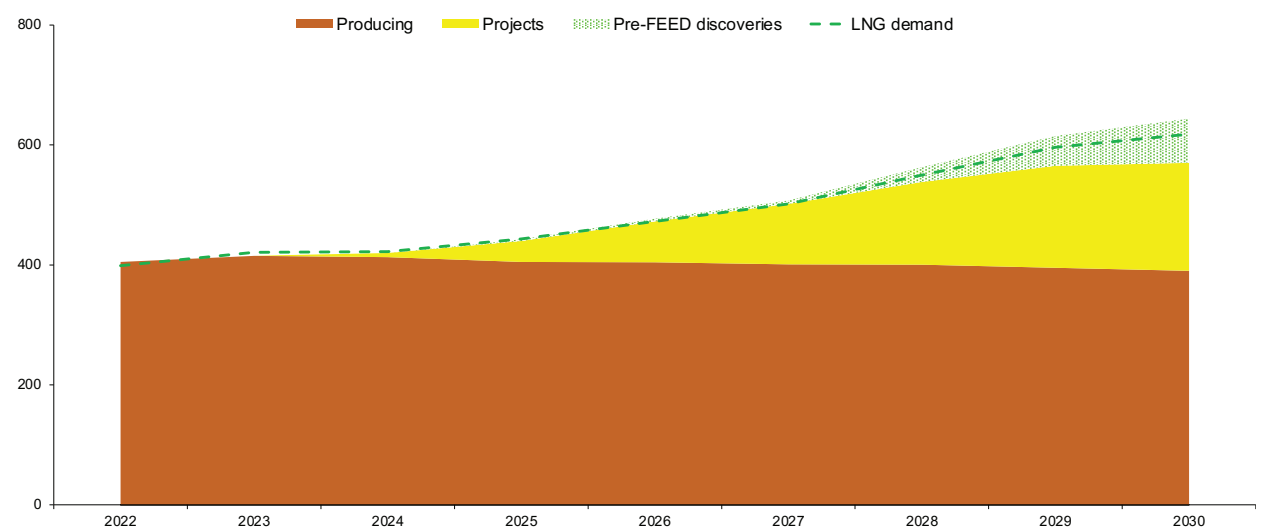
Source: Rystad Energy UCube

and Middle East along with steady flows from other regions is expected to see global LNG exports increase from about 415 MMtpa in 2023 to just over 440 MMtpa by 2025 reflecting a 6% growth and further to a much higher 645 MMtpa reflecting a 55% growth in LNG exports.

While LNG exports are estimated to see a healthy growth from 2023 to 2030, the volumes from currently exporting LNG projects are estimated to stay relatively flat at about 400 MMtpa through the period. However, the resilient LNG demand is expected to see an increase from 420 MMtpa in 2023 to close to 620 MMtpa by 2030. Majority of the growth in LNG supply is estimated to come from the currently under development projects. Currently pre-FEED (Front End Engineering and Design) discoveries are also expected to come online and drive increase in exports through late-2020s. As such these new developments are very important to bridge the gap between supply and demand, similar to global natural gas supply vs demand.

Gas markets review

Global LNG supply vs demand, forecast to 2030 (Million tonnes per annum)



Source: Rystad Energy UCube; Rystad Energy GasMarketCube

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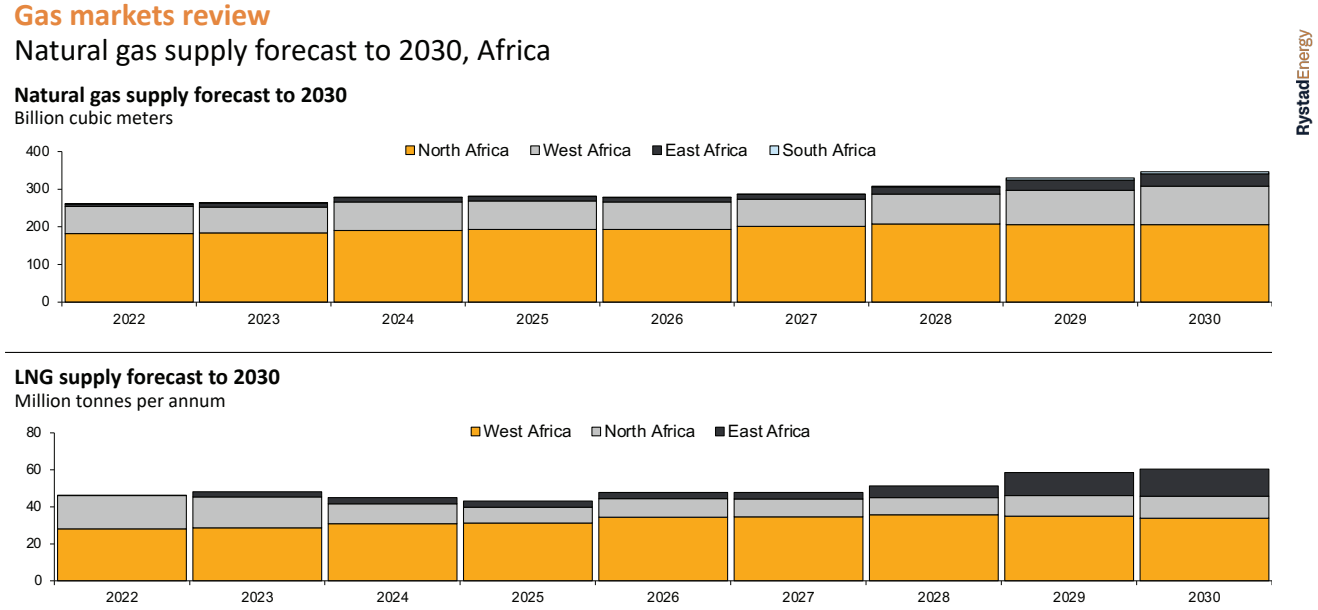
3.3 North Africa and West Africa estimated to drive African natural gas and LNG exports respectively

Africa holds immense natural gas potential and has had historical natural gas trade ties with Europe. The continent continues to be in a position to increase its natural gas output and benefit from an under supplied LNG market and resilient demand from Europe. While estimates from the 2023 outlook suggested not many large volumes coming online in the near-term and overall Africa natural gas output declining from 2022 through 2025, estimates from the latest outlook show increase from 2023 natural gas output of about 265 Bcm to over 280 Bcm by 2025. North Africa drives majority of Africa's natural gas flows but the output is expected to stay flat through the 2020s. Ramp up is expected through the second half of this decade as Mozambique ramps up its LNG output and new gas start-ups across the continent come online and take the output on an increasing trend. But an increased focus on LNG exports is apparent with an expected uptick in near term LNG flows from the continent. Nigeria and Algeria are expected to drive majority of these export volumes with additional flows coming from Egypt, Equatorial Guinea, Mozambique and waters off Senegal – Mauritania. Africa stands at a point where it can benefit from historical gas trade relations with Europe, existing infrastructure to export gas to Europe, geographical vicinity to the demand centres and most importantly abundant natural gas potential. It is very important that both the upstream operators and policy makers grasp this opportunity with both hands and solidify Africa's role as a global natural gas exporter before the opportunity diminishes or even worse, expires.

Gas markets review

Natural gas supply forecast to 2030, Africa



Source: Rystad Energy UCube

4 GLOBAL INDUSTRY REVIEW

Global upstream spending potential going strong despite industry sentiment of underinvestment

Potential greenfield spending in the United States, Africa, Asia and Middle East expected to drive a quarter of the overall spending through 2023 – 2030

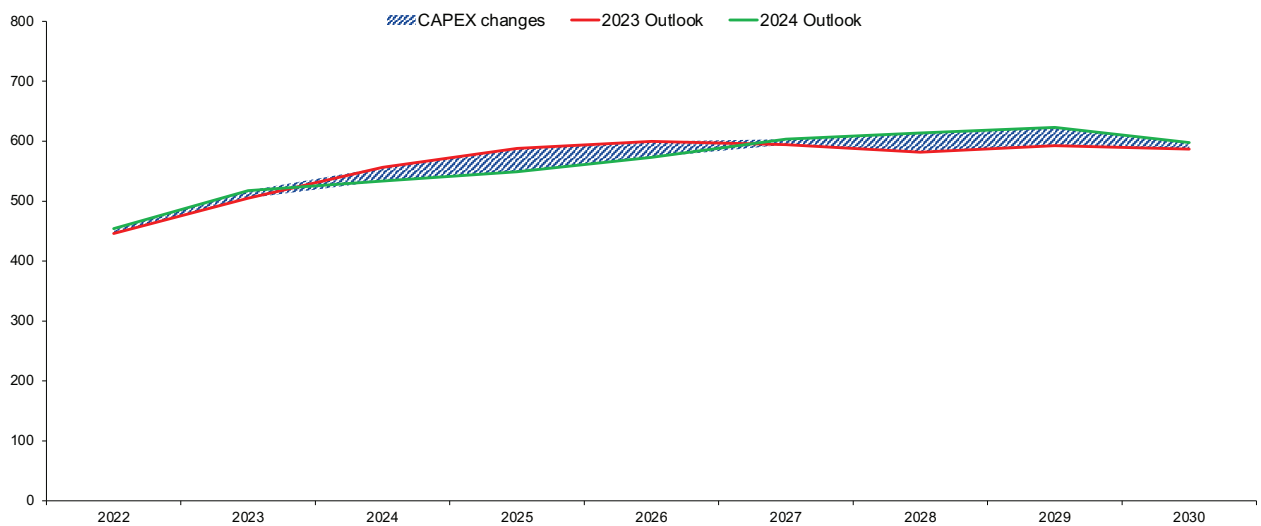
Liquid supply potential relatively lower than previous outlook and gas potential marginally higher

Brent 2023 – 2024 outlook higher than previously estimated

4.1 Global upstream CAPEX – no major revisions from the previous outlook and growth expected from greenfield spending

It has been widely suggested within the oil industry in the post-pandemic era that the current energy crisis is a result of underinvestment in upstream projects on the back of consecutive oil market slumps and the changing strategies of operators. However, persistent claims of chronic underinvestment in the global oil and gas industry appear overblown. Declining upstream levels and investments in recent years have been posited in many quarters as proof of underinvestment, with a shortage of oil said to be on the horizon. While both investments and well activity levels have indeed dropped considerably since 2014, lower unit prices, efficiency gains, productivity gains and portfolio effects have also made the upstream industry much more efficient. In other words, the industry can do the same as before, but at much lower cost. Analysing how much oil is being developed, it is to be noted that there is no underinvestment and activity is at a healthy level, similar to that seen during the last investment cycle from 2010 to 2014. Investments peaked at almost US$740 billion in 2014 before falling to around US$440 billion two years later after the oil price collapse in 2015. There was another drop in 2020 as investments declined to US$345 billion due to the Covid-19 pandemic

Global CAPEX changes – 2023 Outlook vs Latest Outlook (Billion USD)



Source: Rystad Energy UCube

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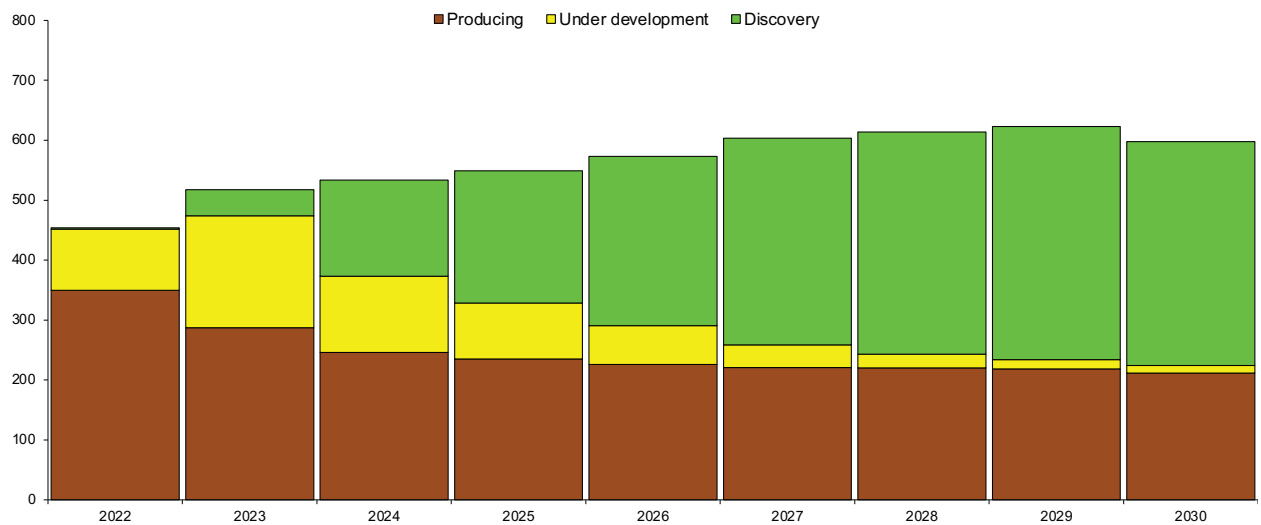
and consequent lower oil price. The latest outlook suggests investments recovered last year to over $450 billion as oil and gas activity once again started to increase. Despite this comeback, last year's investments were only 60% of 2014 levels, and it can be easy to conclude that upstream activity has declined 40% since 2014. The unit prices, that happen when the spending occurs and not when the contracts happen suggest that most of the segments have seen their prices come down by 20% – 30% since 2014. This implies that the oil sector is seeing more activity for every dollar spent now compared to 2014.

The oil price crash due to the Covid-19 pandemic in 2020 and 2021 left a sizeable dent in investments into upstream assets, but the potential CAPEX spending forecast going forward suggests global upstream investments are expected to see a YoY increase over the 2020s. Near-term evolution is marginally lower than the previous forecast, but latter half of 2020s is estimated to see a relatively higher spending. As such, contrary to widespread belief, lower unit prices and steady growth in YoY spending suggests that the global upstream industry is not seeing underinvestment globally.

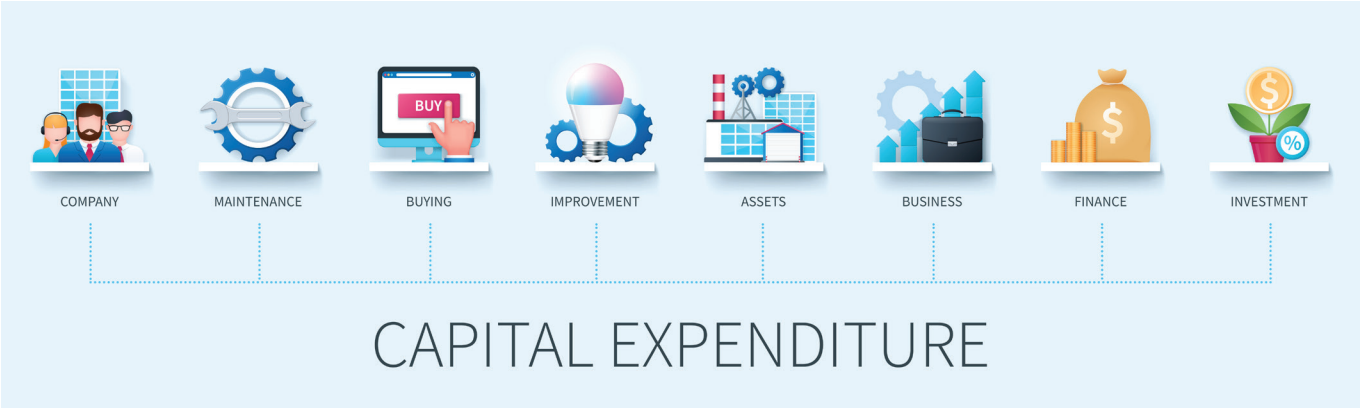
Brownfield spending to maintain output from the producing fields together with the greenfield spending on the FID'ed currently under development projects is expected to drive majority of the spending in the short-term from 2023 through 2025. The YoY share of these projects is expected to decline from over 90% of the total spending in 2023 to about 60% of that in 2025, as the spending on currently pre-FEED projects picks up. Over these three years, producing and pre-2023 approved fields are estimated to drive three quarters of the overall global upstream CAPEX. The second half of the decade, 2026 – 2030, is expected to see a steady relatively flat brownfield spending trend with an average spend of US$220 billion per annum. As the currently under development fields come online and convert to producing fields, the greenfield spending on them is expected to reduce to

Global industry review

Global CAPEX forecast to 2030 split by lifecycle (Billion USD)



Source: Rystad Energy UCube

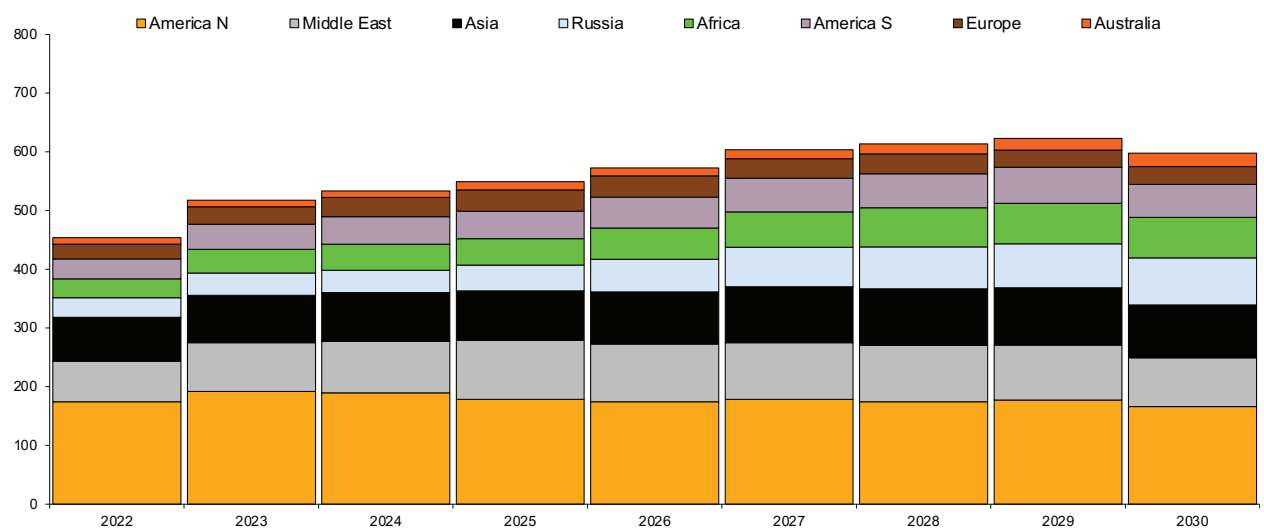


relatively marginal levels. Through this period, the greenfield spending on the currently pre-FEED discoveries is expected to pick up as these projects reach their respective FID's and service contracts – both drilling and facility related – get awarded eventually and payments are made. This spending is expected to see a steep jump by 22% from 2026 levels of just over US$280 billion to almost US$345 billion in 2027. 2028 – 2029 spending on these projects is a marginally higher US$370 billion and US$390 billion respectively, before reducing to almost US$375 billion in 2030. The total spend on these projects over the five-year period is an estimated US$1,760 billion, about 60% of the total upstream capital expenditure. The total greenfield spend over 2023 – 2030 period is an estimated US$2,745 billion, almost 60% of the total upstream capital expenditure. This ratio increases marginally to close to 65% over the second half of the decade as YoY greenfield spend increases and brownfield spend trend flattens.

North America, predominantly the United States, Middle East, Asia, Russia and Africa, are expected to drive over 80% of the total upstream CAPEX over the period 2023 – 2030 and are expected to be the top five spenders in that very same order. In terms of individual spending trend, Russia, Africa, LatAm and Australia are expected to see a YoY growth in spending over the period, the remaining regions are expected to maintain a relatively flat or marginally declining spending trend. Greenfield spending is expected to have a larger share of the overall CAPEX over the period and, North America, Africa and Middle East are expected to be the top three regions in terms of the estimated/expected potential greenfield investments. These three regions are expected to drive almost half the greenfield spend with Middle East at No.4 spot, with an estimated share of 15% of the total greenfield expenditure over the period.

Global industry review

Global CAPEX forecast to 2030 (Billion USD)



Source: Rystad Energy UCube

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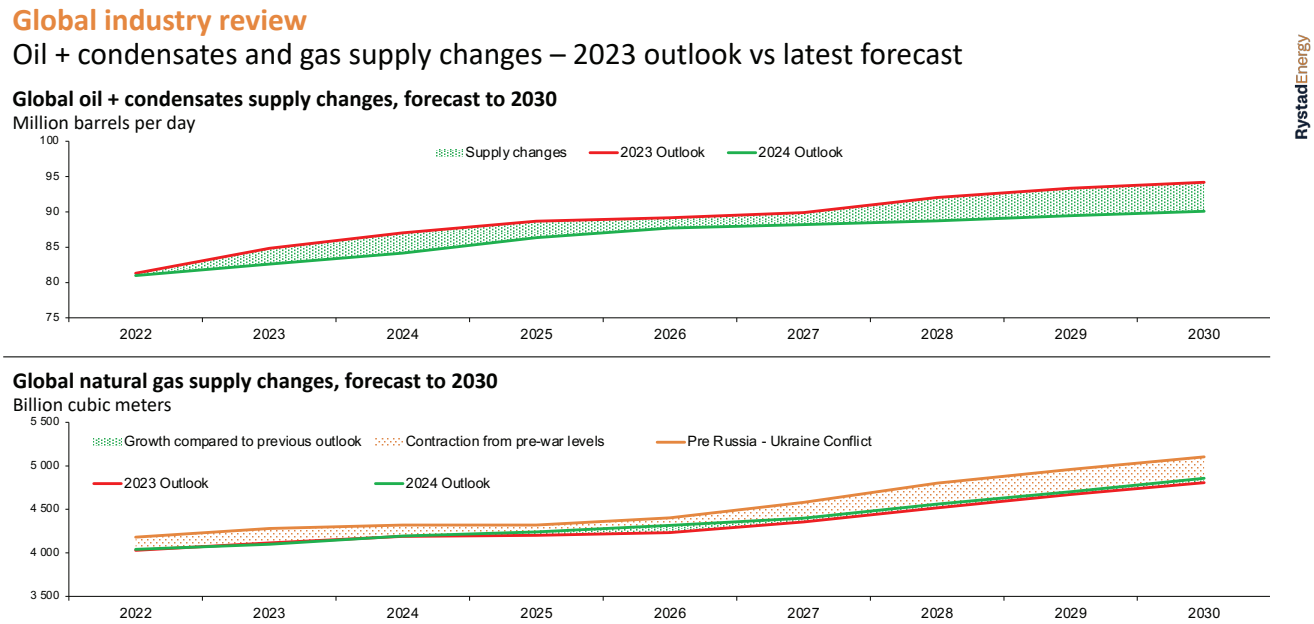
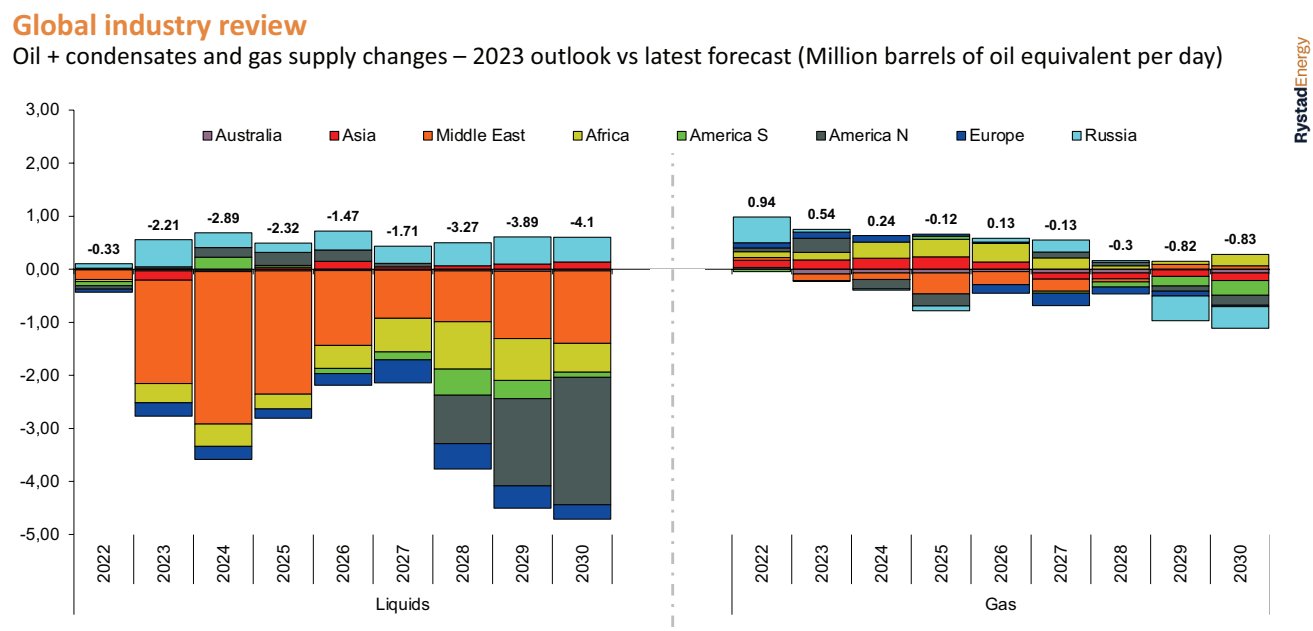
4.2 Global hydrocarbons supply – liquids see a decline and gas remains unchanged compared to the previous forecast

While the unit costs may have dropped from the 2014 – 2015 levels, the evolution is in an increasing trend going forward from 2022 through the decade. So, even though the CAPEX as per the 2024 Outlook remained roughly unchanged from the 2023 Outlook, the increase in unit costs is expected to come into effect. The 2024 Outlook suggest the oil + condensates potential supply evolution from 2022 to 2030 is at a lower level throughout the period. Forecast according to the previous outlook was the supply increasing gradually from about 85 million bpd in 2023 to 94 million bpd in 2030. The





Source: Rystad Energy RenewableCube

latest forecast puts the forecast at 83 million bpd in 2023 to about 90 million bpd in 2030. However, the natural gas supply is expected to remain almost unchanged from the previous forecast.

The downside revision in liquids supply forecast is mainly driven by three regions – Middle East, North America and Africa. The Middle East showed a YoY drop in output throughout the period resulting in negative revisions in the overall global output. The near-term supply drops from the region might be due to the OPEC regulatory cuts as well as voluntary production cuts from the members. The supply drop from Middle East reduced towards the second half of the decade, but the negative revisions in flows from Africa and North America are led to negative revisions in overall global flows.

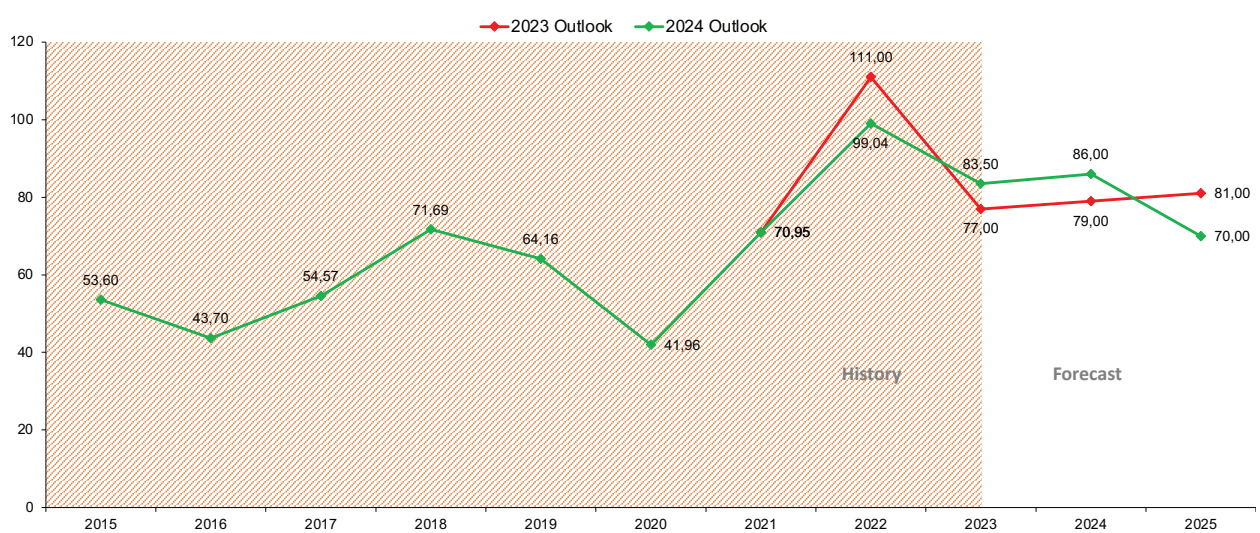
4.3 Brent revised to higher level due to stronger demand outlook

Global oil prices continued an upward trend that started in late June and prices recovered from $72 per barrel to $88 per barrel. The rebound came on the back of a significant market deficit. The extension of Saudi Arabia's cuts also contributed to the bullish market sentiment. In fact, the oil market has now seen evidence of destocking. Global commercial crude inventories experienced a large drop in July (1.22 million bpd), and preliminary weekly stock data suggested that the US would again report significant draws for August. Through September, negative macro sentiment streaming from China weighed on prices. Poor macroeconomic data, real estate problems, and a weak yuan all added pessimism.

While the Chinese macroeconomic situation should be closely monitored, at this point, the Brent outlook remains cautiously optimistic. Moreover, the current negative macroeconomic sentiment could partially be mitigated by an additional extension of Saudi voluntary cuts. The outlook for the rest of the year suggests that upside price pressure will not recede as forecast for global balances points towards a significant deficit in the market and, correspondingly, the de-stocking process continues. Unsolved liquids balance for the rest of 2023 and the whole of 2024 shows a larger-than-previously expected deficit in the market because of tight supply and a more robust demand outlook. In particular, demand is expected to outpace supply by over 2.2 million bpd between August and December 2023. For 2024, the implied deficit is estimated at 1.9 million bpd. The estimated Brent base case for Q3 2023 is an average $84 per barrel and $87 per barrel in Q4 2023. 2024 Brent is an estimated $86 per barrel due to stronger demand outlook tightening next year's global balances.

Global industry review

Brent oil price evolution and forecast to 2025, Africa (Billion USD)



Source: Rystad Energy UCube

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5 AFRICA INDUSTRY REVIEW

NOCs and majors – key driving forces behind Africa' short-term supplies, hydrocarbon potential, medium-term production and spending

Total CAPEX over 2023 – 2030 expected to remain the same as last outlook with differences in timeline of spending

North and West Africa expected to drive bulk of the cumulative as wells as annual spending through the period

Liquids remain the key focus and equal split between onshore and offshore spending expected

Majority of the spending, especially through the second half of the decade, expected to come from currently pre-FEED discoveries

Nigeria, Libya, Algeria, Angola and Mozambique – the top five spenders over the period & NOCs and majors estimated to incur two-thirds of the total CAPEX

Actual CAPEX spending forecast closer to "Mean" scenario which models the global warming cap at 2°C

Drilling and rig demand on the rise till 2024 before assuming a declining trend

Majority of the rig demand robust with only about 32% based on contingent volumes

Healthy levels of exploration drilling expected over 2023 – 2025 with Algeria, Egypt, Namibia and Nigeria driving majority of the activity

11 high impact wells (HIWs) to be drilled in the next 15 months

177 blocks up for grabs as licensing rounds across Africa with to-be-awarded status expected to close in the next 18 months

Liquids portfolios and majority producing assets driving mergers and acquisitions (M&A) activity so far in 2023

5.1 NOCs and majors hold the potential and, drive the supplies and spending

African NOCs, through their vast presence across the continent's upstream operations as working interest owners, and international oil majors, who have been significant stakeholders and investors in the continent's hydrocarbon sector – form the two driving forces behind Africa's fossil fuel industry. Whether it is their presence in the form of a JV with majors like in Nigeria, or as working interest owners like in Algeria, Libya and the likes, NOCs are estimated to hold the largest working interest share of the hydrocarbon potential in Africa and are also expected to own the majority share of the supplies from the continent. NOCs are estimated to flow about 2.63 million bpd of liquids (oil + condensates) and 13.55 billion cubic feet per day (Bcf/d) of gas in the 2023. The volumes are expected to increase to 2.57 million bpd of liquids and 14.17 Bcf/d of natural gas next year. The main NOCs driving these supplies – Algeria's Sonatrach, Libya's NOC, NNPC of Nigeria and Angola's Sonangol, are estimated to drive over 85% of the liquids supplies from NOCs across Africa over 2023 – 2024. These four NOCs' cumulative natural gas flows

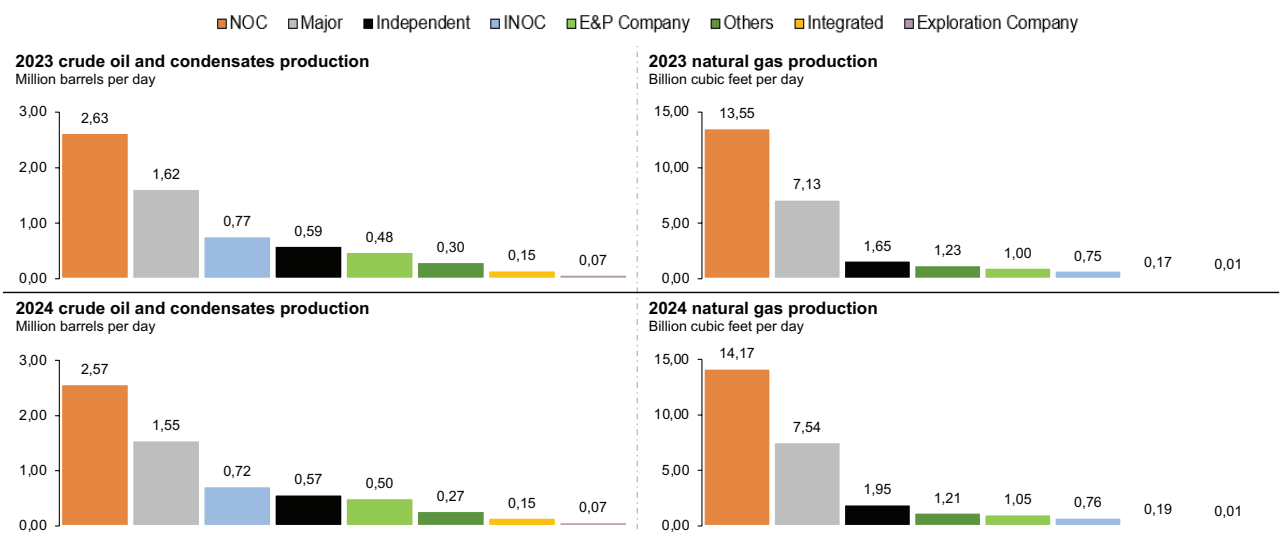
over 2023 – 2024 are an estimated 88% of the total natural gas produced by the NOCs across Africa. It also helps that Algeria, Libya, Nigeria and Angola, where these NOCs operate, drive majority of the liquids and natural gas flows for both the years.

Majors, with their legacy and widespread operations across North Africa as well as Sub-Saharan Africa (SSA), are expected to be the second largest after NOCs, with respect to the company segments driving the oil and gas supplies from Africa. Majors are estimated to flow 1.62 million bpd of liquids and 7.13 Bcf/d of natural gas in 2023 and, 1.55 million bpd of liquids and 7.54 Bcf/d of natural gas in 2024. International National Oil Companies (INOCs) – National Oil Companies that operate globally and independents are expected to be the company segments with Africa's third largest liquids and natural gas production respectively, for the years 2023 and 2024. Norway's state-owned oil company Equinor (formerly Statoil), with its extensive presence in Angola; China's China National Petroleum Corporation (CNPC), Sinopec, China National Offshore Oil Corporation (CNOOC) and PetroChina, with their vast operations in Chad & South Sudan, Egypt & Angola, Nigeria and Chad respectively; and Malaysian energy group – National Petroleum Limited, commonly known as Petronas, with its producing fields in South Sudan are some of the INOCs operating in Africa and together, these INOCs are estimated to drive three-quarters of the overall liquids output from INOCs in Africa over the 24 month period of 2023 – 2024. Independents like APA Corporation, the holding company of Apache Corporation; Marathon Oil, Wintershall DEA, Perenco, Seplat Energy, Tullow, ConocoPhillips and the likes are expected to form the group of companies with the third highest cumulative natural gas output from Africa for the years 2023 – 2024.

The duo of NOCs and majors in Africa, not only drives the short-term oil and gas production in Africa, but also is expected to be the major drive behind the medium-term supplies till 2030. Between the two of them, NOCs and majors' company segments are estimated to hold a potential to produce 4.25 million bpd, 4.06 million bpd and 4.44 million bpd of liquids, and 3.45 million barrels of oil equivalent per day

Africa industry review

Player landscape in Africa: 2023 – 2024 Production



Source: Rystad Energy UCube

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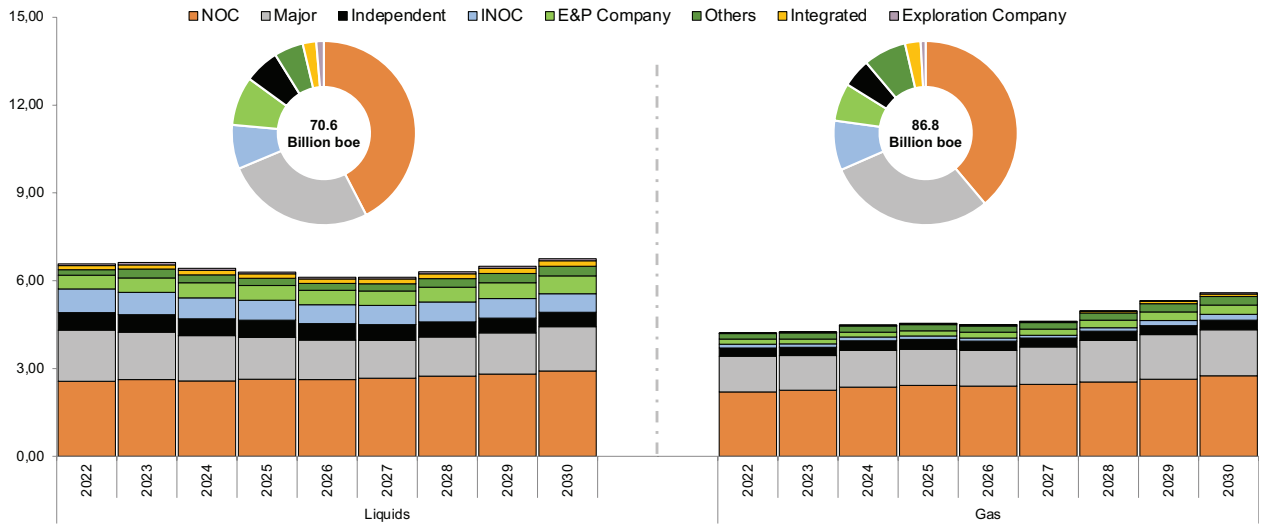
Africa industry review

Player landscape in Africa: Production (Million boe/day) and Resources (Billion boe)



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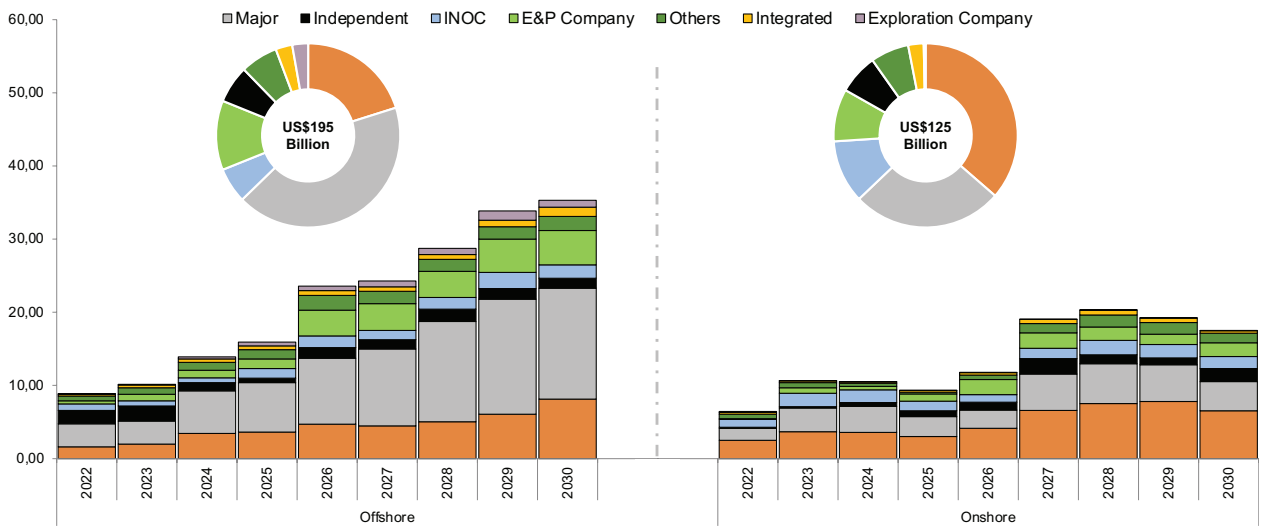
(boepd), 3.66 million boepd and 4.32 million boepd of natural gas for the years 2023, 2025 and 2030 respectively. These volumes represent about 65% of the total liquids and 80% of the total natural gas produced in Africa in hose respective years. The average contribution potential of both these company segments put together over 2023 – 2030 period is 65% of the total liquids and 80% of the total natural gas production potential.

NOCs and majors together are expected to drive bulk of the greenfield spending in Africa over 2023 – 2030. About 65% of the total greenfield spending over 2023 – 2030 in both offshore and onshore supply segments is expected to be driven by these two company segments.

Africa industry review

Player landscape in Africa: Onshore vs offshore greenfield CAPEX Spending (Billion USD)



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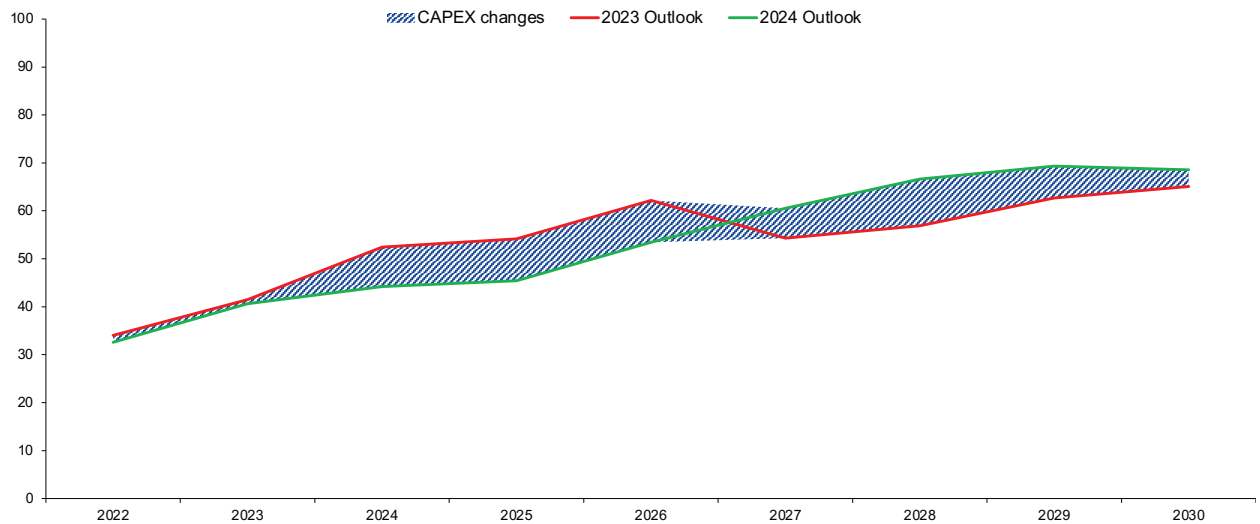
Source: Rystad Energy UCube

5.2 CAPEX revised downwards in the near-term and upwards through late 2020s

Africa CAPEX changes – 2023 Outlook vs Latest Outlook (Billion USD)



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Source: Rystad Energy UCube

Africa potential CAPEX forecast according to the latest outlook is slightly different from the previous outlook where 2023 outlook showed a drop in spending from 2026 to 2027, before taking a gradually increasing trend through to 2030. The latest forecast according to the 2024 outlook, however, suggests a gradual but gentler YoY increase from 2023 all the way to 2030. It is to be noted that the trend variations are a result of a timeline changes in some of the African developments. The overall potential cumulative CAPEX spending from 2023 to 2030 is expected to stay unchanged at close to US$450 billion. The 2023 – 2026 CAPEX spending is now estimated to be close to US$185 billion as opposed to US$210 billion according to the previous forecast. The spending over the second half, 2027 – 2030, reverses with overall potential cumulative CAPEX spending according to the 2024 outlook at a higher US$265 billion vs a lower US$240 billion according to the 2023 outlook. The key reason behind this is estimated delays in spending mainly in the form of FID postponements. These delays push the investments to a later timeline but unless there is downsizing, the spending levels can remain the same

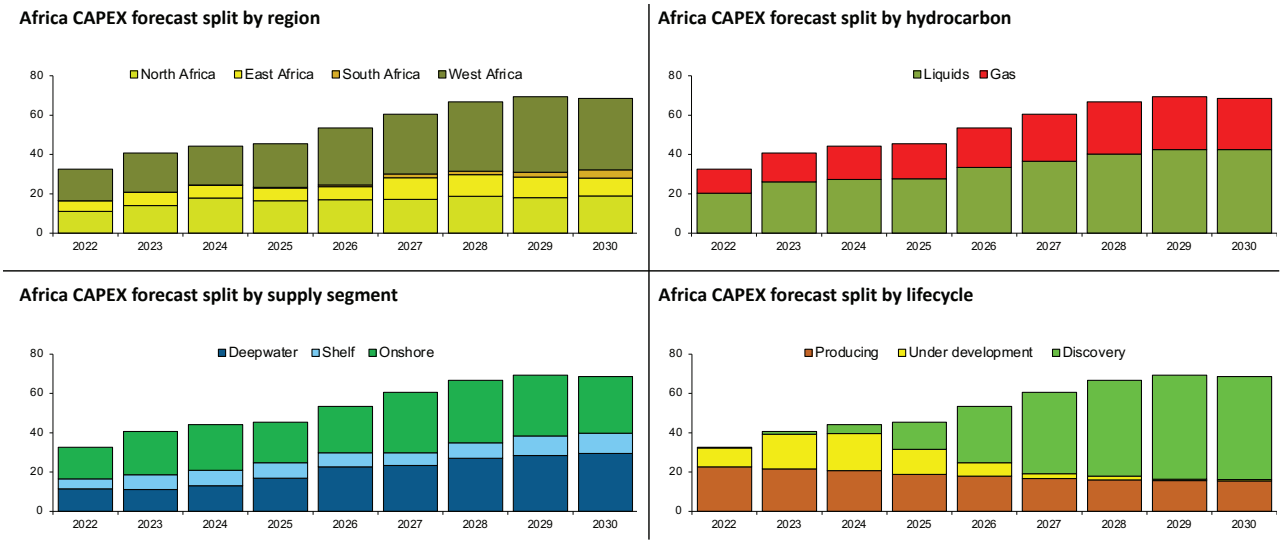
In terms of where this estimated spending is coming from, North Africa and West Africa are the big spenders. West Africa is expected to be the region driving over 50% of the potential CAPEX spending through 2023 – 2030. With a few FIDs estimated to happen over the second half of the decade, the already existing under development projects and brownfield investments are the key drivers of these spending levels. With investments expected through the decade, Libya and Algeria drive the North African spending which is almost a third of the overall CAPEX spending in Africa over 2023 – 2030.

Despite the increasing focus on natural gas, analysis of potential spending over 2023 – 2030 suggests liquids continue to remain the main hydrocarbon drawing over 60% of the total CAPEX. Natural gas, however, is expected to see a gradual increase in share of the total annual expenditure with YoY spending share increasing from about 35% in 2023 to almost 40% by 2030.

The focus or split between onshore – offshore spending is expected to be uniform with just over 50% of the cumulative CAPEX being spent on offshore projects and onshore projects seeing expenditure of just under 50%. Considering the fact that the unit costs on onshore projects are much lesser than offshore projects, it can be said that more onshore developments are expected to kick-off or come online as opposed to offshore fields. Offshore projects' spending is estimated to see a 37% – 15% split between deepwater and shelf

Africa industry review

Africa upstream CAPEX forecast to 2030 (Billion USD)



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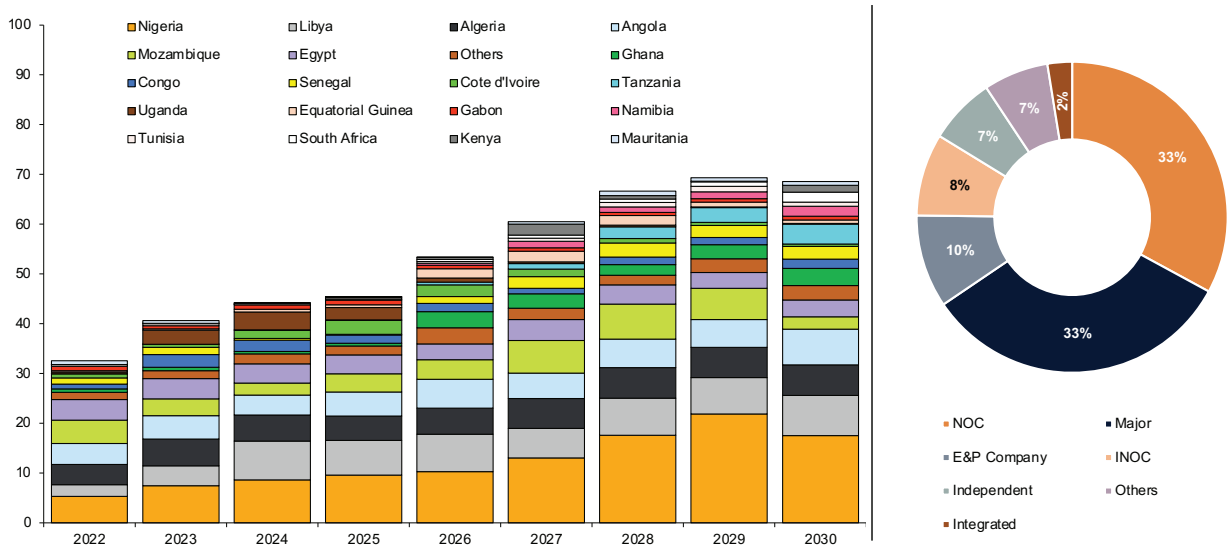
projects respectively. Shelf projects are those projects lying in water depths of a maximum of 125m and anything in deeper waters is considered a deep-water development.

Finally, the spending levels split by life-cycle, or maturity stage of the recoverable resources, suggests Africa is expected to follow a lifecycle split very similar to global spending over the same time period. The brownfield spending levels are estimated to stay relatively flat through the period. The spending on currently FID'ed under development projects is estimated to peak next year before decreasing to marginal levels by late 2020s. Over the second half of the decade, it is the greenfield expenditure on the currently pre-FEED discoveries, that is expected to drive majority of the total CAPEX spending.

Nigeria, Libya, Algeria, Angola and Mozambique are estimated to drive bulk of the potential spending both YoY and over the 2023 – 2030 period. The countries together are estimated to drive a potential spending of almost 65% of the total spending from Africa. As discussed above, NOCs and majors are estimated to be the main spenders, with over 65% of the potential spending coming from their pockets.

Africa industry review

Africa upstream CAPEX 2022 – 2030 split by country and company segment (Billion USD)



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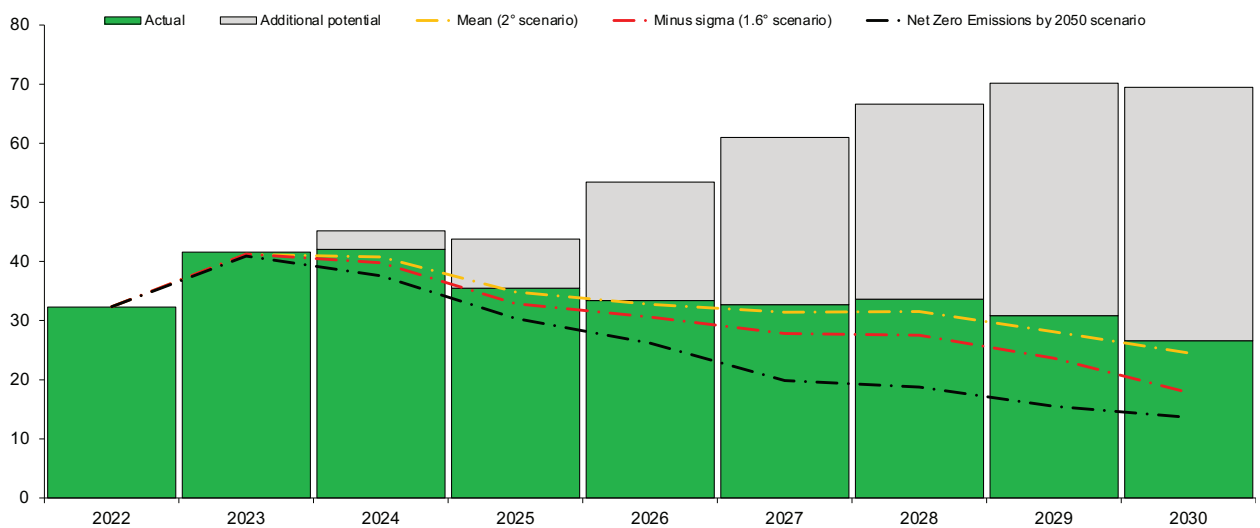
Source: Rystad Energy UCube

5.3 Actual spending close to 2°C scenario

The actual spending share of the overall spending is estimated to reduce from about 95% in 2024 to under 40% by 2030. Actual spending is estimated over the period 2023 – 2030. It is to be noted that the actual spending level is very close to estimated spending in a "Mean" scenario which results in cap-climate regulations are expected to drive the spending levels lower and can deal a critical blow to Africa's upstream sector.

Africa upstream CAPEX 2022 – 2030 in different scenarios (Billion USD)



Source: Rystad Energy UCube

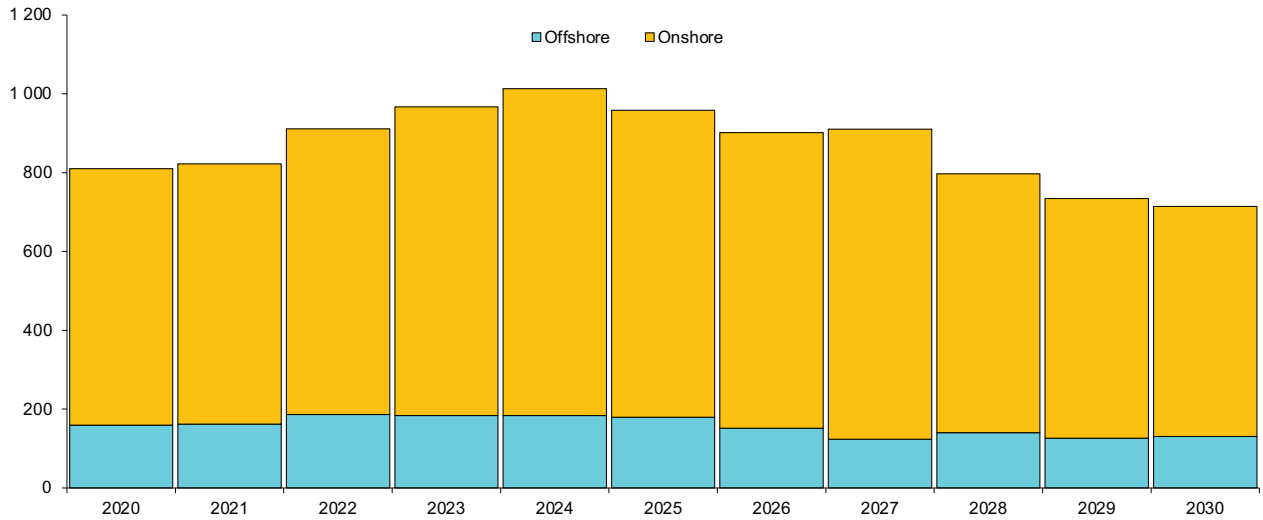
5.4 Onshore drilling expected to drive overall drilling activity

Wells drilled on the African continent and its continental shelves ultimately represent the activity that ensures hydrocarbon recovery from its underground deposits. An estimated 810 wells were drilled during 2020 with about 651 or 80% drilled onshore and the remaining 159 or 20% drilled offshore. The trend since then has been an increasing number of wells drilled per year in the post pandemic era. 2021 saw the overall drilling rise to about 820 wells, with a similar split of 80% of those drilled onshore and 20% offshore. 2022 drilling levels saw an 11% YoY increase over 2021, with 910 wells drilled in total. The number is estimated to increase to 967 wells in 2023, a 6% YoY growth and further to 1013 wells in 2024 representing a 5% YoY growth. Increasing drilling activity onshore in the northern and eastern parts of Africa is the main driver behind this growth. Beyond 2024, drilling activity is expected to see a gradual decline equivalent to an average 6% per annum through to 2030. 2025 well count is estimated at about 960 wells (onshore vs offshore – 180 wells (19%) vs 780 wells (81%)) and at the current expected activity levels, performance of the wells vs actual supply, the count is estimated to drop to about 715 wells – 130 offshore (18%) and 585 onshore (82%) wells. It is also to be noted that the average split between onshore wells vs offshore wells is expected to remain roughly at 80% – 20% split through the period.

The number and type of wells can be

Africa industry review

Africa upstream drilling forecast to 2030 (Count)



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Source: Rystad Energy WellCube

Africa industry review

Africa offshore rig demand forecast to 2030 (Work years)

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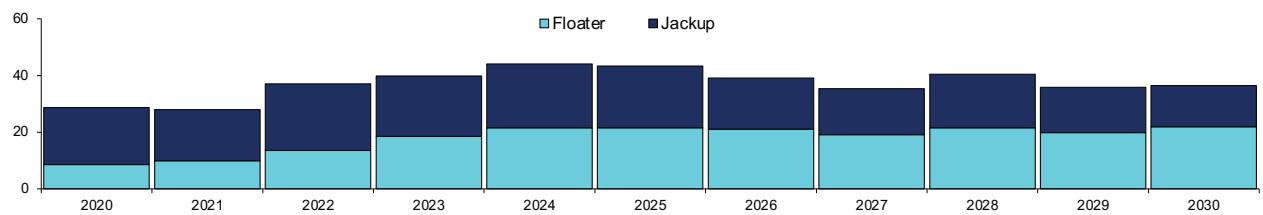
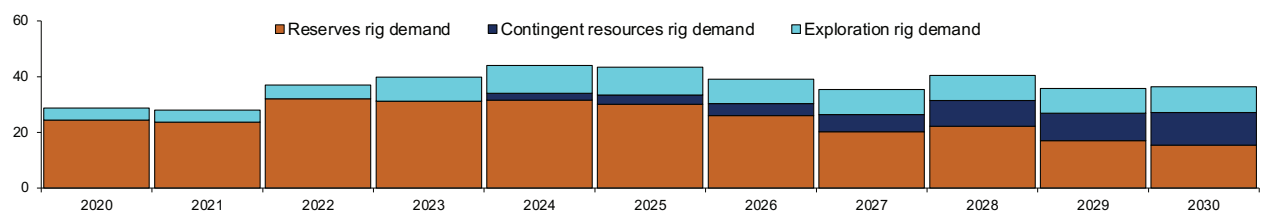
Africa offshore rig demand



Africa offshore rig demand split by resource lifecycle



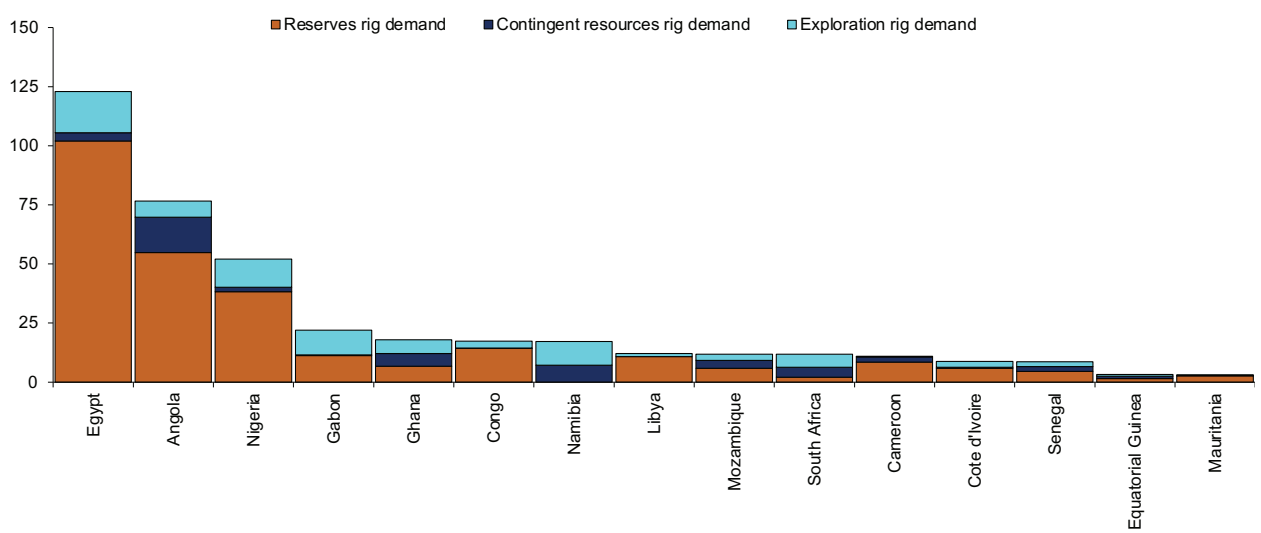
Source: Rystad Energy RigCube

translated into rig demand expectations. In other words, how many drilling rigs have to be operational for a year in order to drill the wells? Jackups are typically used in shallow water with water depth up to 125 meters while floaters serve drilling demand in deeper waters. The rig demand pattern is roughly similar to the estimated number of wells drilled per year. As the number of wells drilled per increase over the period 2020 – 2024, rig demand evolution also saw a similar pattern with demand of about 28 years per year over 2020 – 2021, growing to 37 years, 40 years and 44 years for the years 2022, 2023 and 2024 respectively. The 2024 rig demand represents a 55% growth over that of 2020. This suggest that the rebound that was expected from the pandemic lows happened as significant drilling associated with projects currently under development returned to Africa from 2022. However, going forward, the rig demand – in line with the expected/estimated wells to be drilled per year – is in a declining trend.

It is also to be noted that the rig demand expansion to an average 44 rig years over the year 2024 is contingent on new projects being sanctioned. The current oil market outlook, greenfield and brownfield investment forecast suggests the combined potential of these new projects and further exploration activity will be able to propel rig demand in Africa towards pre-Covid-19 levels. It is to be noted that the rig demand from the existing projects in-pipeline / in the pipeline is expected to decline marginally through 2025 to 2030 and it is the combined impact of rig demand driven by projects contingent on FIDs and exploration is the driving factor for increase. Any delays in these expected FIDs and/or exploration drilling can lead to further decline and thus, an obvious blow to production going forward.

Breaking down cumulative offshore rig demand from 2020 to 2030 per country reveals Egypt as the most active country with about 123 rig years followed by Angola and Nigeria. The breakdown of the top 20 countries by rig demand with associated split on what resource class is supporting the rig demand suggests majority of the rig demand is robust with only about 32% related to contingent resources and exploration. Namibia, South Africa, Equatorial Guinea, Ghana and Mozambique round off the top five countries with the highest percentage of rig demand being related to contingent resources implying that rig demand in this particular area is sensitive to investment decisions expected over the period. Most other producing countries show very little dependence on upcoming project sanctions to drive their rig demand.

2020 – 2030 top 15 African countries' offshore rig demand (Work years)



Source: Rystad Energy RigCube

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5.5 Optimistic exploration forecast in the short-term

Africa exploration drilling, which consists of drilling of both wildcats and appraisal wells, is expected to see a steep growth from 2022 levels The trend is relatively flat through to 2025. The total cumulative well count over 2023 – 2025 is about 375. Estimated annual exploration well count is 132 wells in 2023, 120 wells in 2024 and 123 wells in 2025. Two-thirds of the total wells are expected to be onshore and a little over a fifth of the total wells are estimated to be in the deep waters off Africa. Onshore drilling is majorly driven by the expected exploration activity in Algeria and Egypt, with the exploration well count in these two countries estimated to be almost two-thirds of the total onshore exploration well count. Mega discoveries in the deep waters off Namibia have kicked off exploration in the region and the country, along with Nigeria and Egypt is expected to drive the deepwater exploration drilling over the period. Similar to the remaining recoverable resource, supply and spending potential, NOCs and majors are expected to drill close to 50% of the total exploration wells between 2023 – 2025.

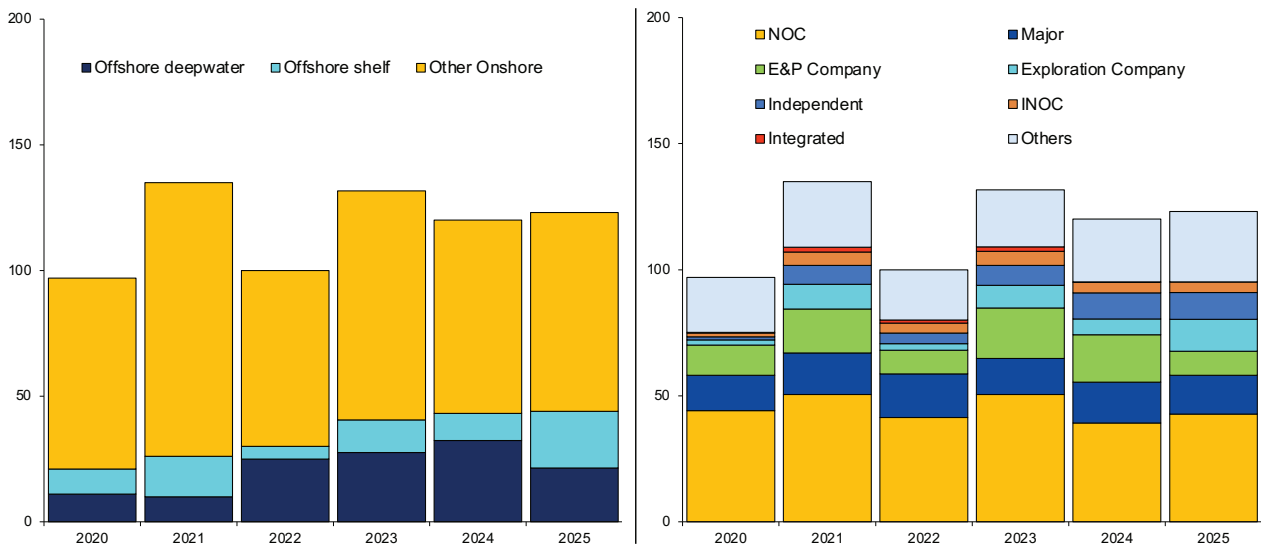
Another positive indicator for Africa's exploration activity is the expected high impact well (HIW) drilling in the continent. Classification of exploration wells as HIWs has to satisfy one or more of the following five criteria –

- Large prospective resources: significant pre-drill estimates by company
- Focus for company: company is pushing for the well
- Emerging basin: well being drilled in area with mostly exploration success but little production yet
- Play opener: well is targeting a new play in mature or frontier area
- Frontier basin: well being drilled in a completely new frontier

2023 has already seen six such HIWs drilled across Africa – one in Mauritania by Shell Plc, one in Gabon by CNOOC, Venus-1A by TotalEnergies and Jonker-1 by Shell Plc offshore Namibia, one well – Raia-1 offshore Mozambique by Eni and finally one well by Eni in Egypt. Eleven more HIWs are expected to be drilled in the next 15 months. Two wells – Cinnamon in Morocco by Eni and an exploration well in the Shell Plc operated North Marina block in Egypt – are confirmed to be drilled before the end of this year. 2023 is also expected to see two more HIWs – Niamou-1, operated by TotalEnergies in Congo and Osprey well offshore Namibia by Eco Atlantic, but the probability is relatively lesser. Seven HIWs are expected to be drilled through 2024 in both mature as well as frontier areas with participation from majors, independents and E&Ps alike.

Africa industry review

Africa exploration drilling, forecast to 2025 (Well count)



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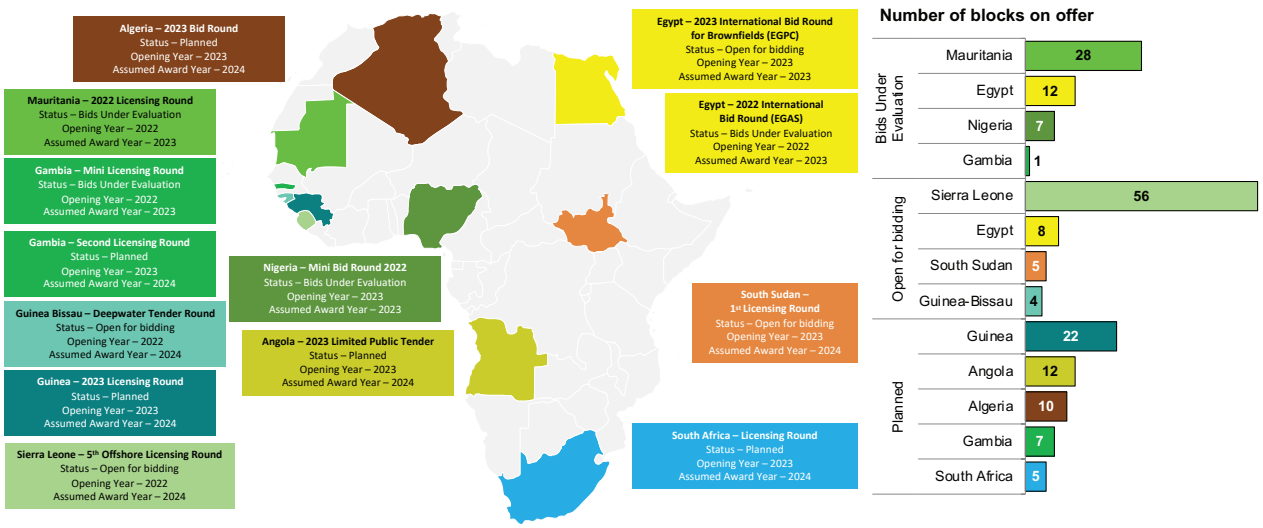
Africa industry review

Africa upcoming exploration licensing rounds



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Source: Rystad Energy ECube

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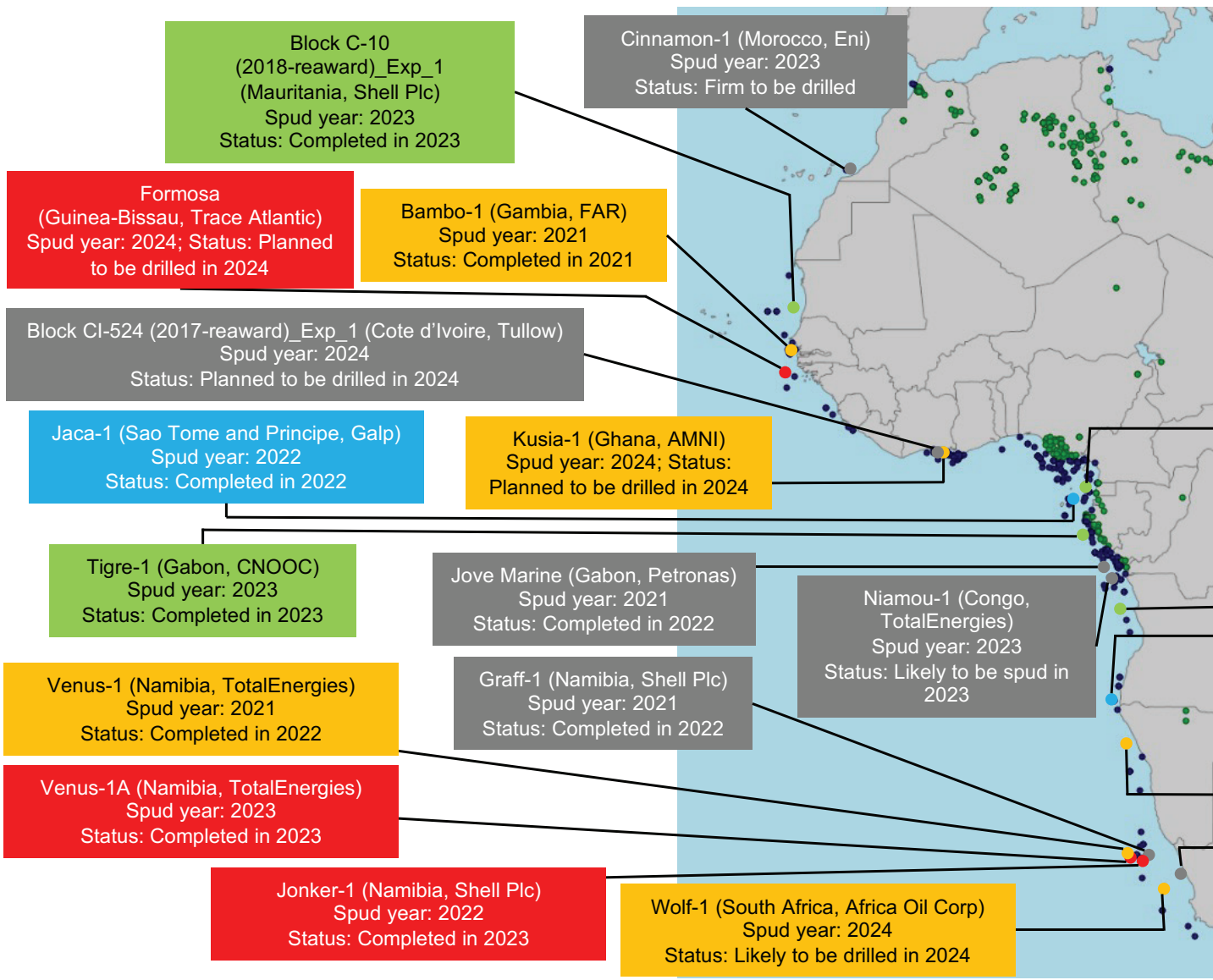
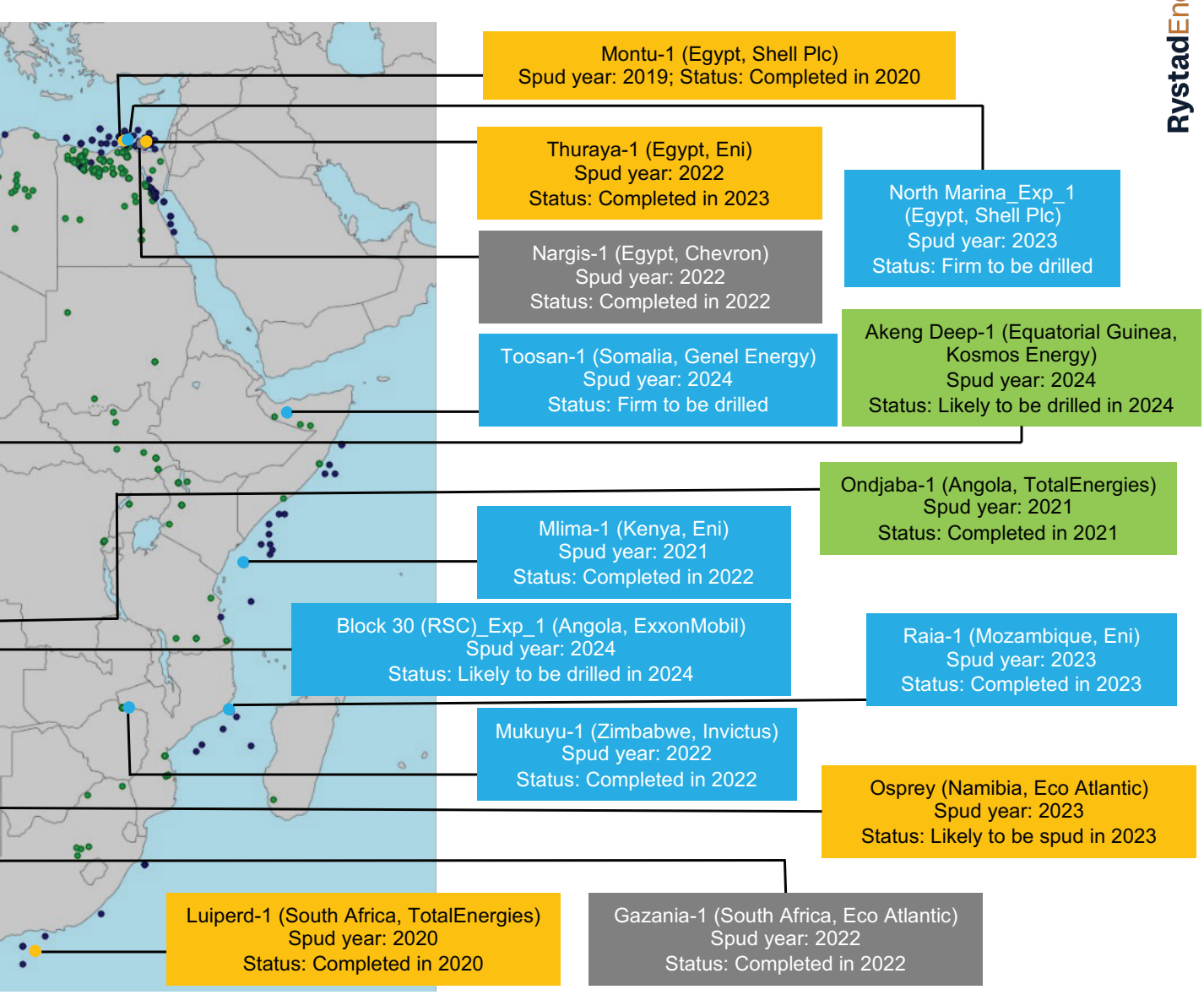
Africa industry review

Africa High Impact Wells, forecast to 2025



Source: Rystad Energy ECube



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5.6 Producing liquids portfolio most sought as per the M&A deal activity in 2023

M&A activity across Africa in 2023 has resulted in a total transaction value of US$3.233 billion in deals either announced or closed. It is to be noted that there were no farm-ins from majors except for Eni's transaction with Neptune Energy wherein Eni acquired stakes in Neptune's African assets via a corporate transaction where Eni agreed to acquire all of Neptune Energy's oil and gas assets excluding German and Norwegian operations. On the contrary, there have been exits, mainly from exploration licenses, by the majors. Considering there is exploration interest from the majors in regions like Namibia, it can be said that exploration focus from the Big Oil can be limited to only certain regions in Africa going forward.

Africa industry review

Africa 2023 major M&A deals till date

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Country	Title	Buyer	Seller	Deal value (Million USD)	Status	Field Type (Liquids / Gas)	Lifecycle (Producing / Pre-start up)
	Maurel & Prom acquires Gabon-focused Assala Energy for $730 million	MAUREL PROM	ASSALA ENERGY	730	Closed	100%	100%
	Galp Energia divests upstream assets in Angola to Somoil for $655 million	SOMOIL	galp energia	655	Announced	100%	84%
	Africa Finance Corporation acquires Ghana-focused Aker Energy	AFC	AKER ENERGY	605	Announced	100%	100%
	Petronas divests assets in Chad to state-owned SHT		PETRONAS	371	Closed	100%	100%
	Octavia Energy acquires interests in Moroccan assets from Sound Energy	octavia energy	SOUND ENERGY PLC	141	Announced	81%	100%
	Eni sells certain onshore Nigerian assets to Oando	Oando	eni	86	Announced	89%	100%
	Afentra acquires additional interest in licenses from Azule Energy for $48.5 million in Angola	Afentra	AZULE ENERGY	48	Announced	100%	55% / 45%
	Apex acquires interests in six concessions in Egypt from Eni	APEX	eni	45	Closed	72%	68% / 32%

Major transactions that drive over 80% of the overall transaction value include US$500 million+ transactions like –

- Maurel & Prom's acquisition of Assala Energy for US$730 million. This gives the oil company, which has financial support from its majority shareholder and hence parent organization, the Indonesian NOC Pertamina
- Angola's legacy producer Somoil bought into South American Galp Energia's Angolan portfolio
- AFC Equity Investment, an affiliate of Africa Finance Corporation, a Nigerian multilateral financial institution, acquired 50.79% and 49.21% stakes in Aker Energy from Aker Capital (100% owned by Aker ASA) and TRG respectively. As a result, AFC became a 50% owner of the Deepwater Tano Cape Three Points (DWT-CTP) block, which holds the Pecan project

While Indonesian Pertamina acquired African assets via its subsidiary Maurel & Prom, its Malaysian counterpart – Petronas finally exited from Chad by transferring is stakes in the producing oil fields of Doba basin and the Chad – Cameroon oil export pipeline to the Government of Chad. Eni struck a deal with Oando to divest its 20% interests in four onshore blocks — OMLs 60, 61, 62 and 63, in Nigeria. This is yet another transaction where an international major is exiting or is looking to exit the Niger Delta, selling their assets to indigenous player(s), due to the challenges like rampant oil theft, pipeline sabotages and the resultant costs for repairs and clean up any environmental damage, court cases and tussles with the indigenous communities. The Italian major also sold its stakes in six concessions in Egypt to Apex International.

The resource-mix of the assets involved in the transactions shows that liquids are the preferred hydrocarbon for buyers. Of the major transactions driving bulk of the valuation, only two transactions involve gas heavy portfolio with the rest being oil fields. Also, recovering the value paid in an accelerated timeline with minimum investments seems to be the strategy behind farming in as bulk of the assets are in producing phase. A top-level observation from the transactions so far in 2023 suggests indigenous operators buying into producing portfolios and trend of operators sitting on assets without development going on. However, lots of factors come into picture when we look for reasons as to why operators sit on blocks/discoveries – securing financing being one of the key issues. Energy transition and prioritizing core areas can be the reasons for larger and more financially secure operators – where the investments are scrutinized for more than just financial or funding reasons. As such, it becomes important for administrations to provide good business environment, transparency in operations and swiftness or reason in approving or disapproving development plans to have their respective blocks thrive with exploration and discoveries reach start-ups sooner without operators looking to either sit on them or just exit the region as a whole.

6 AFRICA VS REST OF THE WORLD

Africa's hydrocarbon extraction emissions in the "mid-range" when compared to other regions, but natural gas flaring emissions intensity the highest globally

Limiting natural gas flaring and utilization and/or monetization of produced natural gas – key to Africa's upstream sector's betterment

Post COP27 exploration acreage awards – Africa accounting for 30% of the global offshore acreage awarded

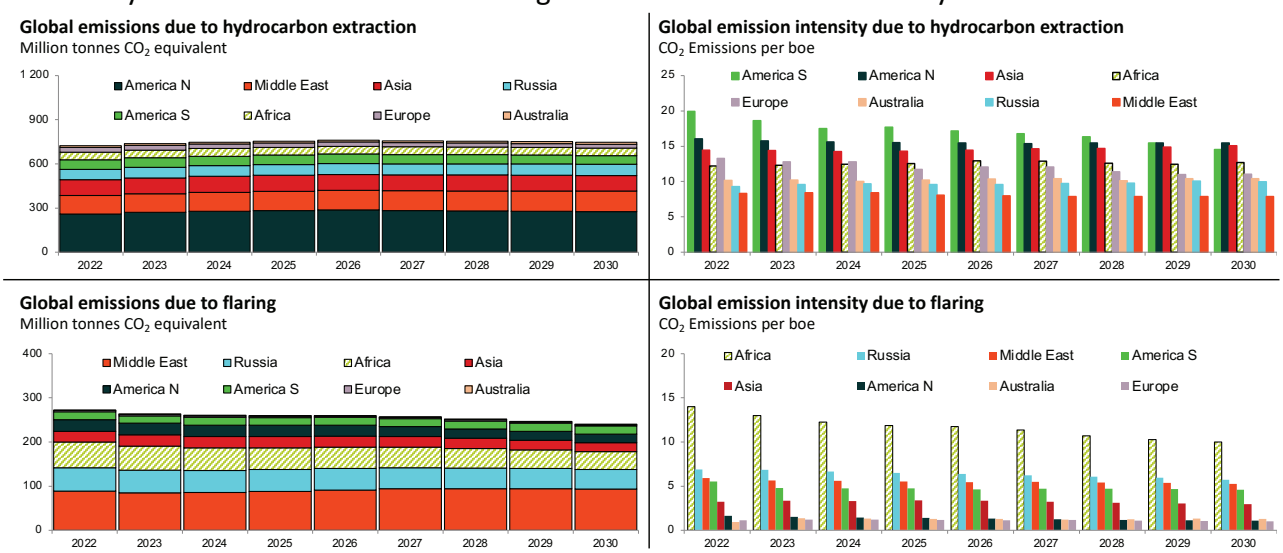
Africa expected to have the least potential greenfield spending probability - the ratio between actual spending and potential spending

Total exploration spend over 2015 – 2025 and discovered volumes over 2019 – 2023 – South America double of that of Africa

6.1 Avoiding natural gas flaring – key to limiting Africa's emissions

Africa vs Rest of the world

Global hydrocarbon extraction and flaring emissions & emission intensity



RystadEnergy

Source: Rystad Energy UCube

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Alarming rates of global warming have led to climate regulations aiming at capping the global warming at 1.5°C. Global consensus is that these regulations should be strictly imposed on the fossil fuel industry that is responsible for different scopes of emissions ranging from hydrocarbon extraction emissions to operations emissions. These regulations are currently being looked at as universal irrespective of the maturity of the regional industry or the recovery levels of the existing hydrocarbon potential. Also, climate regulations are expected to be implemented uniformly across the regions like the developed western world and the developing nations like those in Africa. The dependence on hydrocarbons in Africa is immense with multiple African economies depending on their respective hydrocarbon exports to international markets and also, fossil fuels are expected to play a significant role in providing universal access to electricity across the continent – both rural and urban. African oil and gas fields, especially in West Africa, are historically labelled as high emission assets and this, along with the risks that the region presents to a stable business environment often put the continent first on the chopping block when it comes to operators deciding to limit their upstream exposure and cut down upstream investments to maintain lower levels of individual emissions.

However, comparison of evolution of estimated absolute emissions from hydrocarbon extraction over the period 2022 – 2030 suggests that Africa stands at sixth in a set of eight global regions. While the estimated average annual emissions due to hydrocarbon extraction from North America are close to 280 million tonnes CO2 equivalent as opposed to 52 million tonnes CO2 equivalent from Africa. The production levels are very different, so it makes more sense to draw the comparison in terms of intensity of emissions. A similar regional comparison puts Africa in the fourth spot with average per boe emissions of just over 12.5 kg CO2 equivalent per boe with South America leading the way with almost 17 kg CO2 equivalent per boe average over the same period. This suggests Africa may not be the region with the lowest hydrocarbon extraction driven emissions and emissions intensity in the world but does not seem like this scenario alone should be reason enough to put upstream investments in Africa on the backburner. South America's production levels are similar to that of Africa, so it is an advantage to Africa that the emissions intensity in the LatAm is much higher. North America and Asia may have higher emissions intensity than Africa, but these regions present relatively better and safer business environments. Asia is also working on improving and boosting its Carbon Capture, Usage and Storage (CCUS) and renewables capacity, taking strides towards making the region more "climate-friendly". As such, the real "competition" is with the South American region where there is legacy production and majors have strong exploration and development pipeline in countries like Suriname and Guyana.

When it comes to gas flaring related emissions, Africa paints a slightly different picture. Africa moves up to the third spot with respect to absolute emissions next to only Middle East and Russia. But Africa's natural gas output potential, over the period 2023 – 2030, is estimated to be just over one-third of that of Middle East and under 50% of that of Russia. This suggests Africa is flaring relatively more volumes of natural gas as opposed to produced gas when compared to the regions that are exhibiting more flaring related emissions. This statement is further cemented when we look at the comparison of emissions intensity from natural gas flaring between different regions globally. The average emissions intensity from natural gas flaring from Africa over the period 2023 – 2030 is twice that of Middle East and Russia.

This suggests Africa needs to prioritize the following –

- Limit and eventually eliminate natural gas flaring
- Better utilization of produced natural gas –
    - o Monetize the produced natu ral gas by diverting it demand centres, both domestic and foreign
    - o Re-inject the volumes in ar eas without infrastructure to support gas monetization and enhance crude oil pro duction

African nations like Nigeria and the likes are already looking at this issue of natural gas flaring and implementing measures like capping on flaring volumes and penalties on exceeding these limits, improving natural gas monetization infrastructure and announcing schemes like "Decade of Gas" to improve ways of utilization of produced gas. These measures, although meeting below par success when compared to targets currently, can be a double benefit to Africa – generate revenues through sale of gas and, limit emissions and make the region more climate-friendly. These issues are key to thriving and stable upstream sector in Africa which turn is very essential considering the continent's dependency on hydrocarbons to bring in revenues via international exports, stable fuel prices for transportation via improved refinery capacity and universal access to electricity utilising the produced gas.

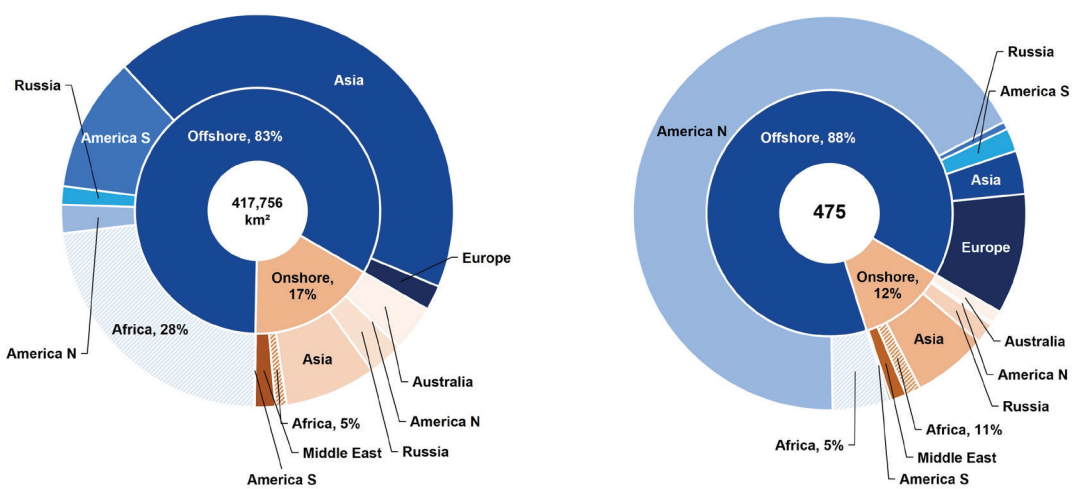
6.2 5% of onshore acreage and 28% of offshore acreage awarded globally post COP27 is in Africa

The 2022 United Nations Climate Change Conference or Conference of the Parties of the UNFCCC, more commonly referred to as COP27, was the 27th United Nations Climate Change conference and held from November 6 to November 20, 2022, in Sharm El Sheikh, Egypt. As many resolutions were passed and pledges taken to comply to climate regulations and achieve energy security, the key objective remained the capping of global warming at 1.5°C. One popular sentiment, especially across the spectrum of climate watchdogs and non-profit organizations is the immediate full-stop to funding the fossil fuel industry. While the European Union (EU) might not agree with this entirely, there has been a strong push to move the industry in a path of energy transition with green sources of energy taking over sooner. These words have not fully translated into actions for a variety of reasons with the next COP summit aiming at "course-correction" to bring the planet on the path towards 1.5°C. Countries, however, seem to have been continuing their own efforts to keep their respective upstream sectors sustaining. This is reflected in the oil and gas exploration acreage awarded globally post the COP27 summit in November 2022. Close to 418,000 km2 of acreage has been awarded since November 2022 of which 83% is offshore and the rest onshore. Asia saw the largest exploration acreage awarded covering over 52% of the total offshore exploration acreage awarded and close to 45% of the total onshore exploration acreage awarded. While 28% of the overall offshore acreage and a much lesser 5% of the total onshore acreage was African awarded acreage, it is clear that globally exploration is here to stay, and respective administrations are looking to bring in more upstream exploration investments.

Africa vs Rest of the world

Awarded exploration acreage (km²) and number of exploration blocks post COP27

RystadEnergy



Source: Rystad Energy ECube; Rystad Energy and Analysis

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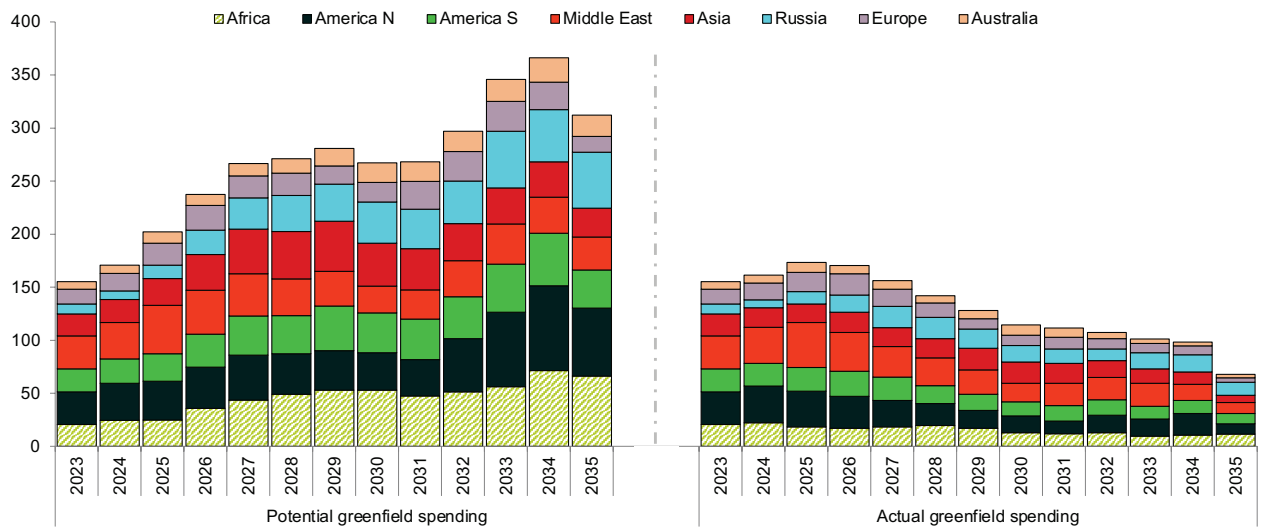
6.3 Actual greenfield spending less than 50% of the potential spending

While flaring related emissions can be controlled by driving efficient management of produced gas and efforts to monetize it, and exploration in Africa is well within the levels of what other regions are aspiring to achieve, it is the stark contrast between Africa and other regions in terms of the ratio between the actual spending and potential spending – or the potential greenfield spending probability – is a matter of great concern. Actual spending is all the spending coming from the projects with their respective breakeven prices less than that of forecasted Brent price. Potential spending is the sum of actual spending as well as the spending coming from the projects with their respective breakeven prices higher than that of forecasted Brent price. In other words, potential spending involves spending on the projects that have a negative valuation or net present value (NPV) currently. For Africa, these projects need to come online for the supply to be sustainable if not reverse the declining trend. However, the actual spending in Africa is about one-third the potential spending. This ratio is close to 0.5 for the Americas, Asia, Russia and Australia and a very healthy, almost, 0.75 for the Middle East. This suggests, regions other than Africa are expected to see a larger share of the potential spending actually materialize while Africa is the region that needs a larger share of potential spending to happen for the production flows to stay stable. This calls for efforts from both the governments and the operators. Administrations need to make these projects more investor-friendly by allowing tax incentives if the situation calls for it, provide better and less riskier business environments, and show more transparency in processes. Operators need to engage with the administrations and work towards implementing measures where unit costs can be cut down and hence, the breakeven prices can be brought down.

Africa vs Rest of the world

Required vs expected upcoming greenfield spending split by continent, forecast to 2035 (Billion USD)



Source: Rystad Energy UCube

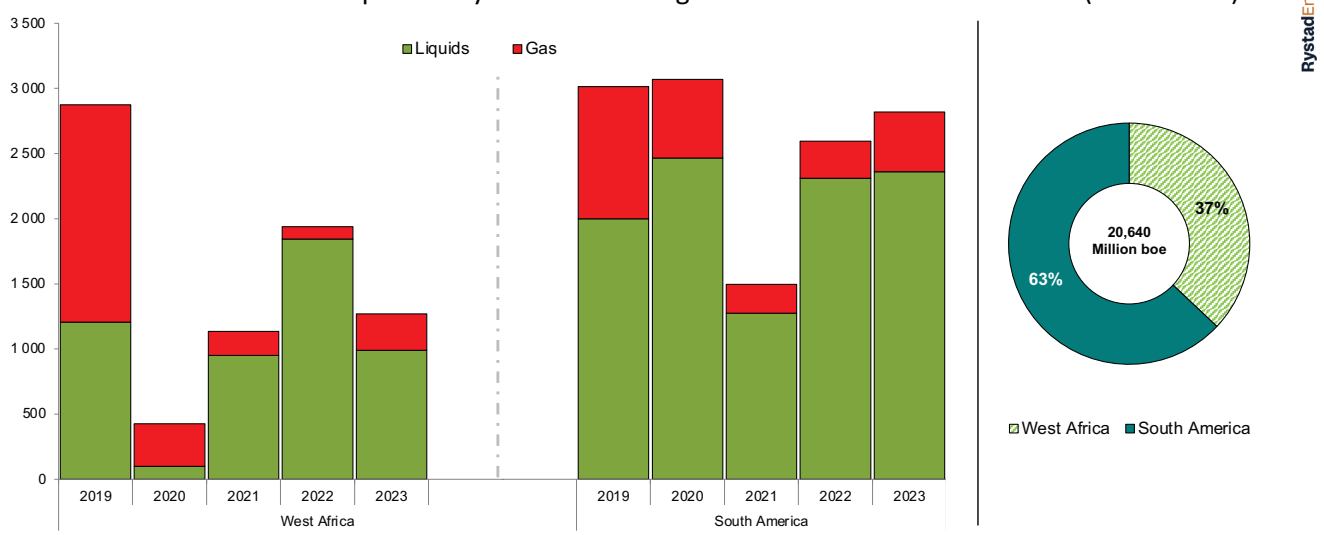
6.4 LatAm discovered volumes and exploration spending double of that of West Africa

Almost every benchmarking exercise involving Africa's upstream sector involves a direct comparison with the South American region and for good reason. The deepwaters off both the regions are said to behave in a very similar manner. Both the regions have seen some prolific discoveries, and the trend continued in the past five years as well. A comparison between the overall discovered volumes in both the regions since the beginning of 2019 suggests both regions have had discoveries every year consistently, but there is a clear winner. South America has seen close to 13 Billion boe (Bboe) of oil and gas discovered volumes in the period as opposed to Africa's 7.65 Bboe, close to 60% lesser. YoY, South America has seen discovered volumes of about 3 Bboe each in 2019 and 2020, close to 1.5 Bboe in 2021, 2.6 Bboe in 2022 and 2.8 Bboe in 2023 running. The overall liquids to gas ratio is 80:20 making the region a booming crude oil hub. In comparison, Africa has seen 2.9 Bboe, 425 million boe, 1.135 Bboe, 1.94 Bboe and 1.27 Bboe in 2019, 2020, 2021, 2022 and 2023 respectively. The split is a relatively more uniform mix of 65:35 between liquids and natural gas.

The overall exploration spend historically since 2015 and forecast to near-term of 2025 suggests that the overall exploration expenditure (EXPEX) is an estimated US$90 billion on both the regions. Similar to the discovered volumes above, the 2015 – 2025 EXPEX in South America is double of that of West Africa. 2020 – 2025 EXPEX evolution in both the regions shows an increasing curve – EXPEX in gradual increase over 2020 – 2025 in both the regions. The overall EXPEX on South America over the same period is expected to surpass the EXPEX in Africa by 216%. Clearly, both the regions are competitive and attracting investments will be key to both the regions if they are looking to expand the discovered volumes and also bring these resources to first oil as soon as possible

Africa vs Rest of the world

Discovered resources in the past five years and running – West Africa vs South America (Million boe)



Source: Rystad Energy ECube

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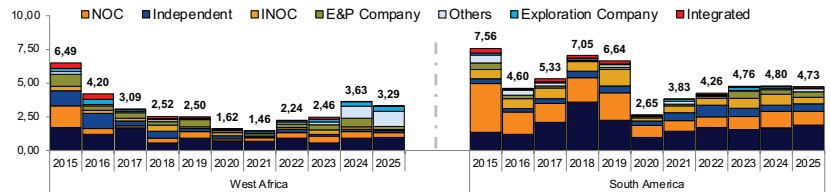
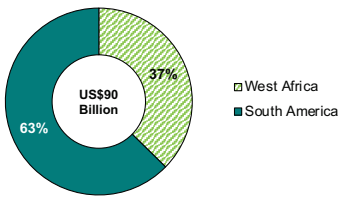
Africa vs Rest of the world

West Africa vs South America offshore exploration spending overview

Exploration cost evolution, forecast to 2025 – West Africa vs South America, split by company segment

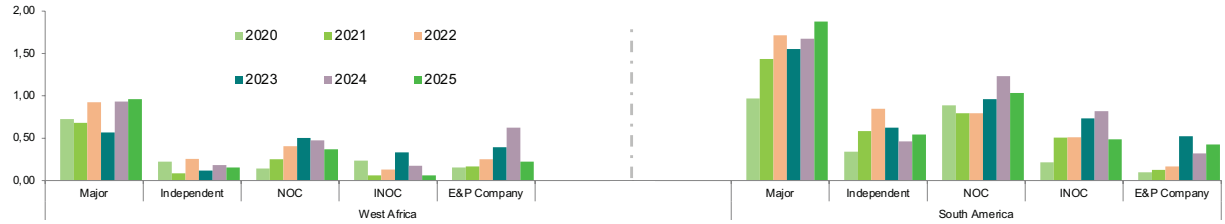
Billion USD





Annual exploration cost evolution, forecast to 2025 from main company segments – West Africa vs South America

Billion USD



Source: Rystad Energy ECube

RystadEnergy

7 AFRICA POWER OVERVIEW

Africa's overall electricity access rates – significantly lower than global levels and even worse in rural Sub-Saharan Africa

Majority of projects to improve the regional power capacity currently at concept stage

7.1 Low level of universal access and even lower rural electricity access

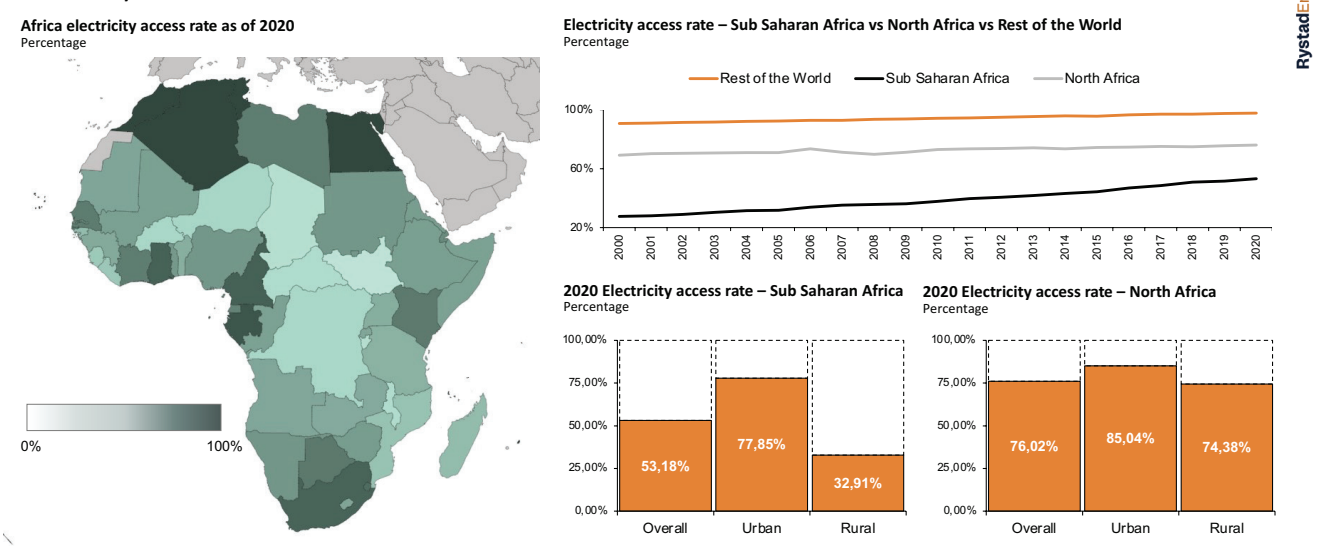
Access to electricity in Africa is still a dream to millions of Africans living in regions and conditions that allow little or no access to electricity. Many countries, especially across Sub-Saharan Africa (SSA), have dismal electricity access rates. As of 2020, as many as 8 countries across SSA had sub-20% levels of electricity access. This, when the world was nosediving into a dark time period with Covid-19 taking millions of lives across the world. While employment, education and business get significantly impacted by lack of electricity, health sector can be the worst hit sector as electricity is key to smooth functioning of hospitals. While there are a few countries like Ghana, Gabon, South Africa with very good electricity access, issues like the load shedding in South Africa can cripple development. Some of the North African countries are estimated to have over

90% electricity access rate and these countries are working in multiple directions to keep this rate high, sustainable and decrease dependency on fossil fuels. The story is completely different when it comes to SSA. On average, just over 50% of the population across SSA has access to electricity – that's almost 50% of the population living in the dark.

The evolution of electricity access rate across Africa in comparison to global standards shows while rest of the world stayed over and above 90% levels and gradually moving towards universal access, Africa, especially SSA moved up much faster but the levels where it began put the region at sub-par levels. SSA since the year 2000, has managed to double the average rate of access to electricity, but the region had a little over 25% access rate back then and now has managed to cross 50% mark. The overall access rate across North Africa is estimated to be close to 80% with the cities at 85% levels and about 75% of the rural population having electricity. While SSA's average access rate is about 55%, it is largely driven by urban regions where the electricity access is as high as close to 80%. Rural SSA is at a crippling rate of about 33%, meaning two-thirds of the rural population across SSA has little or no electricity access. Serious measures need to be taken by the respective administrations to resolve this issue and enable more businesses, employment, health, education and foreign investments.

Africa Power Overview

Electricity access rate across Africa



Source: Rystad Energy Africa Power Market Analysis

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7.2 South Africa – Case study

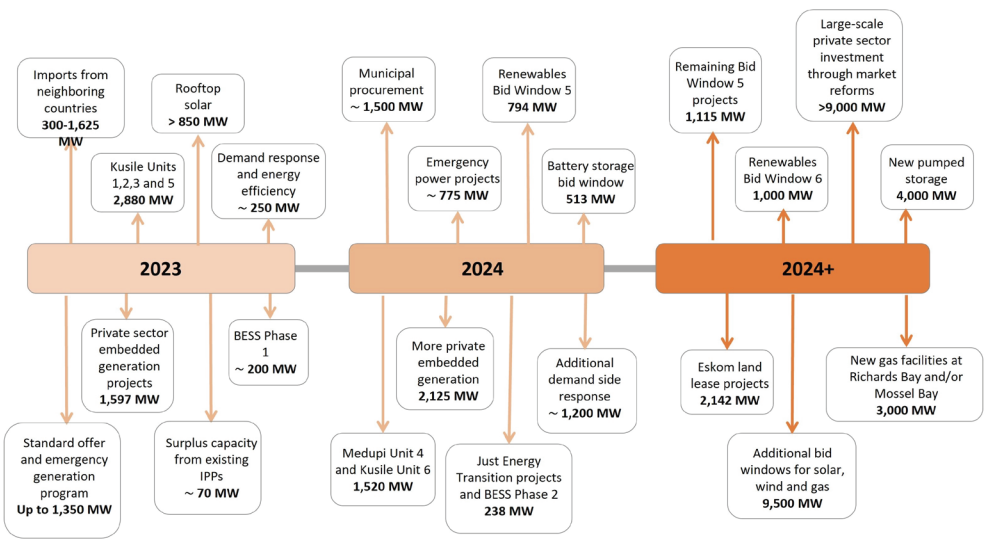
As mentioned previously, even cities in SSA are dealing with stable electricity as problems like load shedding and power outages persist with the population having to plan their lives around the periods of power outages or incur additional expenditure to maintain power back-up. A key example of this is South Africa. Having seen zero days this year without loadshedding – planned rationing enforced by South Africa's power utility Eskom to protect grids and to manage power consumption – the country finds itself in a precarious situation as the supply-demand gap continues to widen. The nation is currently on track to surpass the record-breaking 2022 in terms of both stress on the economy and the extent of loadshedding. Although Stage 2 loadshedding is expected at the very least, South Africa is braced for the possibility of Stage 6 or even beyond, provided Eskom restricts unplanned outages to 15 gigawatts (GW).

Loadshedding situation has taken a turn for the worse over the last year, with the crippling rolling power outages only being spared on 25 December and 31 January as well as a few other occasions. Power outages have become longer of late, leaving consumers with up to 12 hours of daily blackouts – South Africa has had zero days without loadshedding in 2023. Record-breaking 2022 saw more than twice as much load shedding as any other year, with 2023 already to surpassing the amount of loadshedding seen in the entire previous year and already not far behind 2022 in terms of the duration of loadshedding.

Multiple-fold efforts are being enforced to tackle these issues with the government is also streamlining regulatory processes for power projects, such as reducing environmental authorization timelines by half from the previous 100 days, while grid connection approvals are now provided within six months. A total of 2.8 GW of new renewables capacity under the Renewable Energy Independent Power Producer Procurement Program (REIPPPP) is soon expected to begin construction. Eskom plans to construct its solar and battery storage projects at Komati, Lethabo and Majuba, while other projects at Komati, Lethabo and Sere are expected to come online this year. With the country favouring renewables in the long term, solar and onshore wind are to play a major role in the transition away from coal and to account for over half the power generation in 2050 compared to nearly 10% today. The government is also eyeing nuclear as it intends to issue a request for proposal for procuring 2.5 GW of nuclear towards the end of this year. In order to boost innovation and economic diversification, South Africa is also making efforts to secure and invest $98.7 billion over the next five years via its JETIP. The country will, however, only begin reaping the benefits of the majority of these measures towards the end of this year at the earliest. Meanwhile, the tussle between energy security and decarbonization continues for the country as coal continues to dominate, accounting for over 80% of the country's power generation mix at present but the share of renewables increasing from about 11% today to 20% by the end of the decade. Gas-to-power and battery storage will be essential to provide flexible power and balance intermittent renewables like onshore wind and solar PV.

Africa Power Overview
South Africa – Case study

RystadEnergy



Source: Rystad Energy Renewables and Power Solution; South Africa Energy Action Plan, January 2023

7.3 Majority of the regional power capacity in Africa in concept stage

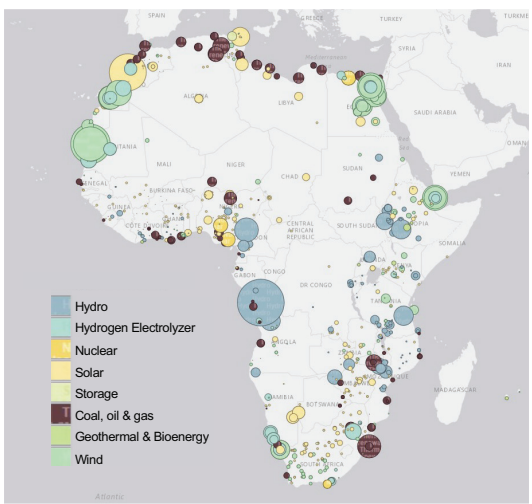
While access to electricity is being taken seriously by multiple administrations and are driving efforts to up the regional power capacity, a top-level overview shows much of the capacity is still in concept phase. The project pipeline across Africa is looking at a capacity of 370 GW – 46 GW from South African projects, 57 GW from East Africa, West African projects' capacity accumulating to 88 GW and finally North African projects driving almost 180 GW. But majority of this capacity – almost 70% of total capacity in South Africa, 45% in the East, 67% in the West and about 65% in the North – is in concept phase, taking the overall share of projects currently in concept phase to almost 65% across Africa.

Of the total capacity, solar and wind are expected to drive almost 50%, suggesting the continent is gearing up to move majorly towards renewable energy powered electricity generation in line with its COP27 pledge. Fossil fuels – coal, oil and gas – add up to a tenth of the total capacity. It is to be noted the capacity here includes the capacity that has come online in 2023 so far and is estimated to come online till 2040, thus including the majority additions to the existing capacity. The fact that only a tenth of this is estimated to be using fossil fuels as energy source shows the increased focus on renewables and the efforts towards reaching a balance between energy security and decarbonization.

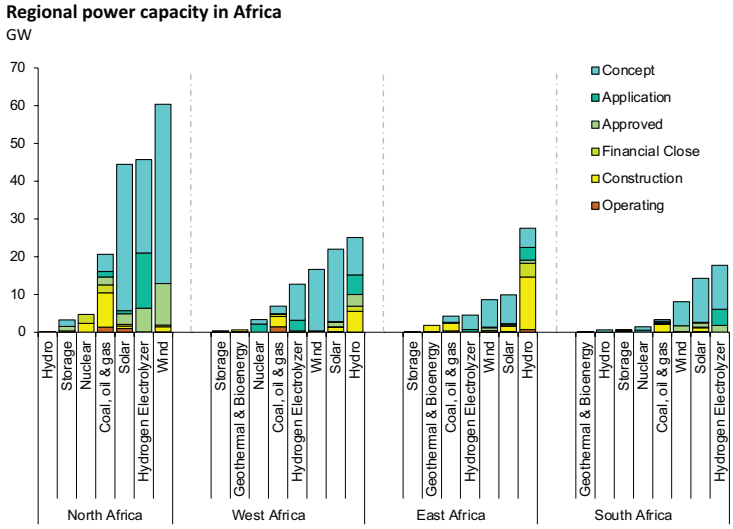
Africa Power Overview

Major power projects and regional capacity overview in Africa

Major power projects in Africa



Regional power capacity in Africa



Source: Rystad Energy Power Cube

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8 AFRICA RENEWABLES OVERVIEW

Renewables capacity to be driven majorly by solar and onshore wind capacity, with hydrogen taking the growth further during the 2030s

Onshore wind and solar expected to drive three-fourths of the total renewables capacity in Africa through to 2040, and along with hydrogen capacity drive over 95% of the capacity through 2030s

Egypt, Morocco, Mauritania and South Africa – key regional renewables capacity drivers

Natural gas to play a role in Africa's power mix even in 2050

European banks, with a negative CAGR in fossil fuel financing in the past few years and strict climate policies, are more prone to fund green projects over upstream projects

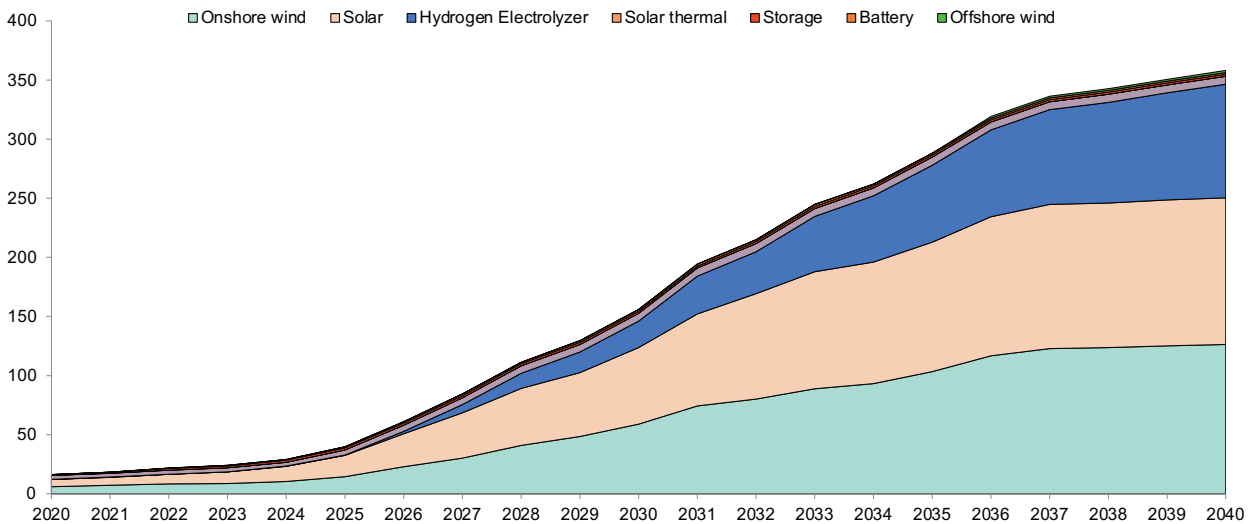
8.1 Onshore wind and solar drive the renewables capacity

2023 renewables capacity in Africa is a mere 24 GW, largely driven by onshore wind and solar capacity. The capacity levels are estimated to stay relatively flat till about 2025 before a jump in onshore wind, solar and hydrogen capacity cumulatively leads to a 55% YoY increase in 2026 capacity over 2025. 2030 onshore wind, solar and hydrogen capacities are estimated to reach about 59 GW, 65 GW and 22.5 GW respectively and drive almost 95% of the continent's renewables capacity. Through the 2030s, the capacity from these three energy sources is estimated to see a gradual increase and the cumulative YoY share as well as the average share of the total capacity during the period is estimated to be north of 95%. This growth is expected to take the continent's overall capacity to close to 290 GW by 2035 and further to almost 360 GW by 2040.

In terms of the current installed or planned to be installed capacity driven by solar, onshore wind and hydrogen energy sources, Egypt leads the way with a cumulative capacity of just over 130 GW – 27. GW of solar PV, 65 GW of onshore wind and 38 GW of hydrogen capacity. However, almost three-quarters of this capacity is still in concept phase. Mauritania, with a total capacity of about 70 GW – 13 GW of solar PV capacity, 21 GW of onshore wind capacity and 35 GW of hydrogen capacity, takes the second place. It is to be noted that most of this capacity is still in concept phase. Morocco, South Africa and Djibouti round off the top five with cumulative capacities of about 65 GW (solar – 20.5 GW, onshore wind – 21.25 GW and hydrogen – 23 GW), 52 GW (solar – 14.5 GW, onshore wind – 14.3 GW and hydrogen – 23.3 GW) and 15.7 GW (solar – 3.5 GW, onshore wind – 7.2 GW and hydrogen – 5 GW) respectively. The trend of majority of this capacity being in concept stage continues for these countries also with three fourths of Morocco and South Africa's capacity and 95% of Djibouti's capacity in concept stage. Nigeria, with its solar PV capacity, and Namibia, with its hydrogen capacity, also join the list of significant players but these projects are all in concept stage as of now.

Africa Renewables Overview

Africa capacity evolution, forecast to 2040, split by energy source (GW)

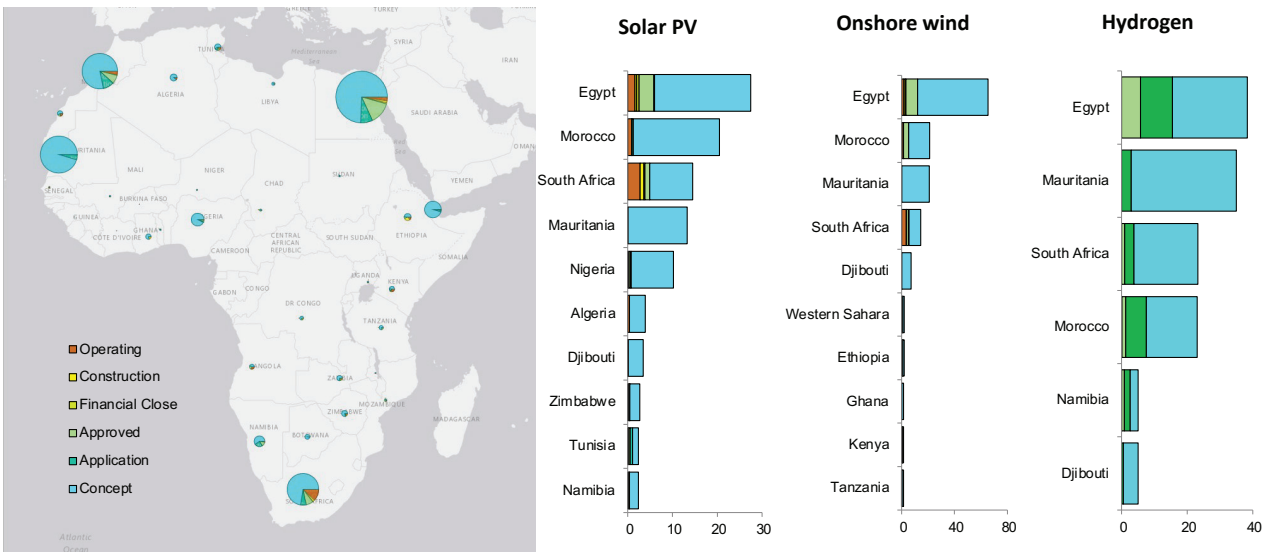


RystadEnergy

Source: Rystad Energy Renewable Cube

Africa Renewables Overview

Major countries with solar PV, onshore wind and hydrogen electrolyzer capacity (GW)



RystadEnergy

Source: Rystad Energy Renewable Cube

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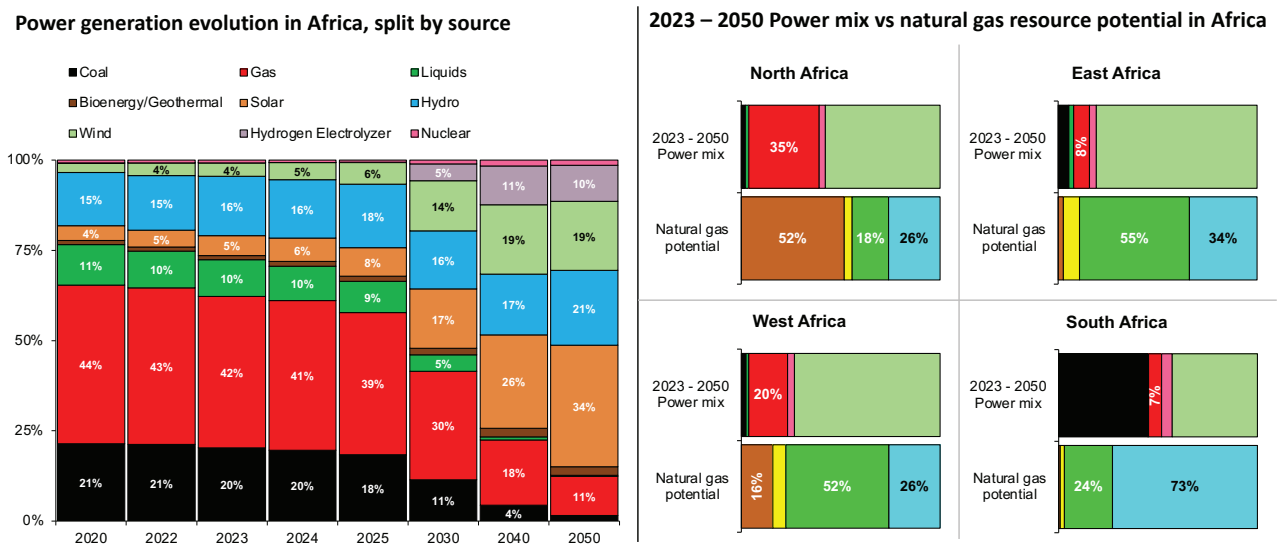
8.2 Natural gas expected to play a significant role in Africa power generation

Africa's power mix currently is dominated by fossil fuels as energy sources with coal, natural gas and liquids (oil and condensates) accounting for three-quarters of the power generated in 2022 and almost 72% in 2023. However, as need for decarbonization takes priority as energy transition regulations and climate policies get stricter, Africa's renewables (solar PV, onshore wind and hydro) driven power mix's share is estimated to increase from 25% in 2023 to 32% in 2025 to 47% in 2030 to 62% in 2040 and finally to about 75% by 2050. While fossil fuels role in the power mix is estimated to decline gradually, natural gas is expected to continue to stay in the mix. Natural gas is expected to drive 30%, 20% and 10% of the power generation in Africa over the years 2030, 2040 and 2050 respectively.

Natural gas being declared as the transition fuel, gas-to-power conversation getting louder, government schemes like "Decade of gas" and operators shifting their focus to gas over oil, natural gas is expected to play a significant role in Africa's upstream and power sectors going forward. All four regions across Africa hold huge natural gas potential, much of which is currently stuck in pre-FEED stage and, if and when brought online can help the continent's gas-to-power ambitions and can also establish Africa as a global LNG hub with cargos destined to international markets like Europe.

Africa Renewables Overview

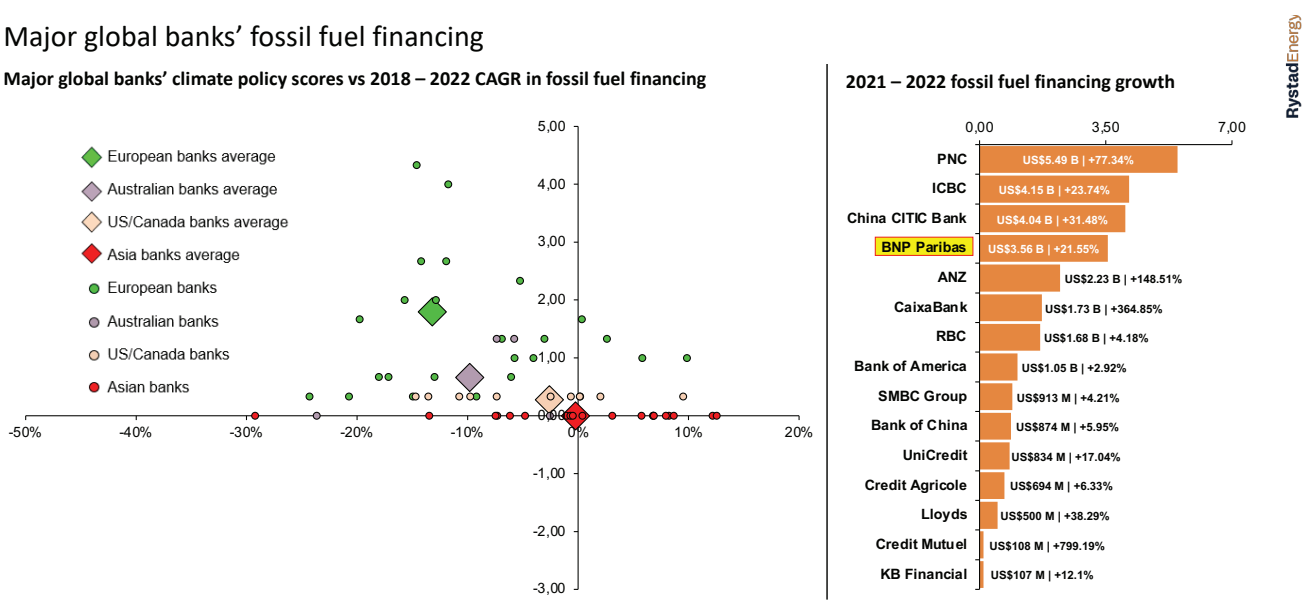
Africa power mix and Africa natural gas potential



Source: Rystad Energy UCube, Rystad Energy Power Cube

8.3 European banks more prone to financing green energy as opposed to fossil fuels

The energy transition era, focused on capping global warming levels, cutting down fossil fuels consumption and decarbonizing the energy sector, has led to financial institutions, especially from Europe, tighten their fossil fuel financing norms towards being more "climate friendly". Major European financial institutions are reported to have seen a negative compound annual growth rate (CAGR) in terms of fossil fuel financing and have seen their climate policies taking their funding policies progressively away from fossil fuels over the past few years. Over the same period, Asian financial institutions are reported to have maintained a steady CAGR in fossil fuel financing and their respective climate policies either staying undefined or remaining unchanged. While these are contrasting stands, similar stance towards fossil fuel financing and climate policies have been observed from a European bank and an Asian bank in the past few months. BNP Paribas, which is Europe's largest oil and gas lender and one of the top banks globally in terms of providing capital to the international oil majors, announced it will no longer be financing for new upstream developments as it aims to reduce its upstream exploration and production (E&P) exposure by 80% by 2030 and seeks to align its credit portfolio with net zero climate targets. Singapore's Oversea-Chinese Banking Corporation (OCBC) also announced that it will not finance any upstream projects that obtained approval for development after 2021. The bank is reported to be targeting a 95% and 55% reduction in absolute emissions from the oil & gas and power sectors respectively by 2030 and 100% by 2040. The bank added that these targets are aligned to the NZE pathway. Moves like these from banks with history of funding oil and gas projects can be significant blows to the sector globally and especially to the sector in Africa which already faces the hurdles of relatively unsafe business environment as opposed to other regions in the world. Both the banks specifically announced stopping of financing newer oil and gas developments and similar strategy from more financial institutions can prove to be serious issue for Africa.



Source: "Banking on Climate Chaos 2023: Fossil Fuel Finance Report" – Oil Change International

Source: "Banking on Climate Chaos 2023: Fossil Fuel Finance Report" - Oil Change International

Wheeling of Electricity

- A FRIEND OR FOE IN THE ENERGY TRANSITION

This study highlights South Africa's existing frameworks for wheeling electricity and the revenue implications for eThekwini Municipality should wheeling be allowed in the current context. Despite allusions to several regulations and acts, wheeling has not yet attained widespread adoption. However, the requirement to deliver electricity to consumers is gaining popularity due to increasing liberalisation in the electrical sector that enables private generators.

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EThekwini Municipality is aware of the broader implications and potential benefits of wheeling in a fully liberalised market; nonetheless, the current tariff structures and price regimes are insufficient to allow wheeling without inflicting revenue losses for municipalities. In eThekwini Municipality, a wheeling penetration rate of 100% among industrial customers would result in a loss of R 520 million. The revenue loss is R 260 million at a wheeling penetration rate of 50% and R 130 million at a wheeling penetration rate of 25%. Permitting wheeling in the Business sector also results in losses. With a wheeling penetration rate of 25%, 50%, and 75%, the corresponding financial losses are R273 million, R546 million, and R819 million, respectively. Changing the pricing mechanisms and tariff structures adopted by municipalities to recover customer network expenses independent of energy charges is one technique municipalities can adopt to avert revenue losses. Changing recovery methodologies, however, is time-consuming and will impact revenue recovery for Nother customers. Therefore, there must be an intense effort to migrate to wheeling frameworks that minimise revenue losses to municipalities while maximising the benefits of wheeling.

1.0 INTRODUCTION

1.1 BACKGROUND

The historically low price of electricity did not allow for a competitive environment and hence did not promote private generation to a large extent. Without private generation, there was no demand for wheeling. However, with the recent change to schedule 2 of the electricity regulation act, generation facilities up to 100MW are now exempt from a licence condition [1]. The licence relaxation, coupled with the higher grid electricity prices, naturally created a more conducive environment for the rise of private generators. As more generators intend to join the grid, there is a need for more off- takers. With the current geographical topology prevalent in South Africa, certain regions tend to support particular generation technologies better than others.

Transporting electricity from private producers to end-users is essential for both generators and consumers, as grid-supplied electricity is currently more expensive than solar/wind generating systems. Moreover, the economic case becomes more compelling as electricity prices continue to increase annually at a rate that exceeds inflation.

The graph in Figure 2 depicts the ten-year increase in the price of electricity, and the solar PV and wind prices tendered during the fifth bid window of the Renewable Energy Independent Power Producer Program (REIPPP).

1.1.1 Technology Advancement

Technology advancements and a maturing alternate energy sector promoting economies of scale in South Africa have

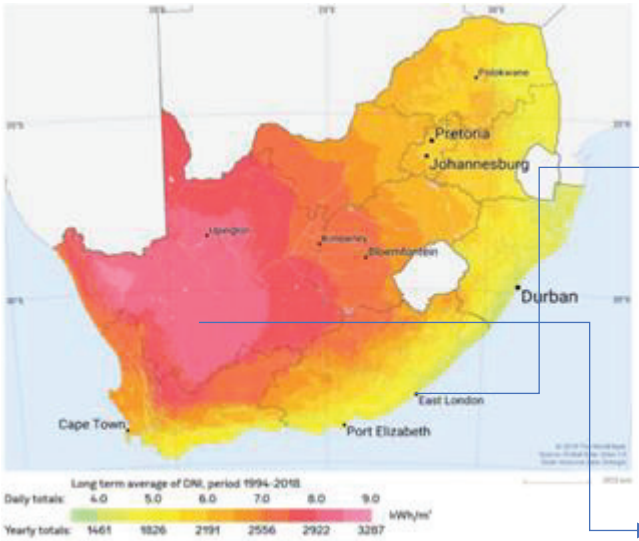


Figure 1 Solar Resource Map [2]

Coastal Region

Coastal locations, mainly from East London to the Western Cape and the neighbouring areas, are windy due to the consistently increasing airflow. For instance, the average yearly wind speed at Cape Point is 14,1 meters per second, with 42,1% of wind speeds exceeding 8 meters per second [3].

Interior Region

Due to the higher sun irradiation, the western interior regions of South Africa are optimal for solar PV. Recent trends show that solar-specific energy projects are widely implemented in these regions. Having achieved a significant concentration of independent private generators, the search for electricity off-takers has intensified. Many off-takers are located within municipal boundaries and contribute to the municipal revenue base.

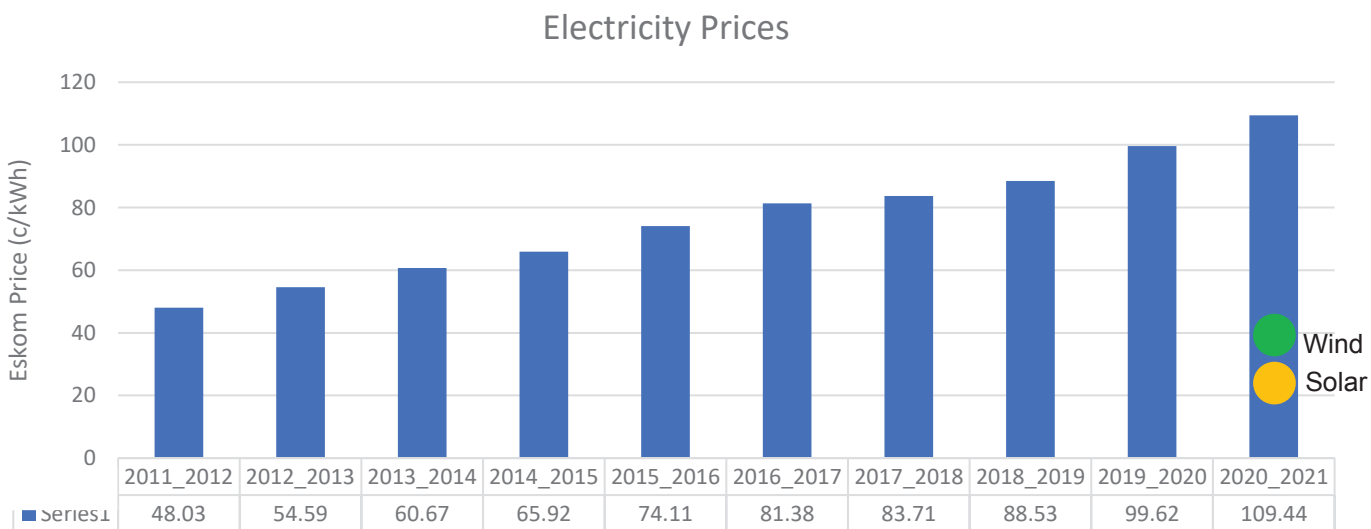
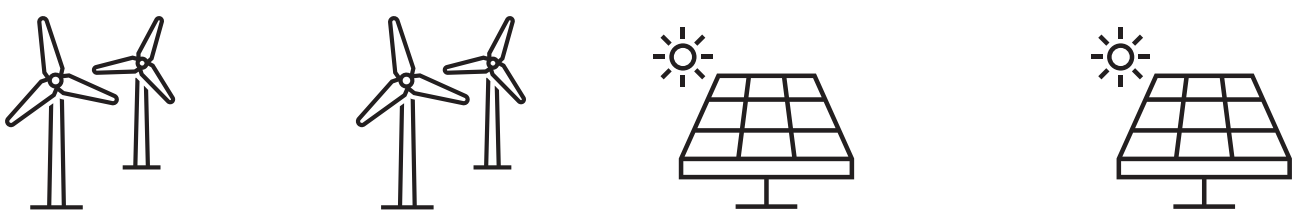


Figure 2 Electricity Prices: Eskom vs bid prices – Own elaboration based on [4], [5]

Table 1: REIPPP bid window five rates for wind and solar projects. [4]



Facility	R/ MWh	Facility	R/ MWh
Dwarsrug Wind facility	344.25	Kentani Solar Facility	374.79
Beaufort West Wind Facility	427.41	Klipfontein Solar Facility	374.79
Trakas Wind Facility	427.41	Klipfontein 2 Solar Facility	374.79
Sutherland Wind facility	428.27	Leliehoek Solar Facility	374.79
Rietrug Wind Facility	428.27	Braklaagte Solar Facility	374.79

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drastically dropped solar and wind prices. Solar and wind are intermittent generation sources; therefore, comparing these prices directly with non-intermittent sources distorts the picture. The cost of suitable backup must be included to affect a fair comparison.

With that said, the case of alternate generation at reduced prices is now a reality in South Africa. Impressing the business case would be where alternate energy could be made available per its intermittence, and backup is taken care of by another service provider.

The arrangement then gives rise to wheeling, where the generator will make electricity available per the technology's intermittency. This energy is wheeled to prospective off- takers, and the utility would make provision for the backup/ shortfall in the customer's demand. In the electricity sector, there are various definitions for the word wheeling. Simply stated, wheeling refers to utilising the network and infrastructure of the utility for conveyance by another person.

An alternate definition summarises wheeling as the movement of electrical power between a seller and a buyer via a network owned by another party [6]. Within the Electricity Pricing Policy (EPP) [7], wheeling is defined as the transportation of electricity by an electricity supplier (utility) to a third party through a network not owned, controlled or leased by either party.

The financial case for a wheeling transaction can be lucrative as renewable energy can be generated at almost one-third the price compared to traditional generation. Furthermore, wheeling to a customer at a municipal level makes the financial case even more attractive as distribution charges are also factored in.

1.1.2 Energy Shortage/Load Shedding

As a result of South Africa's electricity shortage, the demand for wheeling has also increased. The energy shortage results in frequent load shedding plaguing the country into darkness. Private power investment can quickly introduce new generation capacity to the grid; however, there would need to be an understanding and framework that would detail how electricity would be transported from generator to off-taker. Amendments to Schedule 2 of the ERA currently allow the generation of up to 100 MW without needing a licence. The amendment is a clear message from the national level that there is support for large-scale alternate energy generation. However, energy generated must be transmitted and/or distributed; therefore, a key enabler to quickly growing the generation capacity is to ensure that the transport mechanism for electricity generated is developed and implemented. Such a transport mechanism is commonly referred to as wheeling.

1.1.3 Climate Targets / Goals

In accordance with the United Nations Framework Convention on Climate Change (UNFCCC) and its Paris Agreement (PA), South Africa has pledged to contribute to global climate change efforts. Many customers, primarily large multinational corporations, have also agreed to the framework agreement's principles and set goals to transition to cleaner and greener energy sources. Entering into wheeling agreements with renewable energy suppliers is one way to meet and sustain these commitments.

1.2 IMPORTANCE OF WHEELING

Notwithstanding the challenges associated with wheeling, there must be a progressive implementation plan, as it is not only policy driven but is now becoming a crucial component of connecting private generators to off-takers. If there is a failure to accommodate wheeling, there is a risk of underutilised generators.

Moreover, the relationship between private generators and off-takers is becoming economically more robust in value as grid-priced electricity continues to grow above inflation yearly. Municipalities will therefore continue to feel the pressure to implement wheeling frameworks to enable the virtual flow of energy from private generators to off-takers.

1.3 UNDERSTANDING THE THEORETICAL CONCEPT OF WHEELING

A wheeling transaction depends on three main aspects, a generator, a network, and an off-taker. There could also be multiples of each within the transaction. However, note that this relationship is conceptual as it does not correlate with electron flow. See Figure 3.

EThekwini Municipality currently procures electricity from Eskom at the transmission level at an average rate of 109 c/kWh. However, the average retail price of electricity in the industrial sector is approximately 191 c/kWh. Therefore, the difference of 82 c/kWh (average) contributes to the costs incurred by the municipality for the distribution and related activities.

In the case of a wheeling arrangement, energy can be generated at 37.5 c/kWh, and the green electricity becomes more marketable to customers. Assuming that customers would still be prepared to pay 191 c/kWh, the wheeling transaction could earn a gross margin (excluding wheeling fees) of 153.5 c/kWh. This rate is 46% higher than what is available,

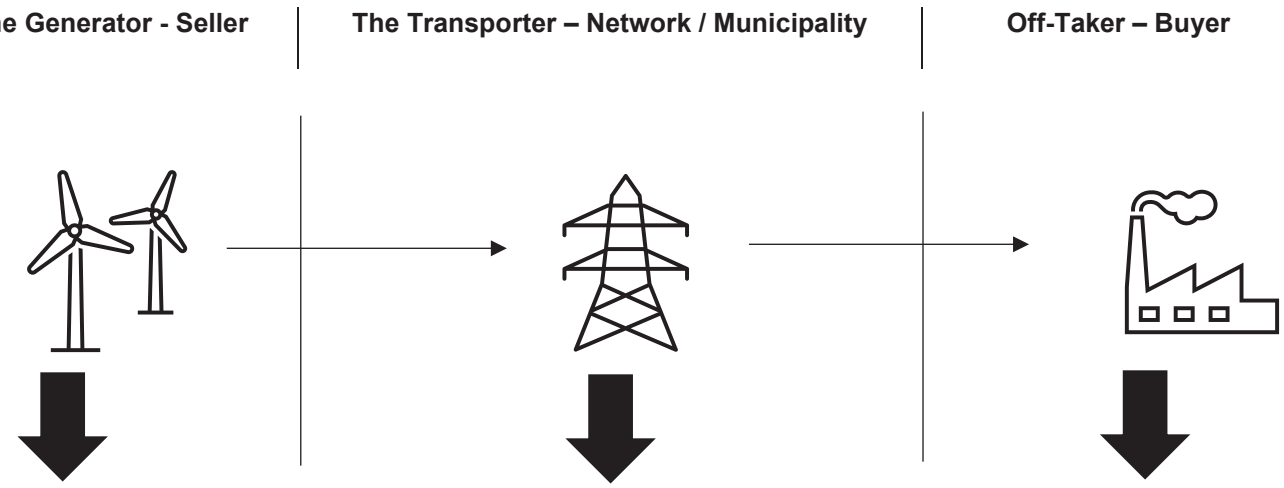

Figure 3 Single line diagram depicting the concept of wheeling. Own elaboration based on [8], [9]

considering the municipality's traditional purchase and sale of electricity. Therefore, the wheeling tariff becomes a crucial component in determining the final margin generated from the transaction.

Hence it is clear that the development of wheeling tariffs in South Africa will be subject to severe scrutiny. Furthermore, with the ongoing liberalisation of the sector, determining wheeling tariffs is becoming more complicated and crucial [10].

1.4 TYPICAL PRICING PHILOSOPHIES FOR WHEELING AT THE TRANSMISSION LEVEL

A range of wheeling pricing methodologies applies to the movement and management of electricity via the transmission network. Whilst this paper focuses on the distribution network, understanding the principles of transmission wheeling pricing is valuable as it illustrates the various cost recovery methods and their advantages and disadvantages. Similar approaches and principles could be emulated within the distribution network. See Figure 4.

There are no unified rules for calculating the wheeling charge; however, there are recommended approaches as it is impossible to colour code an electron [6]. As a result, each method varies in accuracy and complexity when calculating wheeling charges. In addition, the calculation becomes more complex when wheeling occurs across multiple municipalities through the Eskom network. In these cases, charges will be raised by all of the network operators, and the methodology of charging may be different as there is no

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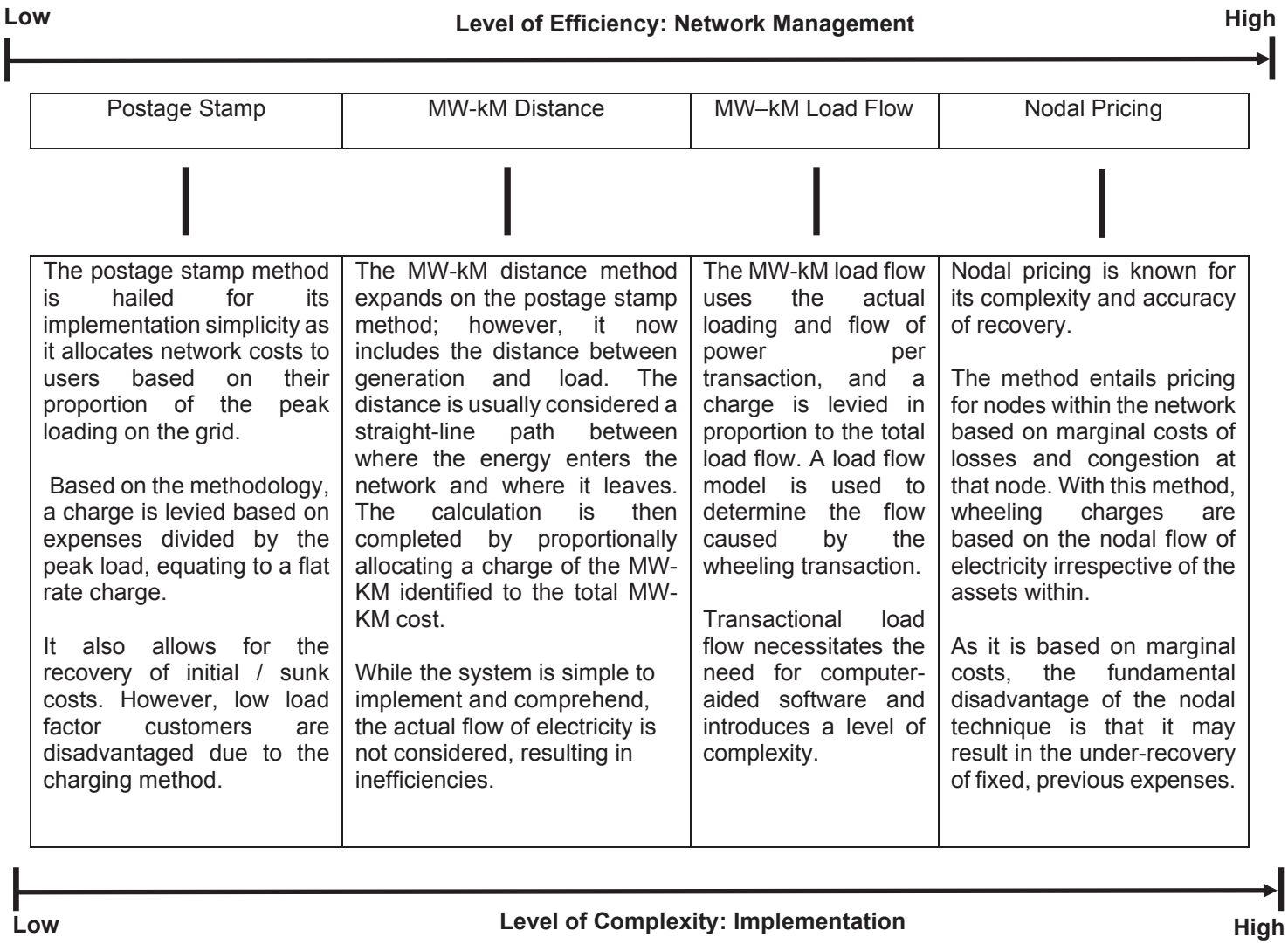

Figure 4 Methods of calculating wheeling costs: Own Elaboration based on [11], [12], [13]

uniform method of charging at this stage nationally.

1.5 UNDERSTANDING THE CURRENT CHALLENGES OF WHEELING WITHIN MUNICIPAL NETWORKS

When trying to integrate such wheeling principles within current municipal frameworks, there is a lack of harmony, tariff discrimination and, in many cases, the loss of revenue to the municipality.

Recovery of costs on the distribution grid is carried out via cost pooling per voltage level. This methodology is regulated amongst municipalities. This cost recovery method will either be a kWh recovery, a kVA recovery, or a combination of both. The costs allocated to the voltage pool, the number of customers participating, the loading size and the load factors are essential factors in determining the cost recovery method.

In times of high growth coupled with high load factor customers, a kWh recovery method is most plausible as it spreads costs amongst a more prominent aspect of a tariff component.

The kWh recovery method has the effect of reducing the average tariff for all customers.

1.5.1 Costs and Tariff Mismatch: Deviation from Cost of Supply

The third-party transportation rule document states that the increase in UOS charges must be indexed to CPI [14]; however, the UOS charges are indexed to actual costs experienced. Further, the UOS charge is calculated by dividing the total cost by the total sales; should sales drop significantly, the UOS charge rises significantly, irrespective of CPI. See Figure 5.

In the case of EThekwini Municipality, a portion of the network-related costs is recovered via the sale of kWhs. As a result, any attempt to reduce the kWh

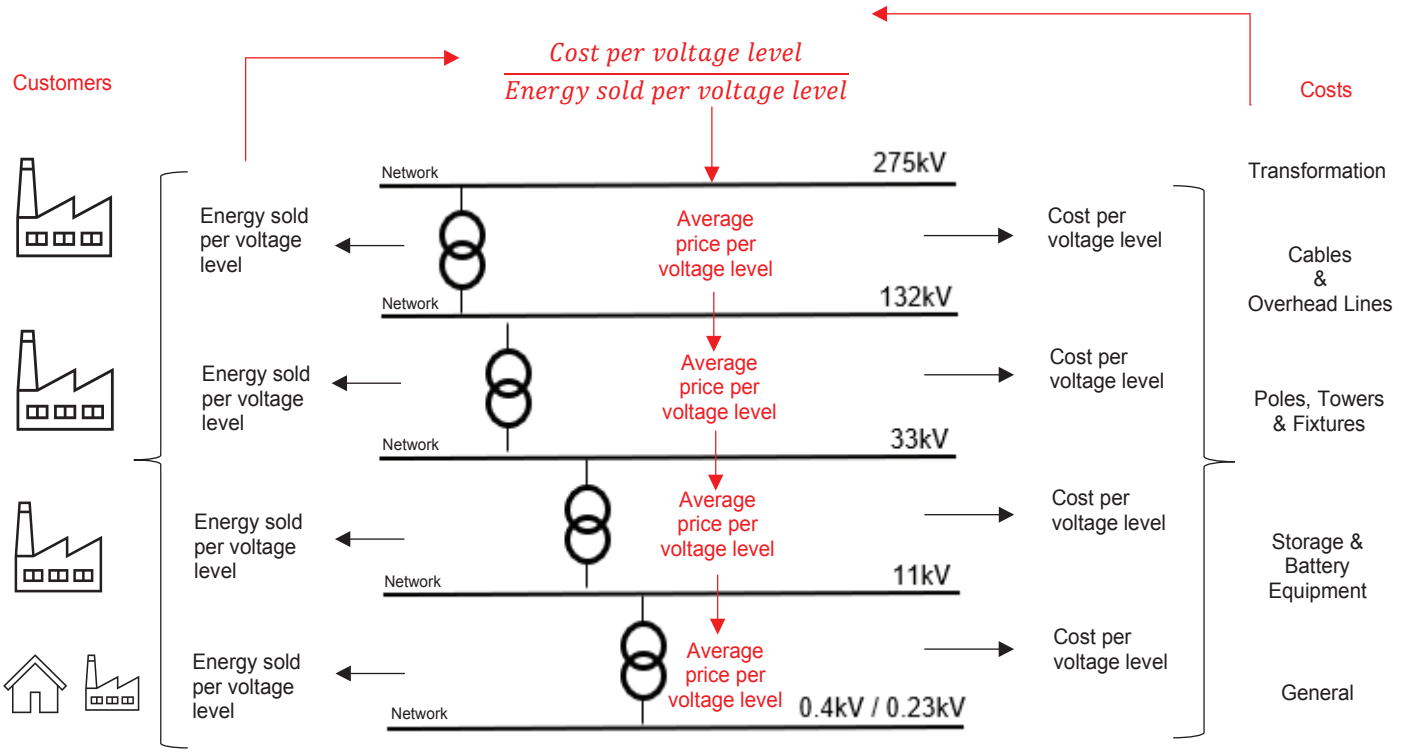

Figure 5 Illustration depicting voltage level model of eThekwini Municipality: Own Elaboration

sales contributes less to the network-related costs. As a result, the tariff for other customers must be increased to cater for this loss.

In this context, the implementation of wheeling is not gaining popularity in Municipalities. The following sections attempt to quantify and highlight these challenges and further try to provide realistic approaches to harmonise wheeling within the changing electricity supply landscape of South Africa.

1.5.2 Contractual Matters

Contractual arrangements become complex as multiple parties are involved in the electricity transaction. The transaction is affected when the generator is unable to supply electricity as agreed, the customer is unable to consume electricity as agreed, or the municipality is unable to provide the network as agreed. Network unavailability would generally be due to load shedding and or network faults. These scenarios would place a significant burden on the management of the transaction.

Generally, when a municipality is a party to a contract with financial obligations, a supply chain procedure is followed, and the duration of the contract is limited. It is uncertain if wheeling is exempt from supply chain procedures. There are compelling reasons against the necessity of following predetermined supply chain procedures. It would be of great use if the national treasury issued a circular directing municipality in this regard.

1.5.3 Billing and metering systems

Wheeling transactions necessitate expanding billing and metering systems to accommodate the necessary adjustments and offsets. Additionally, intercity electricity wheeling would necessitate increased collaboration, as the various systems would need to be integrated; otherwise, manual transactions would be required.

Electricity wheeling is supported within the electricity framework in South Africa. The framework alludes to principles and rules that would be best suited to enable wheeling; however, it is not necessarily feasible to implement currently.

Therefore, migrating towards the electricity framework that supports wheeling will affect all electricity network users.

Wheeling may therefore be ready to be enacted in theory but not necessarily in reality unless the matters are suitably addressed.

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1.6 THE SOUTH AFRICAN WHEELING CONTEXT

2006

ACT | **POLICY**

The Electricity Regulation Act [15]

The Electricity Regulation Act relates not to wheeling but rather to trading electricity. As defined, "trading" refers to the commercial purchase or sale of energy. Therefore, one may claim that wheeling constitutes trading because it involves buying and selling.

Notwithstanding the lack of reference to wheeling, sections 2 (a) and (b) define the act's objectives as follows:

(a) Achieve the efficient, effective, sustainable, and orderly development and operation of electricity supply infrastructure in South Africa.

(b) Ensure that the interests and needs of present and future electricity customers and end users are safeguarded and met, having regard to governance and efficiency. Effectiveness and long-term sustainability of the electricity supply industry within the broader context of economic energy regulation in the

(c) *F*acilitate investment in the electricity supply industry - (d), (e), (f), (g) also apply.

It is evident within the objectives that effectiveness, sustainability and competitiveness must be supported.

The Electricity Pricing Policy [

Unlike the ERA, the electricity pricin Africa dedicates a paragraph to disc of wheeling. The principal points ar per policy position 5 below:

5 a) Fair and non-discriminatory ac of networks to all users of the releva

b) The total cost to operate the netw in the various connection and use of therefore, no additional charges electricity will be levied unless the introduces incremental costs.

c) Any incremental wheeling costs a specific wheeling transaction ar must be recovered as a connection

d) Wheeling of electricity can only b action complies with all technic commercial requirements.

e) A methodology for transmission wheeling, including the treatme congestion, must be developed by N

The policy has forward stepped and two specific issues of wheeling, inclu rights of wheeling (5a) as well as the (5b,5c); however, it also pronoun NERSA must develop a methodolog

Figure 6 Summary of selected wheeling refere

7] g policy of South cuss the concept re highlighted as ccess to and use ant networks. works is reflected system charges; s for wheeling wheeling action s associated with nd its fair share charge. e permitted if the cal, safety and and distribution ent of network NERSA. d pronounced on uding the access pricing methods ces in (5e) that gy for wheeling.	**The Distribution Grid Codes [16]** The tariff grid code v6.2 states the following: 5.5.1. Embedded generators, including those that wheel, that use the distribution network to export power shall pay the Distribution generator use-of-system charges. 5.5. (2) All customers receiving a network service (including wheeling) shall pay the distribution use of system charges (DUoS), irrespective of any energy trading arrangement, which may or may not be unbundled depending on the tariff structure. 7. (5) All load customers, including those wheeling energy, shall be required to contribute to network-related subsidies. However, what form or quantity the customers shall contribute to subsidies is unclear.	**Third-Party Transportation of Energy [14]** Section 6.11 of the rules says generators' UOS system charges must be fixed and indexed annually to CPI. Unfortunately, not all costs are indexed to CPI; hence, municipalities may be under recovering in these cases where costs exceed CPI. Section 11.3 states, Upstream reinforcements costs shall not be raised from wheeling generators but an early termination guarantee for shared assets. The non-raising of costs can be viewed as municipalities funding infrastructure used by generators. 12.2 Generators connected below 11kV shall not be allowed to wheel energy.

ences within the act, policy, grid code & rules

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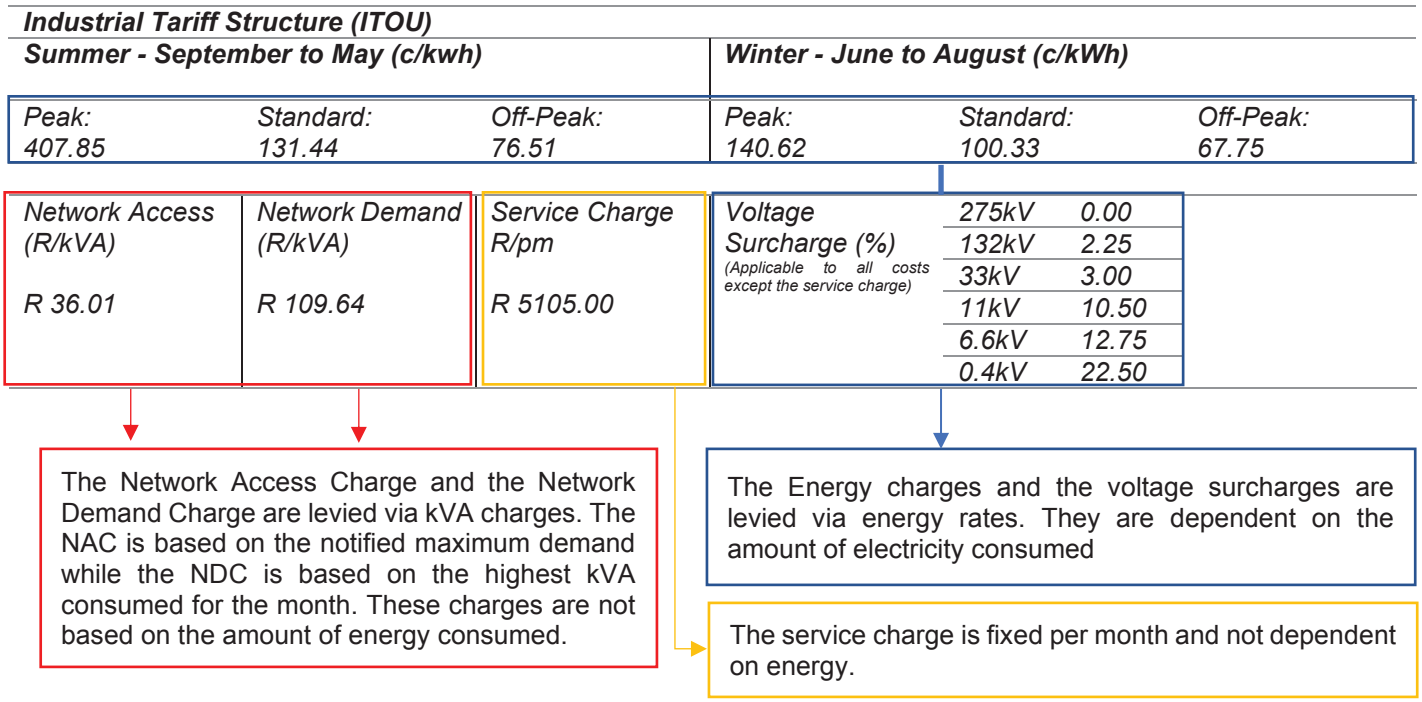

Figure 7 Industrial Time of Use (ITOU) tariff structure [17]

Table 2: Applicability of wheeling amongst customer categories

RESIDENTIAL CATEGORY	BUSINESS CATEGORY	INDUSTRIAL CATEGORY
Most customers within eThekwini Municipality are residential customers that procure electricity on the low voltage on either credit or prepaid electricity. The residential sector consumes 34 % of the total electricity per annum and contributes 38% to the revenue stream. The retail price of electricity is 182.09 c/kWh. Therefore, wheeling to this customer base would make an excellent financial case; however, consumption is relatively low to attract wheelers. Therefore, it is unlikely that the sector would be targeted for wheeling at this stage. A large contingent of informal settlements within eThekwini Municipality is not electrified. These informal settlements depend on subsidised connections and Free Basic Electricity (FBE) monthly due to their low level of affordability. However, there has not been a significant demand to wheel to these communities despite the sector's need for cheaper and cleaner electricity. There is little prospect of large-scale wheeling in this sector; therefore, this sector has been excluded from scenario modelling.	There are 43587 Business customers in the city. They consume 2041 GWh per annum. Business customers are primarily serviced via low voltage credit meters and contribute 21% of the annual revenue stream. The retail price of electricity is 205.62 c/kWh. Therefore, wheeling to this customer base would make an excellent financial case. However, individual consumption is relatively low to attract wheelers at a large scale. Therefore, it is unlikely that this sector would be targeted for individual wheeling. Traders and aggregators may find it lucrative to wheel to multiple customers within this sector. Customers within this sector may also have set renewable energy targets, and wheeling external energy might be the only way to achieve them. Therefore, this sector (scale 1 tariff) has been included for scenario modelling.	There are 1100 customers consuming electricity via the ITOU tariff structure. They account for 43 % of the total electricity consumption. Furthermore, due to extensive electricity requirements at higher voltage levels and high load factors, this sector contributes 40 % to the total revenue stream. This sector is the most likely to be targeted for wheeling electricity due to significant customer sizes. Further, companies within this category are progressively setting renewable energy goals, which may only be met through wheeling arrangements. This sector (ITOU tariff) has therefore been included for scenario modelling.

2.0 THE DILEMMA OF WHEELING: A CASE IN POINT

Large electricity users in eThekwini use the Industrial Time of Use (ITOU) tariff structure to purchase electricity [17].

Given the standard typology of wheeling, it would typically be applied to consumers who buy electricity through this tariff. See Figure 7.

The tariff structure closely depicts that of Eskom Megaflex. The tariff is broken up into 3 energy periods, i.e., Peak, Standard and off-peak. It is further differentiated between summer and winter periods. In addition to the energy charge components, there is a fixed network access charge (kVA), a demand charge (kVA) and a fixed service charge. The fixed network access charge is based on the notified demand, while the maximum demand charge is based on the highest kVA drawn for the month.

A voltage surcharge is a percentage levied on the sum of the energy and demand components. The percentage levied varies depending on the voltage level of operation. The voltage surcharge is levied on the sum of the energy and demand components. The tariff component aims to recover costs that vary based on energy, including losses and other energy- driven costs. Customers are billed monthly.

2.1 APPLICABILITY OF WHEELING AMONGST CUSTOMERS IN ETHEKWINI

See Table 2: Applicability of wheeling amongst customer categories

2.2 AGGREGATED CUSTOMER MODELLING

The municipality's loss will vary based on the scale of wheeling adoption, contingent on several circumstances. Therefore, the ITOU & Scale 1 customer base was modelled using four

Scenario 1: Industrial Time of Use Tariff Extent of wheeling: 100%

This scenario illustrates what would occur if all ITOU users' energy consumption was wheeled rather than purchased from the municipality.

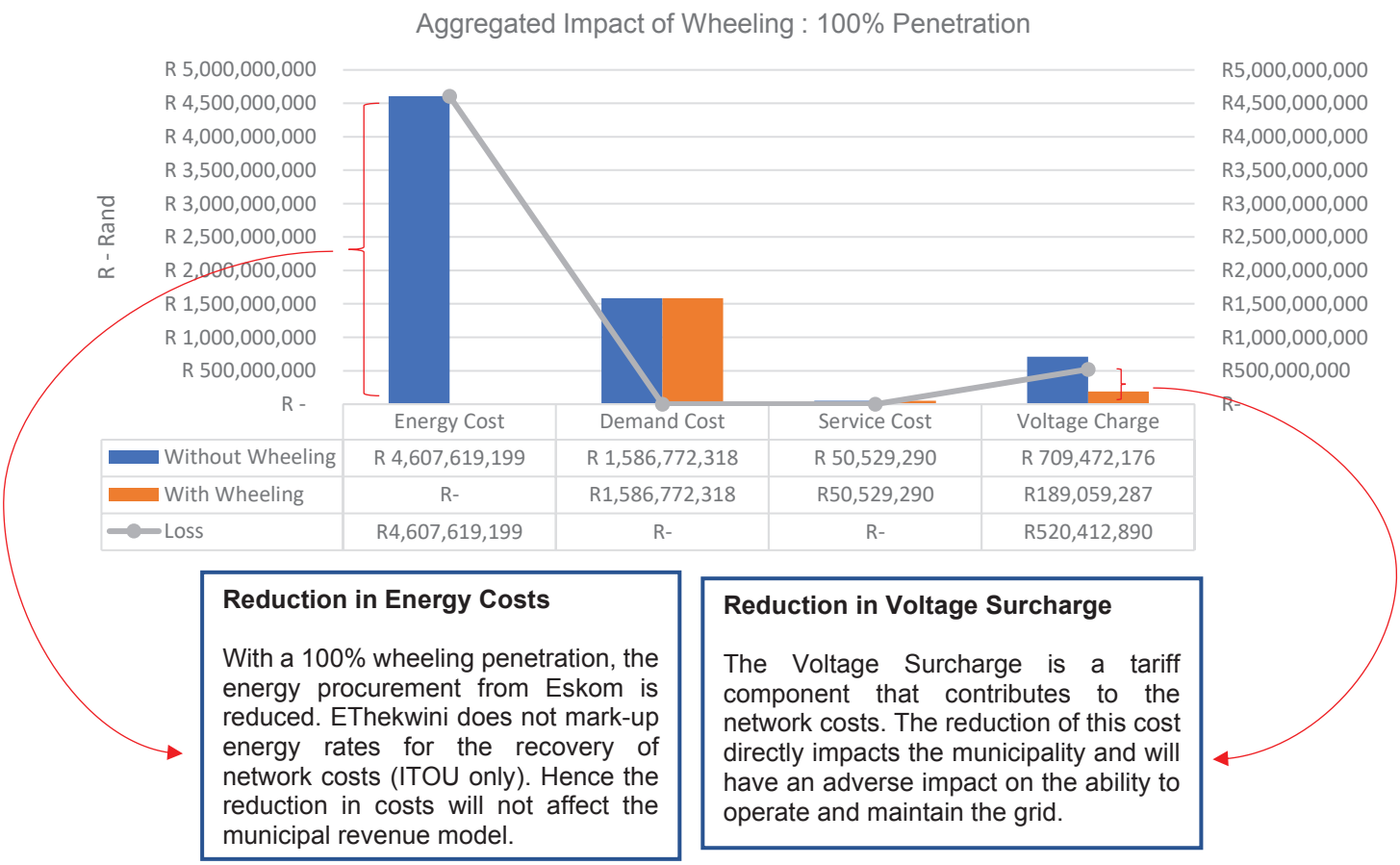

Figure 8 Cumulative revenue impact at 100% wheeling penetration

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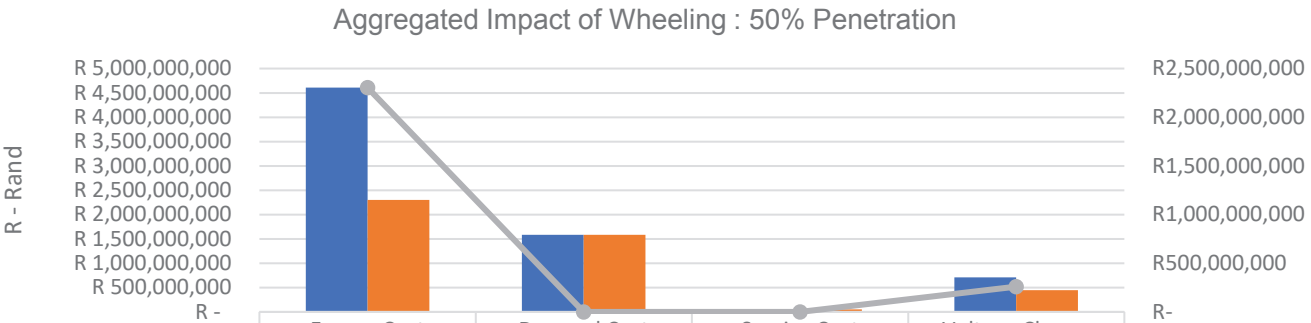
Scenario 2: Industrial Time of Use Tariff Extent of wheeling: 50%

This scenario illustrates what would occur if half of all ITOU users' energy consumption was wheeled rather than purchased from the municipality.

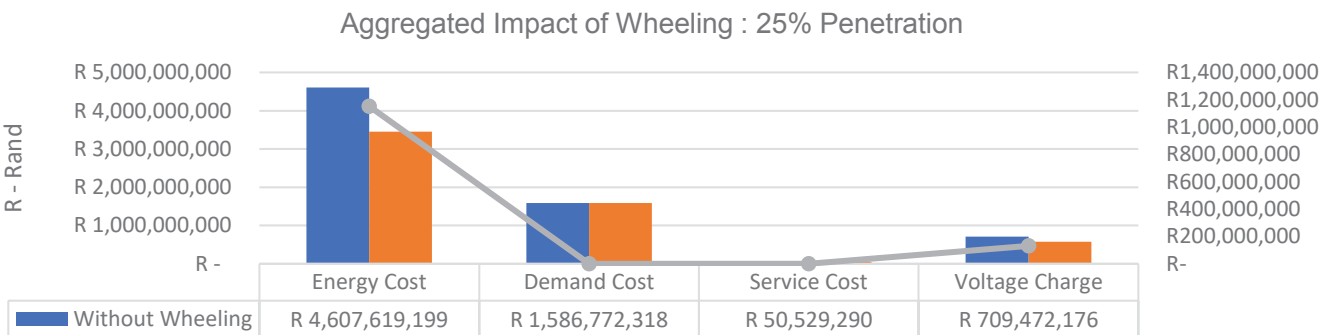


	Energy Cost	Demand Cost	Service Cost	Voltage Charge
Without Wheeling	R 4,607,619,199	R 1,586,772,318	R 50,529,290	R 709,472,176
With Wheeling	R2,303,809,600	R1,586,772,318	R50,529,290	R449,265,731
Loss	R2,303,809,600	R-	R-	R260,206,445

Figure 9 Cumulative revenue impact at 50% wheeling penetration

Scenario 3: Industrial Time of Use Tariff Extent of wheeling: 25%

This scenario illustrates what would occur if a quarter of all ITOU users' energy consumption was wheeled rather than purchased from the municipality.



	Energy Cost	Demand Cost	Service Cost	Voltage Charge
Without Wheeling	R 4,607,619,199	R 1,586,772,318	R 50,529,290	R 709,472,176
With Wheeling	R3,455,714,400	R1,586,772,318	R50,529,290	R579,368,954
Loss	R1,151,904,800	R-	R-	R130,103,222

Figure 10 Cumulative revenue impact at 25% wheeling penetration

enumerated scenarios to provide higher and lower revenue loss thresholds based on predetermined wheeling penetration rates.

Note:

1. *Modelling assumed that all demand-related charges remain constant and only kWh are offset during wheeling.*
2. *Assumes that the ITOU tariff structure is cost-reflective*

In scenarios two (Figure 9) and three (Figure 10), the characteristics of the financial losses remain. With a 50% penetration rate of wheeling, the municipality is subject to a shortfall of R 260 206 445, which will directly affect its

Scenario 4:	Business & General	Extent of wheeling: 25 / 50 / 75%

This scenario details the impact should wheeling occur within the Scale 1 tariff category.

Within the Scale 1 tariff, 96% of the network costs are recovered via the energy rate. The retail price per kWh for business customers is 205.62 c/kWh. On average, 100 c/kWh (49%) is attributed to network and services-related costs, while 105.62 c/kWh (51%) is attributed to direct energy costs.

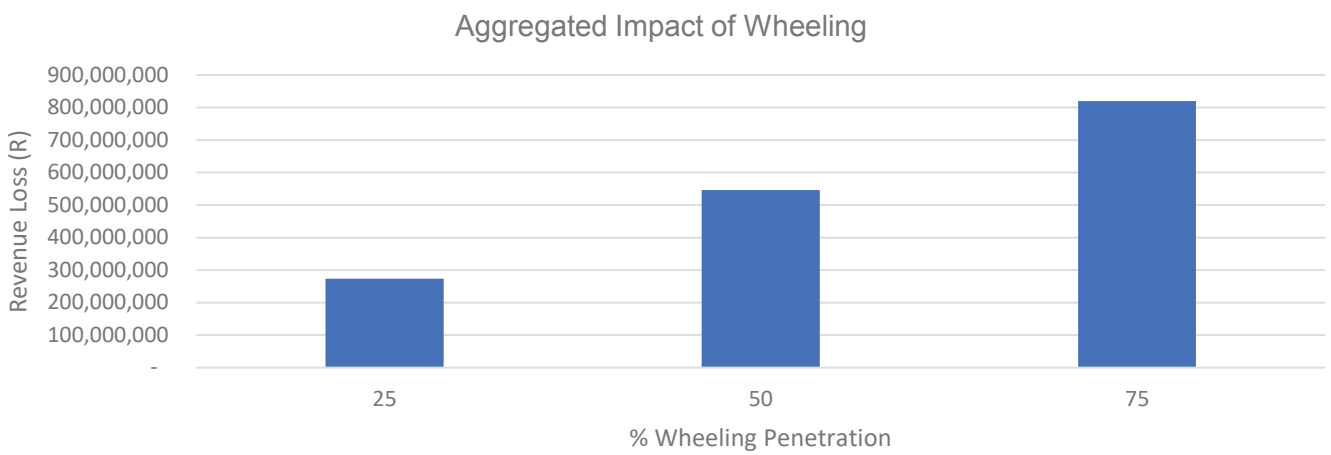


Figure 11 Cumulative revenue impact at varied rates of wheeling penetration

ability to operate and maintain the grid. In scenario three, due to the reduced penetration of wheeling, the shortfall to the Municipality is R 130 103 222.

This shortfall represents an under-recovery of network and related costs.

As the prevalence of wheeling increases, municipal revenue losses increase proportionally. While it seems unlikely that wheeling will penetrate this sector in the short term, the significant revenue losses indicate the difficulty of incorporating wheeling into the current tariff structures and revenue models.

2.3 INTERPRETATION OF THE LOSSES

The energy rates included in the ITOU tariff structure are based on the Eskom Megaflex. As a result, a decrease in energy sales will not affect the municipality, as the cost is passed through. Ultimately, Eskom will bear the brunt of the decreased energy sales. Nonetheless, the municipality continues to incur losses because some tariff components recover network-related charges based on the amount of energy sold.

The ITOU tariff structure recovers network-related charges via the tariff components as shown in Table 3.

The NAC and NDC are not dependent on the flow of energy and, therefore, are not affected when energy is wheeled across the network. However, the voltage surcharge depends on the quantity of electricity sold. Therefore, any attempt to reduce the amount of energy sold will reduce the revenue to the municipality. The UOS charge philosophy embedded in the wheeling literature assumes that the recovery of network charges is independent of energy flow. For many municipalities in South Africa, this is not the case. As a result, any attempt to wheel electricity across the network will attract a loss of network recovery charges to the municipality. Historically

Table 3: Tariff components that contribute to the recovery of network costs

No.	Network recovery tariff component	Method of charge	% Contribution to the recovery of total network costs
1	Network Access Charge (NAC)	kVA	69%
2	Network Demand Charge (NDC)	kVA	
3	Voltage Surcharge (VS)	% Levied on kWh & kVA	31%

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the tariff structure took advantage of high growth rates in energy to share network costs and drive down the overall cost of electricity. Customers on the ITOU tariff structure pay, on average, 191 c/kWh; this is 82 c/kWh above the Eskom Megaflex tariff. The total of the recovered charges helps fund the Unit's operations and contributes to the city. Due to cost pooling and the bundled nature of tariffs, the actual flow of the revenue verse costs is difficult to track. Structural cross recovery is not a flaw, and it was a strategic hold position in the move to cost-reflective tariffs to keep prices lower for the broader customer base.

3.0 PROPOSALS TO INCORPORATE WHEELING WITHIN ETHEKWINI

3.1 OPTION 1: RECOVER NETWORK CHARGES INDEPENDENT OF ENERGY USAGE

Option 1 is to shift the revenue recovery mechanism of network charges away from the voltage surcharge. Shifting the network charge recovery away from the voltage surcharge would make the network recovery costs independent of the amount of energy that flows within the network. Enabling such a shift means that an additional 31% of network costs must be collected through kVA charges rather than kWh charges. This shift would significantly increase customer demand charges and exceed the NERSA benchmarks. The increase per customer would be highly dependent on the load factor of operation. On average, an increase of 141% would be required in the NAC. The increased kVA amount would prevent the loss to municipalities and should not be interpreted as a wheeling charge.

3.1.1 The rationality of implementing option 1:

Implementing option 1 would result in high customer increases, as their kVA component would rise sharply, especially for low load factor customers. However, considering the high electricity costs experienced in South Africa, such a move may not gain popularity amongst customers or the National Energy Regulator of South Africa (NERSA) at this time.

3.2 OPTION 2: MUNICIPALITIES REMAIN AGNOSTIC TO WHEELING

Considering the cross recovery of network charges via energy rates, any form of wheeling will lead to an under-recovery.

A simple yet effective means to avoid this scenario and implement wheeling speedily is to retain the voltage surcharge on the pre-wheeled consumption. The voltage surcharge varies per voltage, inherently by design, and the wheeling contribution will also vary based on the operational voltage. This variation will allow for a self-calculating mechanism to prevent municipal losses as wheelers are introduced into the network. However, wheeling will introduce many administrative processes that must be carefully managed via an automated billing system. Therefore, incorporating wheeling tariffs would require additional design, development, and maintenance of the billing system. As a result, it would be prudent to introduce a monthly administration charge to cater for this additional administration.

In essence, all energy wheeled will be quantified based on the energy value of the ITOU tariff structure, which is equivalent to the purchasing tariff. The quantified value will be decreased by the voltage surcharge percentage of the receiving party. Subsequently, the receiving party will be credited. Adopting this method will result in the municipality being revenue neutral to wheeling transactions.

3.2.1 The rationality of implementing option 2:

Considering the need for wheeling tariffs urgently, Option 2 aims to achieve a balance between introducing wheeling tariffs and maintaining the sustainability of the distribution grid. In this case, the wheeler helps the municipality preserve revenue neutrality by paying the wheeling tariff. However, the wheeler is not surcharged for their activity.

Furthermore, with alternate generating technology producing electricity at rates considerably cheaper than Eskom, the opportunity to wheel electricity is likely still lucrative even while contributing to the loss in network charges.

3.2.2 A typical pricing approach based on principles of option 2:

A plausible wheeling framework based on revenue neutrality for eThekwini Municipality is highlighted in Table 4.

The rates would be adjusted yearly following relevant tariff increases. Another dynamic area for the municipality is the percentages levied per voltage level. In an ideal case, this would depend on the cost of the supply study. The cost of supply study is highly dependent, among other things, on the loading of the network, maintenance, and growth factors.

The tariff will be adjusted following NERSA-approved cost of supply studies. Unfortunately, as the sector changes, the wheeling costs will also change. Varying costs are the sector's reality under these circumstances. All parties must be able to share such volatility. Signing into long-term agreements without fully understanding and appreciating the costs is not in the municipality's best interest.

Table 4: Wheeling tariff rates to maintain revenue neutrality

Based on 21/22 tariff rates

	Winter Season - Energy Wheeled (c/kWh)			Summer Season - Energy Wheeled (c/kWh)			All Seasons (R/pm)	All Seasons
Voltage	Peak	Standard	Off-Peak	Peak	Standard	Off-Peak	Admin Charge R	Annual Average 24 hrs (c/kWh)
0.4kV	92	30	17	32	23	15	5105	40
6.6kV	52	17	10	18	13	9	5105	23
11kV	43	14	8	15	11	7	5105	19
33kV	12	4	2	4	3	2	5105	5
132kV	9	3	2	3	2	2	5105	4

Note:

1. *The above rates only augment revenue loss due to how costs are recovered amongst tariff components.*
2. *The above rates do not lead to additional revenue but maintain the current status quo.*
3. *The above rates are not adjusted for the state of cost of supply/cost reflectiveness.*

Option 2 could serve as a revenue-neutral transitionary wheeling framework for eThekwini Municipality until the actual cost of supply tariffs has been implemented. At such time, a new wheeling approach can be devised. The implementation of option 2 bears no advantage directly for the municipality. The municipality is only enabling transactions that allow other parties to engage in the sector. Notwithstanding the policy and regulatory requirements and the potential for overall economic benefits, there is no direct business case for the municipality to promote wheeling in its current form. [18]

3.3 OPTION 3: MUNICIPALITIES PARTICIPATE IN THE WHEELING ARRANGEMENT TO ENHANCE REVENUE GENERATION

A more innovative strategy would be to establish a mutually beneficial relationship around wheeling, which would contribute to a more substantial business case for the municipality. For

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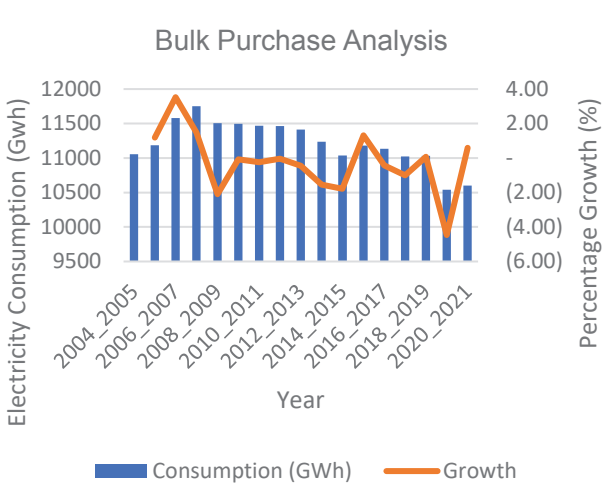

Figure 12 Bulk consumption analysis

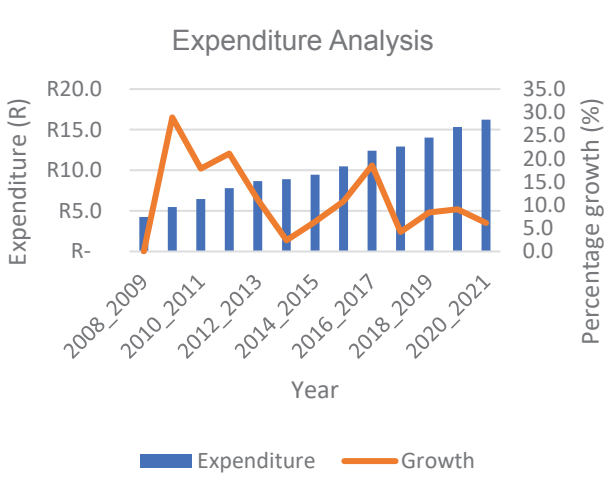

Figure 13 Expenditure analysis

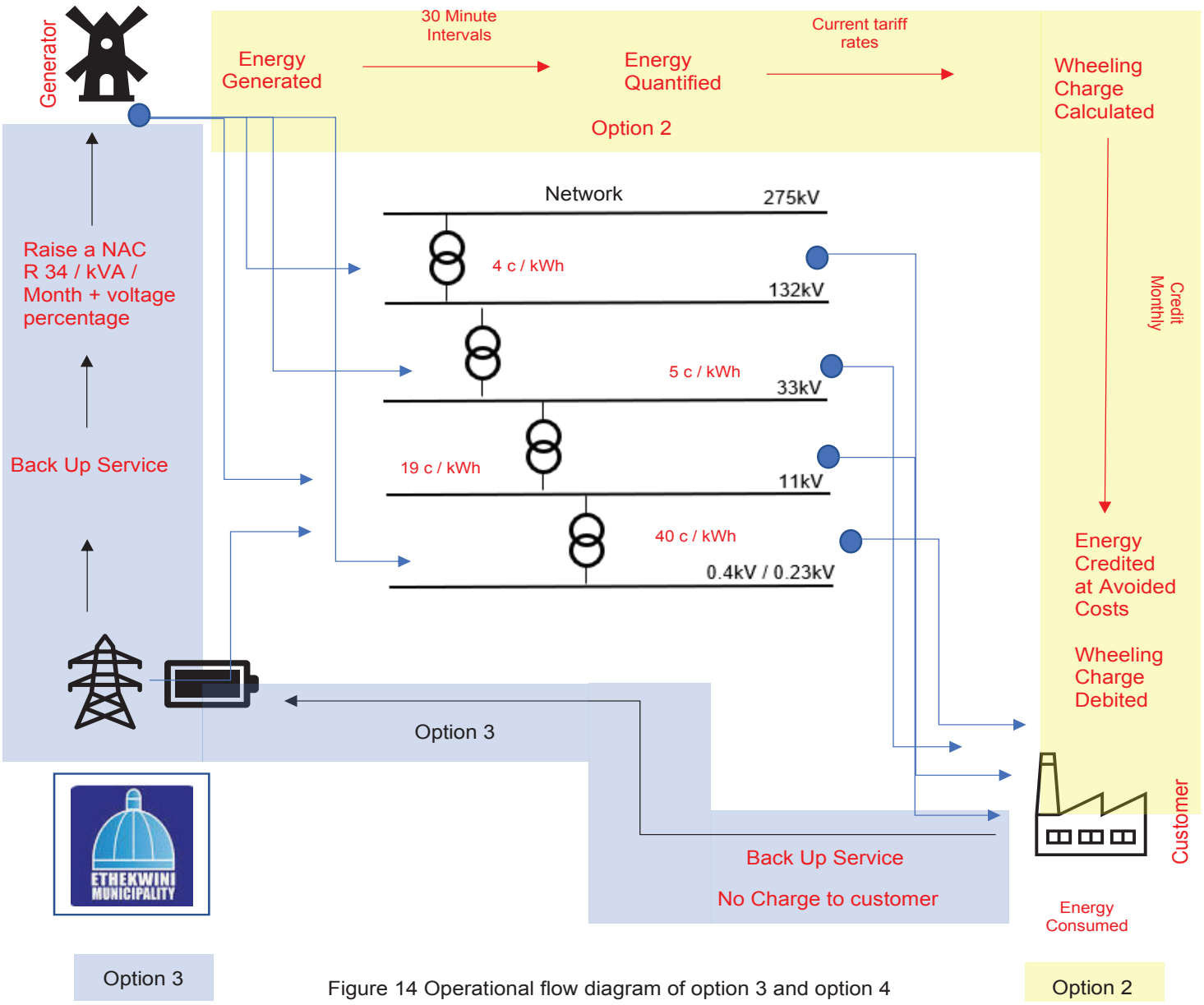

Figure 14 Operational flow diagram of option 3 and option 4

example, a situation in which a wheeling entity could provide a scenario in which the wheeling of electricity would increase the municipality's revenue. This arrangement would be a "win" – "win" scenario that would encourage municipalities to implement wheeling as a diversified revenue stream instead of the conventional value-neutral virtual transaction.

3.3.1 The rationality of implementing option 3:

Due to the current state of the economy, municipal revenue models fail to meet their projections. No growth and rising input cost further hamper the revenue model's rationality. Municipalities will benefit from an opportunity to diversify revenue streams, and wheeling could serve as a pilot case. Electricity consumption has steadily decreased in eThekwini.

As a result of a rapidly dwindling consumption base and a rising cost structure, the electricity price would escalate beyond inflationary expectations. A death spiral is a reality with rising electricity costs and continuous negative electricity growth.

4.0 MECHANICS OF THE WHEELING TRANSACTION

The mechanics of option two and option three are illustrated below. In addition, allowing Municipalities to provide a backup service to the wheeling transaction allows municipalities to enhance their revenue generation through the transaction. See Figure 14.

Localised renewable energy generators are variable since they are intermittent by nature. Failures and malfunctions are also a reality. Uncertainty exists as to who will provide backup functionality in the developing South African market; nevertheless, municipalities can provide this capability through their existing grids and contractual agreements with Eskom. Therefore, it would be prudent to contract with municipalities for this service. By contracting this service to municipalities, they can engage in the market for auxiliary services.

5.0 THE FUTURE OF WHEELING

The world has experienced restructuring in the energy supply industry (ESI). This restructuring's primary goal is to create competition in the electricity supply sector to improve service quality and efficiency [8]. Although many countries

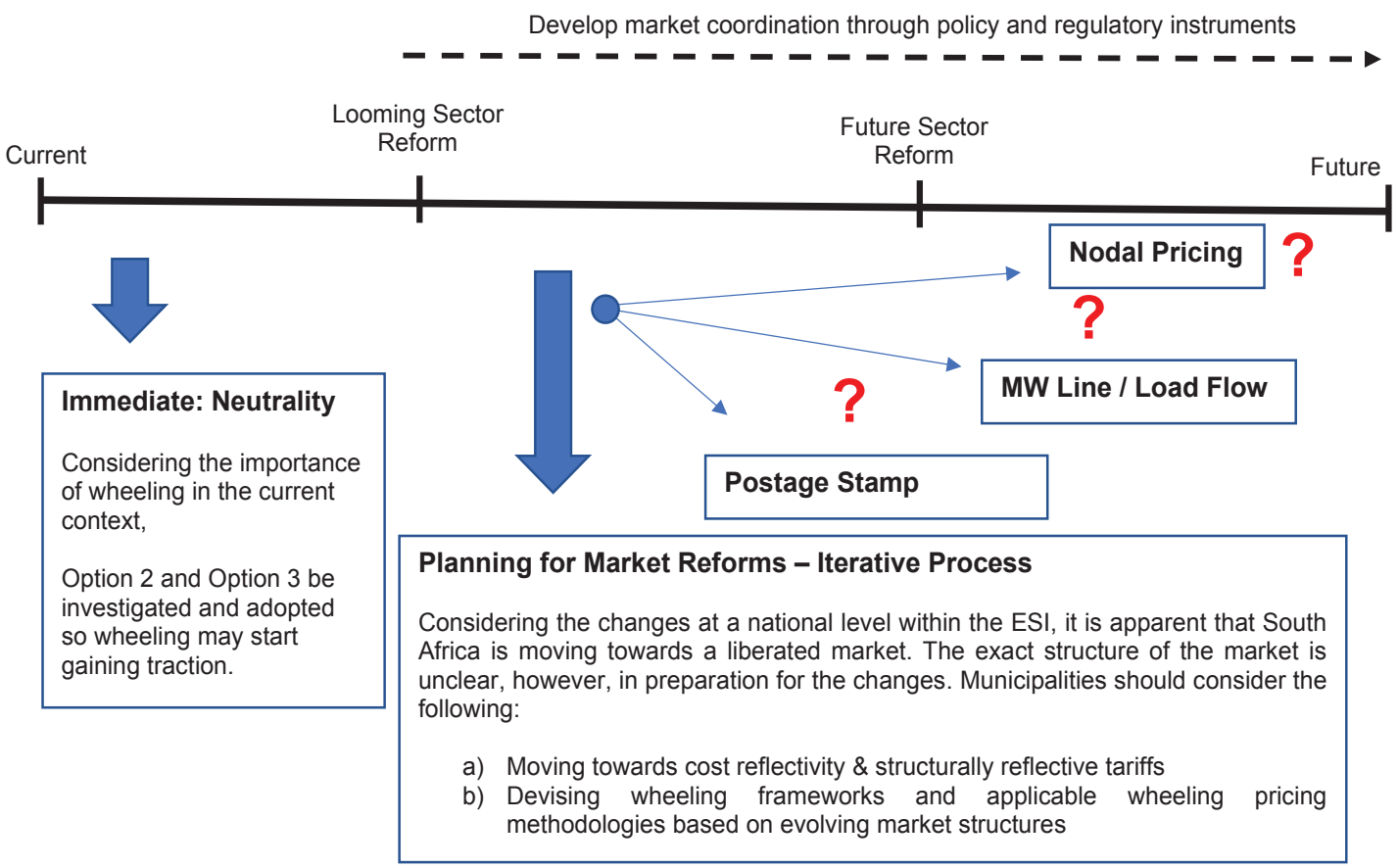

Figure 15 Probable roadmap to respond to wheeling as the sector reforms

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worldwide have engaged in some deregulation, the concept does not adhere to a standard model and is frequently viewed and executed based on each country's unique conditions and needs [19]. Therefore, some significant adjustments must be made in the municipal sector to meet the challenge and fully use the potential presented by the continuous deregulation. In addition, each party's rights and obligations must be clear in a competitive setting. As a result, municipalities will be encouraged to make better investments, enhancing system performance [6].

In South Africa, wheeling has been progressively liberated through the ongoing amendments to regulations, acts, and policy, primarily driven by the notion of creating a competitive generation sector. However, costs and unpinning tariff structures must be fully unbundled to appreciate and utilise wheeling fully. Such unbundling must be classified into energy costs, wires costs (network), and retail costs (commercial). Unfortunately, this is not the case in many distribution utilities within South Africa. Further, as wheeling gets more pronounced, the would be a need to control network congestion management, and a range of pricing methodologies apply, each with its pros and cons.

The rush to a competitive market must be balanced with the coordination of the market as the cost of incoordination is expensive and leads to inefficiencies [20].

As the country moves away from vertical integration, structured coordination falls away, which must be replaced by market coordination amongst the various role-players. Market coordination must be implemented through stringent policy and regulatory instruments, minimising misalignment of incentives and improving the market's overall efficiency.

Market coordination is an iterative and challenging task. The integrative wheeling framework and current regulatory protocols are inadequate, leading to an uncoordinated approach to wheeling amongst municipalities.

6.0 CONCLUSION

Should wheeling be permitted under the current tariff structures, eThekwini Municipality will experience revenue shortfalls threatening its viability.

Shortfalls in revenue are caused by the use of energy-related tariff components to recover non-energy-related revenue. Therefore, any attempt to reduce or eliminate energy sales will affect the bottom line.

The current framework that enables the concept of wheeling is incapable of harmonising and integrating wheeling within the existing operational spheres. This discord leads to circular arguments that frequently lack a conclusion.

The significance of wheeling today cannot be denied, nor can the concept of wheeling. However, to reach amicable solutions, parties must find common ground and prioritise a discussion that strikes a balance between the wheeling entity's interests and the municipalities sustainability if wheeling is to gain traction in the near future. This type of discussion will contribute to the advancement of the industry as a whole.

Following the principles of a just energy transition, wheeling should neither be restricted nor ignored but instead incorporated to enable sector growth. However, transitioning from a monopolised structure to a liberalised market is neither simple nor instantaneous. Consequently, the revenue-neutral wheeling framework should be adopted immediately but adapted gradually over time as the market develops, ensuring that all parties acclimate to this process in a JUST manner.

7.0 BIBLIOGRAPHY

REVIVE

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Revive Electrical Transformers (Pty) Ltd is one of the leading manufacturers of distribution transformers in South Africa, with two manufacturing facilities in Gauteng: Steeledale and Kliprivier.

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Metaheuristics in Electricity

- OPTIMISING WITH NATURE'S INSPIRATION

Metaheuristics are powerful optimisation tools inspired by natural processes like animal behaviour and physical phenomena. Metaheuristics Optimisation Techniques attempt to mimic living organisms' behaviour and life processes. These algorithms are highly stochastic, with position update equations always containing the utilisation of random numbers, usually in the domain of zero to one.

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Nelson Mandela University

Metaheuristic algorithms are evaluated based on numerous factors. Such factors are exploration, exploitation, and rate of convergence. The convergence rate relates to how quickly an algorithm can determine the optimal solution. Exploitation is the capability of an algorithm to search a particular area in the search space precisely. Exploration indicates the ability of an algorithm to search the entire search space. A well-performing algorithm has a strong balance between exploration and exploitation. Metaheuristic Optimisation Techniques can be classified into four categories.

These are swarm intelligence, evolutionary, physics-based, and human-inspired algorithms. Of these four categories, swarm intelligence is the most applied technique to solve optimisation problems in the energy sector. Swarm intelligence mathematically models the daily behaviour of numerous animals. This article will focus on four swarm intelligence techniques.

PARTICLE SWARM OPTIMISATION

Developed in 1995 by an electrical engineer and clinical psychologist, particle swarm optimisation is the first proposed swarm intelligence technique.

The algorithm was developed based on close observation of the collective movement of schools of fish and flocks of birds. This algorithm paved the way for all other swarm intelligence algorithms. Despite its ability to converge quickly, the algorithm needs better exploration and exploitation capabilities.

GREY WOLF OPTIMIZATION ALGORITHM (GWO)

Inspired by the behaviour of the Grey Wolf, this algorithm models the pack-like behaviour of such animals. This includes the hunting and democratic behaviour of the Grey Wolf. The algorithm utilised the alpha-beta-delta hierarchy, commonly found in packs of wolves. This algorithm has strong exploitation capabilities, but poor exploration and slow convergence.

AFRICAN VULTURE OPTIMIZATION ALGORITHM (AVOA)

Mimicking the behaviour of the African Vultures, this algorithm is a recently inspired metaheuristic. The algorithm aims to mathematically model the scavenging nature, as well as the flight characteristics, of these elusive birds. The algorithm is known to strike a good balance between exploration and exploitation. However, split into five distinct phases, the algorithm is computationally intensive, often taking longer to produce an optimal result.

GORILLA TROOPS OPTIMIZER (GTO)

Inspired by the social behaviour of the silverback gorilla, gorilla troops optimiser seeks to represent the various behaviours of the large primate mathematically. The silverback gorilla shares various traits with other wild mammals, such as social hierarchy, male dominance amongst the group, and fierce rivalry for the attraction of mating

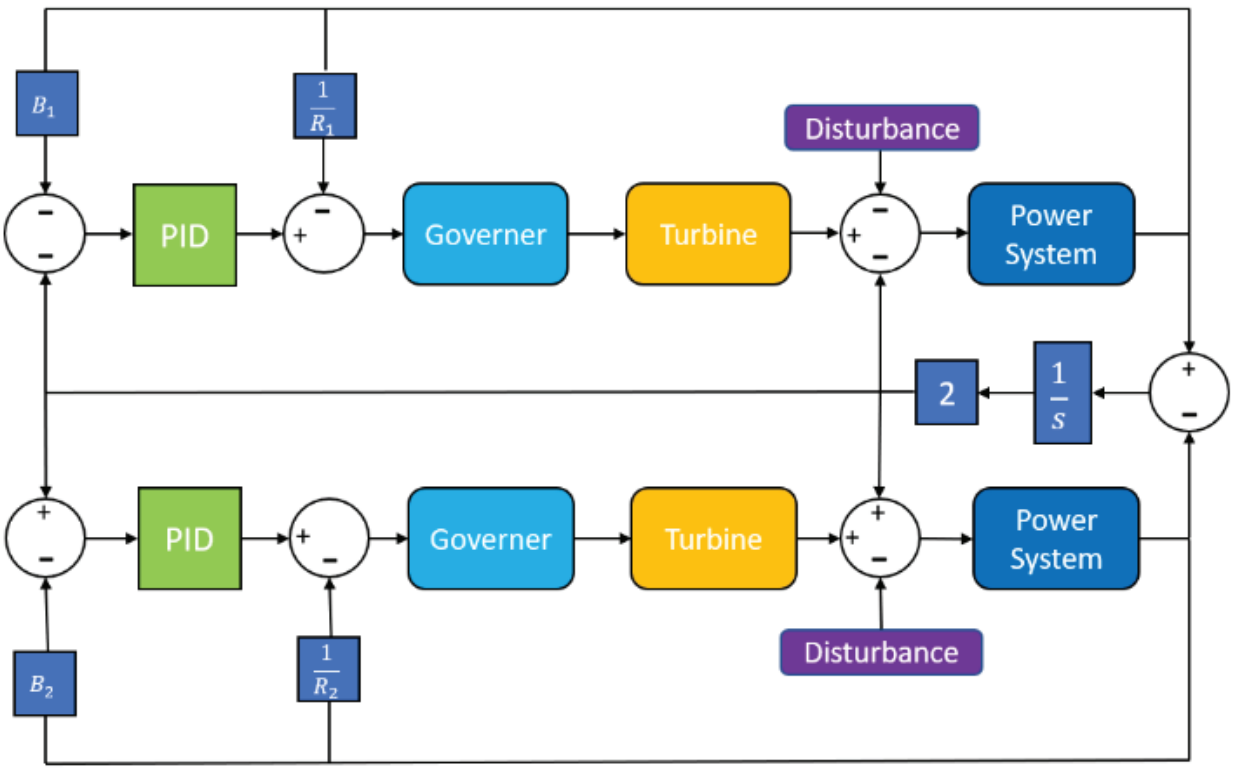

Figure 1

partners. However, silverback gorillas are highly intelligent species and share a 98% similarity with humans' genetic makeup. Although the silverback gorilla often lives in troops, a few members occasionally move to another location. This could be to find a new food source, seek new mating partners, or join other groups for better protection.

This recently inspired algorithm, therefore, attempts to model the complex behaviour of these creatures. As with the African Vulture Optimisation Algorithm, the Gorilla Troops Optimiser has a strong balance between exploration and exploitation. However, from the algorithm's structure, it is noticed that each search agent undergoes a definite dual position update. This increases the computational complexity of the algorithm.

In the realm of electricity, Metaheuristic Optimisation techniques help tackle complex optimisation problems across various stages, from planning to operation. Let's take a look at the application of these algorithms to well-known optimisation problems in electrical engineering.

The Gorilla Troops Optimiser has been recently applied to the conventional load frequency control problem. As known, sudden perturbations in load demands affect the frequency response of generating systems. It is, therefore, essential to control such systems, to ensure that transient as a result of these perturbations is minimal. Standard operating conditions are restored as quickly as possible. This type of control is usually achieved via the utilisation of the Proportional-Integral (PI) controller. While this method works well, obtaining the optimal controller gains of the PI controller takes time and effort. This may result in sub-optimal controller performance. Therefore, the Gorilla Troops Optimiser was tasked with obtaining these optimal gains. The system under study was a conventional two-area power system, as indicated by figure 1.

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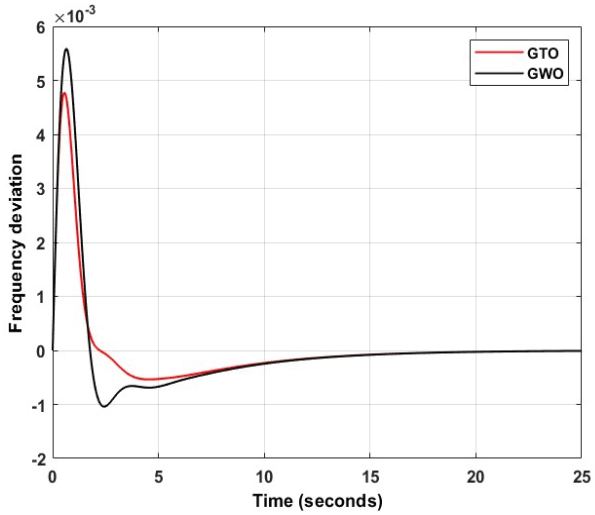

Figure 1: Area 1

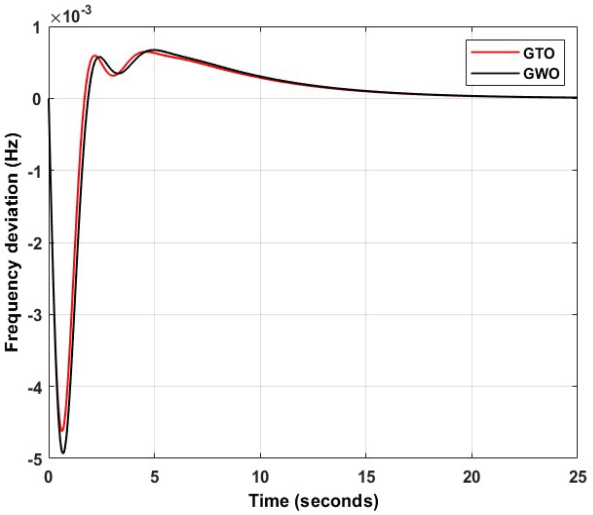

Figure 2: Area 2

Figure 2: Area 1

Figure 3: Area 2

The results were compared to PID controllers optimised via the Grey Wolf Optimiser. The results for a 15% load increase in area one and a 10% load decrease in area two are presented in Figure 2 and 3. From the results, it is evident that both algorithms are successful in achieving load frequency control. However, the Gorilla Troops Optimiser produced a superior result to the Grey Wolf Optimiser in both areas. This concerned both parameters being evaluated, which were overshoot and settling time.

Economic Load Dispatch is another well-known engineering optimisation problem. Given the non-linear cost curves of conventional generating systems, optimal dispatch of electrical energy is a complex task. A recent study evaluated the effectiveness of utilising the African Vulture Optimisation Algorithm for optimal dispatch.

The research problem considered practical aspects, such as transmission losses and the effect of valve-point loading. Further, minimum and maximum generating constraints were adhered to. The algorithm's effectiveness was compared to numerous older swarm intelligence techniques. The results for a 600 MW load demand on a six-bus system are shown in Figure4.

The tabulated results indicate the African Vulture Optimisation Algorithm's ability to produce results superior to that of other, older swarm intelligence algorithms. This was with respect to the best, worst, and average results. The stochastic nature of the algorithms, evaluated via the standard deviation, indicates the superior reliability of the results obtained by the African Vulture Optimisation Algorithm.

Further, the convergence curve suggests that despite the African Vulture Optimisation Algorithm beginning at a poorer value than others, the algorithm was quickly able to produce a superior solution.

Beyond these specific models, the broader benefits of metaheuristics in electricity include:

- Improved efficiency: Optimised grids, resource allocation, and scheduling lead to lower energy losses and reduced operational costs.
- Enhanced reliability and stability: Algorithms can help optimally place reactive power devices, ensuring a consistently reliable electricity supply.
- Integration of renewable energy: Efficient placement and management of renewable sources like solar and wind power are facilitated by metaheuristics.
- Grid modernisation: Optimising smart grid technologies and integrating distributed energy resources becomes feasible with these powerful tools.

CHALLENGES AND CONSIDERATIONS:

- Tuning: Metaheuristics often require specific parameter settings for optimal performance, which can be complex.
- Computational cost: Some algorithms can be computationally intensive and require substantial resources.

	PSO	BA	WOA	AVOA
Best	6053.4	6169.9	5292	**5288.73**
Rank	3	4	2	**1**
Worst	13900.6	13346	7967.6	**6344.7**
Rank	4	3	2	**1**
Average	8550.6	7740.6	6136.4	**5552.9**
Rank	4	3	2	**1**
Std. Dev.	2355.99	2186.7	855.4	**310.6**
Rank	4	3	2	**1**
Overall rank	4	3	2	**1**

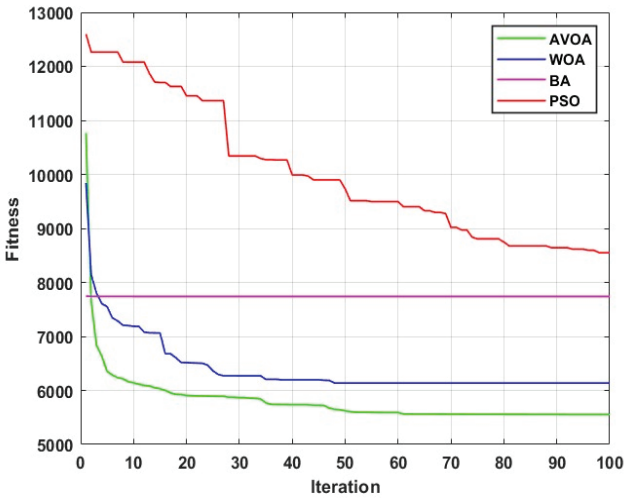

Figure 4

- Interpretation of results: Understanding the solutions generated by metaheuristics and their real-world implications is crucial for successful implementation.

Metaheuristics are revolutionising the electricity sector by providing innovative solutions to complex optimisation problems. The evolution of Metaheuristic Optimisation Techniques has resulted in better results when applied to power engineering problems. As research and development in this field continue, we can expect even more significant advancements in electrical power's efficient, reliable, and sustainable delivery.

Navigating the New Norm

- UNPACKING NIST CSF 2.0 AND ITS SIGNIFICANCE FOR SOUTH AFRICAN ORGANISATIONS

The the National Institute of Standards and Technology (NIST) released Version 2.0 of the widely used Cybersecurity Framework (CSF), its landmark guidance document for reducing cybersecurity risk. The NIST Cybersecurity Framework 2.0 has emerged not just as an update, but also as a transformative approach to securing digital assets and infrastructures.

By; Matthew Taljaard
Meenal Vala
Sibusiso Dlamini
William Stucke
SAIEE Cybersecurity Chapter

NIST RELEASES V2.0 OF CYBERSECURITY FRAMEWORK

After a decade, the National Institute of Standards and Technology (NIST) has released an update to its Cybersecurity Framework (CSF). The main updates include:

- An expanded aim of the NIST CSF is to assist critical infrastructure entities and all organisations in managing and reducing cybersecurity risks.
- Revised core guidance and a suite of new resources designed to help organisations of all types achieve their cybersecurity objectives, with a renewed focus on governance and supply chain security.
- The revised framework is designed to be helpful to organisations at any level of cybersecurity maturity and technical sophistication.

WHAT IS THE NIST CSF?

The National Institute of Standards and Technology (NIST) is an agency within the U.S. Department of Commerce. It focuses on:

- Establishing standards and measurements to ensure consistency and quality across various industries;
- Developing new technologies that pave the way for innovative products and processes; and
- Providing cybersecurity guidance to a wide range of industries and organisations.

WHAT MADE IT SO POPULAR?

Since its release in 2014, the NIST CSF version 1 has gained widespread popularity for several key reasons:

Enhanced Cybersecurity Posture: The framework provides comprehensive guidelines and best practices that help organisations improve their ability to prevent, detect, and respond to cybersecurity incidents. By following the CSF, organisations can strengthen their defences against cyber threats.

Improved Risk Management: CSF emphasises risk management, allowing organisations to identify, assess, and manage cybersecurity risks more effectively. This systematic approach helps prioritise resources and efforts to areas of greatest need, reducing potential vulnerabilities.

Greater Compliance: Compliance with legal and regulatory requirements is crucial for many organisations, especially those in regulated industries. CSF aligns with various compliance frameworks, making it easier for organisations to meet compliance obligations while enhancing security measures.

Customisation and Flexibility: The framework is designed to be adaptable to organisations of all sizes and types across various industries. This flexibility allows entities to tailor the guidelines to their specific operational environments and risk profiles, making the framework broadly applicable and effective.

Steps for creating and using a CSF Organisational Profile.
© Image courtesy of NIST.

Strategic Resource Allocation: By providing a clear understanding of an organisation's current cybersecurity posture and the areas that need improvement, CSF helps in making informed decisions about where to allocate resources most effectively to mitigate risks.

Improved Incident Response: CSF provides clear guidelines on response strategies to help organisations plan and prepare for potential cybersecurity incidents. This preparation improves the speed and efficiency of an organisation's response to incidents, minimising potential damage and recovery time.

Enhanced Communication and Collaboration: The framework encourages improved communication between internal stakeholders and external partners regarding cybersecurity risks and defences. This enhanced communication helps align strategies and actions across the organisation and with external parties such as suppliers, customers, and regulatory bodies.

Long-Term Resilience: By continually updating and refining cybersecurity practices in line with CSF, organisations can build long-term resilience against evolving cyber threats. This ongoing improvement process helps sustain business operations and protect organisational assets over time.

Cost Efficiency: By providing a structured approach to cybersecurity, CSF can help organisations avoid unnecessary expenditures on security measures that may not align with their specific risks or needs. This targeted approach can lead to more efficient use of financial and human resources. Organisations seeking cybersecurity insurance can use their cybersecurity framework to reduce their ever-increasing premiums.

Competitive Advantage: Organisations demonstrating robust cybersecurity measures aligned with CSF can enhance their reputation with customers, partners, and stakeholders. This can provide a competitive advantage as clients increasingly prioritise security in their decision-making processes.

Accessibility: The NIST CSF is freely available, removing any cost barriers to adoption. This has made it particularly attractive to smaller organisations or those with limited cybersecurity resources. It also helps businesses meet various compliance requirements, saving time and effort and provides a clear roadmap for improving cybersecurity posture without being overly prescriptive.

HOW CAN SOUTH AFRICAN ORGANISATIONS MOVE FORWARD WITH THE NIST CSF 2.0?

Organisations can effectively move forward with the NIST Cybersecurity Framework (CSF) 2.0 by taking a structured approach to implementation and integration within their existing cybersecurity practices. Here are some steps to guide this process:

Understand the Framework: Start by gaining a comprehensive understanding of the framework's core components—the Govern, Identify, Protect, Detect, Respond, and Recover functions—and how they have been updated in CSF 2.0. Familiarise yourself with any new domains or revised guidelines.

Assess Current Cybersecurity Posture: Conduct a thorough assessment of the organisation's current cybersecurity measures and policies. This baseline assessment will help identify gaps between existing practices and the recommendations of CSF 2.0.

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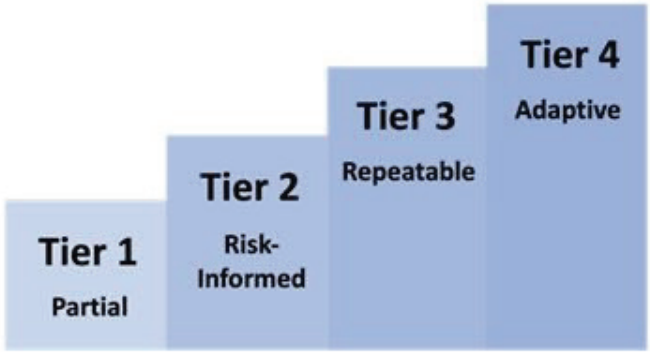

CSF Tiers for cybersecurity risk governance and management. © Image NIST.

Set Clear Objectives: Define specific cybersecurity goals that align with the organisation's overall business objectives and the capabilities outlined in CSF 2.0. This might involve enhancing data protection, improving incident response, or strengthening system resilience.

Customise the Framework to Fit the Organisation: Tailor the CSF 2.0 to fit the organisation's specific needs, size, and complexity. This customisation should consider the organisation's industry sector, regulatory requirements, and risk environment.

Develop a Roadmap for Implementation: Create a strategic plan that outlines the steps to achieve the set cybersecurity goals. This plan should include timelines, resource allocations, and clearly defined responsibilities.

Train and Educate Staff: Ensure all employees understand their roles in maintaining and improving cybersecurity per CSF 2.0. Regular training and awareness campaigns can embed cybersecurity into the organisational culture.

Implement the Changes: Start integrating the CSF 2.0 recommendations into the organisation's cybersecurity practices. This could involve updating policies, deploying new technologies, and enhancing processes.

Monitor and Review: Continuously monitor the effectiveness of the implemented changes and adjust as necessary. Regular reviews against the CSF 2.0 will help identify areas for improvement and ensure the organisation remains aligned with best practices.

Engage with External Partners: Collaborate with industry peers, security experts, and regulatory bodies to stay updated on emerging threats and evolving best practices. Such engagement can provide insights and support to enhance the organisation's cybersecurity efforts further.

Report and Communicate Progress: Keep all stakeholders informed about the progress in implementing CSF 2.0. Regular reporting will not only ensure transparency but also help in building trust and accountability within the organisation.

WHAT RESOURCES ARE AVAILABLE FROM NIST CSF 2.0?

Framework Document: The core NIST CSF document outlines its structure, functions, categories, and subcategories. It explains the implementation tiers and profiles, which help organisations measure their cybersecurity maturity and tailor the framework to their specific needs.

Implementation Guidance: NIST provides detailed guidance, known as the Quick Start Guide (QSG), on implementing the CSF in an organisation. This includes step-by-step instructions, best practices, and examples of how other organisations have successfully adopted the framework.

Reference Materials: NIST offers a set of reference materials that include terminology, methodologies, and the rationale behind the framework's structure and elements. These materials help users understand the foundational concepts and methods used in the framework.

Self-Assessment Tools: To aid organisations in assessing their cybersecurity posture, NIST provides templates and checklists. These tools can evaluate how well current cybersecurity measures align with the framework's guidelines.

Training and Workshops: NIST collaborates with various educational and industry partners to offer training sessions and workshops. These programs are designed to help stakeholders from different sectors understand and implement the CSF effectively.

Case Studies: To illustrate practical applications of the framework, NIST publishes case studies detailing how various organisations—from small businesses to large corporations—have implemented the CSF. These case studies provide real-world insights and best practices.

Cybersecurity Measurement Guide: This guide helps organisations measure their cybersecurity performance, which is crucial for continuous improvement. The guide provides metrics and methodologies for assessing the effectiveness of cybersecurity measures.

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SCAN QR CODE

Could Artificial Intelligence have prevented the Three Mile island (TMI-2) Accident?

Artificial Intelligence (AI) can be essential in safety and reliability engineering, especially in large industrial installations. It can monitor control systems in real-time and promptly advise operators of appropriate actions. There is little doubt that the Three Mile Accident in the United States in 1979 could have been avoided.

By: Fred Catlow (FSAIEE)

The accident was a simple one of a stuck open pilot-operated relief valve (PORV), which could have been identified before any severe consequences occurred. As it was, even though the design of the plant had effectively contained radioactive gases and nothing of consequence was released to the atmosphere, therefore no one suffered from radiation release, and the result was catastrophic. The reactor was destroyed, but worse than that, public confidence was badly shaken, more than 100 orders for new nuclear plants were cancelled, and no new plants were built in the USA for 30 years.

HISTORICAL

In the 1960s and early 70s, the only help that operators had to determine abnormal conditions was one or more pen recorders, known as sequence of event recorders, which were connected to monitor selected plant parameters.

These were only sometimes operating as they depended on an adequate chart paper and ink supply. The paper had to be installed correctly and run smoothly through the recorder. After an incident, the chart recorders could be examined to ascertain the problem. The introduction of plant monitoring computers in the control room improved incident analysis, which was enhanced further after incorporating the recommendations of the TMI-2 post-accident reports and upgrading the control room computer into a critical function monitor display (CFM).

THREE MILE ACCIDENT[ii]

The power station at Three Mile Island, Londonderry Township, Harrisburg, Pennsylvania, is powered by two pressurised water reactors (PWR) iii, which provide heat to produce the steam to drive steam turbines and hence the alternators to generate electricity. The net nameplate capacity (design rating) of unit 1 is 819MWe, and unit 2 is 906MWe[iv]. As the name, pressurised water reactor, implies, the reactor is cooled by pressurised water, that is, ordinary distilled water under pressure so that the boiling point is changed from the normal 212°F (100°C) to approximately 653°F (345°C).

The plant had three cooling loops, each comprising a 'hot leg' of water from the reactor, a heat exchanger ('steam generator') and a 'cold leg' which returns water to the reactor. An essential part of the plant is the pressuriser, located in one. This primary coolant loop regulates the pressure at approximately 2200 psi (152 bar or 15MPa) and prevents the water from the hot leg at 575°F (302°C) from boiling. A gas bubble at the top of the pressuriser is controlled to achieve this. If the bubble is lost and the reactor becomes 'water solid, ' control is lost, and the reactor must be temporarily shut down until control can be re-established.

To avoid over-pressurising the system, a pilot-operated relief valve is fitted to the top of the pressuriser. If the pressure exceeds the design value, the valve

opens, and when the pressure drops back to normal, it re-sets automatically. If it sticks open, the system will depressurise, and the hot water will flash into steam, forming steam bubbles which prevent the reactor from operating correctly and cause overheating. This is known as a Loss of Coolant Accident (LOCA) and can lead to the reactor boiling dry and, in the worst case, the reactor core melting (just as a domestic kettle on a naked flame would melt if it boiled dry). One of the recurrent problems in the plant is this pilot-operated relief valve (PORV). I need to find out whether this was unique to B&W plants or all PWR.

Because of the problems, modifications to the plant were required as follows:

1) instrumentation was provided to detect coolant leakage downstream from the pressuriser.
2) A remotely operated block valve, 9, was installed between the PORV and the pressuriser. If the PORV fails to close, it can be closed from the control room.
3) A further addition was the provision of an indicator light to show the valve's state. Unfortunately, this light does not show the valve's state as intended, but only that power has been applied to the activating solenoid.

The TMI-2 accident was the worst that had happened to a commercial reactor in the United States of America, USA. It was the first major upset on a 'Westinghouse type' pressurised water reactor (PWR). Still, whilst the basic principle was the same, the actual implementation of the design was completely different as it was a Babcock & Wilcox (B &W) adaptation, which had a less forgiving 'once through' cooling system. It also seems to have had many minor problems, which the supplier should have resolved, as it led the operators to ignore essential events that affected the safe running of the plant. Although this unit had performed reasonably well in the three months since it started commercial at the end of December 1978, it had had numerous problems during the previous nine months since the reactor first went 'critical' (started up), which had not been satisfactorily resolved.

The accident is characterised by some of the statements and observations that stemmed from investigations and rumours of the events but, moreover, by the catastrophic effect it had on the public and the nuclear industry. A not-unusual turbine trip developed into a significant incident; no one was killed or injured, but it was the prospect of what might have been that worried people. This was exacerbated by a science fiction 'blockbuster' movie deliberately intended to shock and frighten people, which was being shown on public release then. The movie "The China Syndrome" was initially launched at the Cannes Film Festival in May 1979 and released for showing to the general public later that year. The actual accident followed a similar scenario to the movie, and it is likely that fantasy replaced reality in many people's minds.

Following the accident, public confidence in nuclear power was shaken (precisely what the film intended to do, but with a success they could hardly have imagined in their wildest dreams). Over a hundred orders for new power stations were cancelled. It devastated the US Nuclear Industry, and no new power stations were built for 30 years. However, as they say, "Every dark cloud has a silver lining", and post-accident improvements, which were more precise and less vague, were made, including improved control room layout, more exact and discriminating plant monitoring, more precise operating and training manuals; better operator training on plant simulators, using accident scenarios, which resulted in vastly improved operator and hence plant performance with fewer outages and plant capacity factors rose from the sixties to about 90% or better in 2022. It is common now for many plants to achieve 99+%. The owners of nuclear plants also fought against the prospect of plant closures due to age, and rather than decommissioning them after their 40-year life at great expense with no return, they applied to extend their licences for 20 years. Sixty years of life is now common for all nuclear plants. In some cases, extensions were requested for 80 years, doubling plant life, using resources better, and making nuclear much more cost-effective.

Early on the 28th of March, 1979, alarms began to sound in the unit 2 control room. It was the beginning of what could have been a severe accident. Hundreds of alarms were going off simultaneously, sending the operators into 'panic mode' as they didn't know how to turn and didn't have a cohesive plan. As it

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happened, the training the operators had received led them to take all the wrong actions and, consequently, made the situation very much worse. After the accident a commission was set up by President Carter known as the Kemeny Commission.[v]

SEQUENCE OF EVENTS

The following description has been taken from Wikipedia, "Three Mile Island Accident", but is mainly a summarised version of OSTI. GOV[vi]; "Technical Report; Three Mile Island: a report to the commissioners and to the public, Volume 1" highlighting the important events that took place. The seeds of the accident were sown by a minor problem, a blocked pipe in a subsidiary system, 'the condensate polishing plant', associated with the secondary cooling circuit. Two auxiliary operators battled for 11 hours to remove the blockage. Unfortunately, this inadvertently led to a mischance on a turbine trip.

There were two control room operators, Craig & Edward Frederick; the shift supervisor of both units, Bill, and a senior plant operator, Fred, on watch on the night shift of 27th - 28th March 1979. They made their final adjustments as they approached the second half of the shift.

Ed Frederick added more water to the primary reactor coolant system, diluting the amount of boron in the system to compensate for leakage occurring through one of the relief valves. (Any persistent leakage through one of these valves will tend to raise the concentration of boron, which will inhibit the chain reaction, which is also known as a 'chemical shim')

- 04:00 28th March 1979; an alarm sounded in the control room of unit 2, and almost simultaneously, several alarms and annunciators were activated. The operators appeared to need help with what to do and how to respond. Operator Craig recalled taking instrument readings showing temperatures downstream of the relief valve to be well above the allowable maximum temperature, indicating that the upstream block valve should be closed. This was evidence of a leaking valve.
- Bill, the Shift Supervisor, was alerted by this alarm, a 'trip' (automatic shutdown) of the main feed pumps. After this, a water hammer occurred on the main pipes of the turbine in the Conventional2 Island, the main turbine steam stop valves closed, and the turbine tripped. Bill announced over the public address system that the turbine had tripped.
- Following the turbine trip, water in the nuclear reactor primary coolant system heated & expanded quickly since the (turbine) heat sink had been lost. The coolant pressure rose to 2,255 psi (155.5 bar), and the pressuriser relief valve (PORV) was opened correctly to relieve the pressure by diverting water to the reactor coolant drain tank (RCDT). As pressure continued to rise to 2,355 psi (162.5 bar), the reactor protection system (RPS) was activated to 'scram' (by automatically dropping the shutdown rods into the reactor core) the reactor 8 seconds after the turbine trip.
- Once down, the reactor continued to put out fractional power due to decay heat energy released by the continued intense radiation from the fuel. However, the heat-removing function of the steam generator overtook the reactor's reduced heat output; the coolant water cooled and 'shrinks', lowering system pressure. The PORV should have automatically shut but failed.
- The relief valve was stuck in the open position as the reactor system pressure dropped. Steam rushed out through the stuck-open valve at a rate of some 110,000 pounds per hour (67,500 litres per hour) (equivalent to loss of some 220 gallons of water per minute = 836 litres per minute), which it continued to do for more than 2 hours before the operators realised that the valve had failed to shut and had possibly been misled by the indicator light that showed that the valve was closed when in fact it was still open.
- The stuck-open valve further depressurised the coolant system. Most of this took place within 12 seconds of the first alarm. After about 2 minutes, coolant system pressure dropped 25% from a normal 2155 pounds per square inch (148.6 bar) to 1640 psi (113 bar).
- As the reactor coolant system pressure continued to drop and fell below 1640 psi (113 bar), the high-pressure injection (HPI) pumps started automatically replenishing the coolant loop's water inventory from the borated water storage tank (BWST) at a rate approaching 1000 gallons a minute (4550 lpm), aiming to ensure that the reactor core remained covered with water. *[Note: The actuation of the high-pressure injection system is a sign that a LOCA is taking place and is one of the engineered safety features recommended by NRC 10-CFR-50 "Domestic Licensing of Production and Utilization Facilities". Its compliance is a condition of plant licensing, and in my opinion, interference by plant operators is contravening the conditions of plant licence. However, the TMI-2*

operators experienced HPI pump starts on several occasions when there was a loss of feedwater flow or when the reactor scrammed; a most undesirable feature of the B & W reactor design is that it tends to mix up "normal" and "emergency" reactions by the automatic systems. I believe the plant should not have been operating until these problems were resolved.]

- As the situation worsened, the operators continued to believe that the PORV had closed, were misled by the indicator light and trusted this false information in preference to a great deal of consistent information from elsewhere that a LOCA was taking place.
- The pressurised water level indicator is a more important factor contributing to the operators' failure to recognise that a LOCA was in progress. Their training on this particular equipment has taught the operators that the only credible check on the amount of coolant in the system is the indicator showing the water level in the pressuriser. (In this Babcock & Wilcox reactor, there is no instrument for measuring the water depth around the fuel rods.)
- If the pressuriser level remains high, the operators are not trained to anticipate that coolant water may leak out of the primary system. Indeed, the operator training at B&W tells these men that the condition to avoid at all costs is 'going solid,' permitting the pressuriser to fill with water and thus losing the ability to regulate system pressure through controlling the pressurised steam bubble.
- The training and the written emergency procedures of the operators never postulated a LOCA through the top of the pressuriser itself, as it happened. With the relief valve stuck open, the steam bubble would collapse. Low system pressure is a sign of a LOCA. However, the pressurised water level indicator increased because the system had reached 'saturation', causing coolant to boil and form steam pockets 'voids' at high points. The expansion of these 'voids' continued to force coolant water up into the pressuriser, which was no longer regulating pressure but acting as a conduit for coolant to escape from the primary system through the stuck-open valve into the 'reactor coolant drain tank' in the containment building.
- The operators showed little understanding of how the plant works and failed to use common sense logic about the measurements that they were receiving. They were convinced that the system must be going solid since the coolant level was rising. Because of this, instead of asking why the HPI pumps had started, they made the fatal error of overriding an emergency system!
- 04:05: At Bill's direction, Operator Ed Frederick shut down one HPI pump and throttled back the other one from a maximum of 400 gallons per minute (gpm) (1820 pm) to about half that flow. Not only does he throttle HPI, but Frederick also lifts the plug at the bottom of the reactor coolant system to maximise 'letdown' through the usual 'makeup and letdown system' that (like a swimming pool filtration system) constantly works to purify the primary reactor coolant water.
- The effect of these two actions was to reduce the amount of water added to the system to a trickle. This miserly flow rate, perhaps 25 gpm (114 lpm), continued for the better part of 3 hours and was more than offset by the amount of coolant lost every minute through the stuck-open PORV.
- 04:08: Ken Bryan from Unit 1 noted on entering the control room that emergency feedwater No. 24, known in operator parlance as 'the 12's,' was closed.
- Craig also noticed that the control panel lights for both 12s indicated "closed." Supervisor Bill instructed them to be opened. *[When closed, these valves prevent emergency water supply to the steam generators, which at that point have lost regular feedwater flow, which is needed for cooldown].*
- The 8-minute delay in restoring emergency flow did not directly affect the accident's outcome-though it did divert the operator's attention. During the ensuing 3 hours, Shift Supervisor Bill dismissed two warnings from a temperature instrument showing relief valve discharge temperatures about 100 degrees (38°C) (Bill later testifies that he had seen higher readings than these under reasonably normal circumstances and that he felt that if the relief valve were stuck open, readings would have been much higher-over 300°F3).[viii]
- 4:14: with the accident sequence barely settling in, there were other conspicuous clues that the relief valve was still open. Continued discharge of coolant into the reactor coolant drain tank from the stuck-open relief valve caused the pressure to increase. When the pressure reached 192 psi (13.2 bar = 13,200 kPa), the rupture disc at the top of the tank burst.
- 04:20: Bill noted this but again misinterpreted it. With the rupture disc open, coolant from the stuck-

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open valve escaped to the reactor coolant drain tank, overflowing onto the reactor containment building floor.

- 04:38: an auxiliary building operator reported that the automatic containment sump (floor drain) pumps were transferring water into the auxiliary building. Bill and Frederick agree to turn off the sump pumps.
- 05:00: the temperature inside the containment building had risen from 120°F (49°C) to 170°F (76.7°C), and building pressure had increased from 0 to 2.5 psi (0.17 bar = 17 kPa), another sign that the PORV was stuck open.
- There were non-essential people in the control room, which I believe was unnecessary as they were distracting the operator's[ix]
- 05:13: the operators noticed severe vibrations in the two 'B' loop pumps and turned them off to avoid damage. The water circulated until vibrations in the other 'A' loop pair became severe.
- 05:41: the 'A' loop pumps were shut down. While the pumps ran, a mixture of steam and water was being pumped through the core, keeping it cool, but as soon as they were stopped, the flow ceased. The steam and water were separating, with the steam rising to the upper part of the reactor system.
- The operators did not know how much steam the system contained. Since the pressuriser level indicator was still high, they believed that it was nearly full of water and were hoping that a process called "natural circulation" (convection flow of hot and cold water around the system) would cool the core.
- However, with all that steam in the system, no natural circulating flow could occur, and the system stagnated. Severe core damage was to begin during the next half-hour. With no flow, the hot core boiled away the water, making more steam and gradually dropping the water level until the 12 ft (3.66m) fuel bundles were more than half uncovered.
- 06:00: Station manager Gary Miller called a conference from home to discuss the situation with John Herbein, Metropolitan Edison's vice president and previous TMI station manager. On the line was George Kunder from the control room, Leland Rogers, who had been site manager for B&W here at TMI since 1972 and, at the time, directed B&W's technical support personnel at the site. Like Miller, Kunder quickly briefs the other three on general plant status, including the plunge in system pressure levels from an initial surge at 2500 psi (172 bar) down to 700 psi (48 bar) (by this time, it had dropped as low as 6254). He also told them that the coolant pumps had to be turned off to avoid damage from excessive vibration. Lee Rogers asked, "Is the pressuriser block valve closed?" Kunder replied that he didn't know and would check. A few seconds later, Rogers reported, "Yes, the block valve is closed." No one asked him the follow-up question, "When was the block valve closed?" The answer was that it had just been closed.
- Brian Mehler, who came on to relieve Bill as shift supervisor for the next period, was credited with the day's first major correct move. Mehler checked the reactor coolant instruments and concluded that there was a steam bubble in the "hot legs" of the coolant loop. With the low coolant system pressure, there must be a bubble somewhere else, expanding and forcing water into the pressuriser. "I went to the computer," he later testified, "and punched out the temperatures on both the [safety] valves and the Electromatic relief valves." Based on readings showing the relief valve discharge line some 30 degrees hotter than the safety valve discharge lines,
- Mehler dismissed the pressuriser level reading and moves concluded, "The PORV is leaking." Mehler ordered the PORV block valve closed. Mehler made the right decision just 20 minutes after coming on shift.
- Armed with this intelligence, any of the four men could be expected to reason that, with the pressuriser relief valve stuck open for more than 2 hours, a loss of coolant accident had been in progress and full operation of the HPI system was critical.
- Instead, never having asked the second question, all will grope in bewilderment for another whole day before the truth strikes. Much later, long after the accident had run its course, there was an extensive technical analysis of the accident, including the study of events that did not actually happen that fateful day at TMI.[x]
- Perhaps the most interesting of these alternative sequences is the one that responds to the question, "What if the PORV block valve hadn't been closed at 06:18?" If the valve had remained open and the TMI operators had done nothing, water and steam would have continued escaping from the PORV, lowering the water level around the core further. With less water in the lower part of the core, there would have

been less boiling and less upward flow of steam cooling the fuel rods, leading to higher temperatures in the upper part of the core.

AFTERMATH

FROM THE REPORT:

"Eventually, the upper portions of the core started to melt, liquefying the fuel. Starting at the top of the fuel bundles (the hottest part), this melting would have proceeded to about the middle of the core. Engineering calculations done for the Special Inquiry Group show that within 30 to 60 minutes, a substantial portion of the fuel is certainly in the centre of the top half of the core, and perhaps as much as half of all the fuel would have melted. NRC experts believe that portions of the liquefied fuel would probably have fallen into the water pool below, making more steam that could have reversed the meltdown. Whether or not this reversal occurred depends in part on how long beyond 06:18 the block valve would have stayed open. Nevertheless, an eventual full-core meltdown probably would have occurred, especially if one assumes that the operators cut off all water being pumped into the core. This meltdown might have stopped or proceeded until the molten fuel had ruptured the bottom of the steel reactor vessel and dropped onto the basement of the reactor building. Any analysis of how far it could have gone, or whether the reactor building would have held it, is speculative and depends on complex analysis with many necessary assumptions. One thing the analyses do seem to agree on, though, is that even with a core meltdown, there is only a small probability that the consequences of TMI would have been catastrophic to public health and safety. The most likely probability is that the reactor building would have survived in this accident scenario, and the vast majority of the radioactive material released from the fuel would have been retained within the building, not released to the surrounding environment."

ANALYSIS OF TMI-2 FAILURES

After the accident, there was extensive analysis of the sequence of events that ensued and what could have occurred if the plant had been configured differently or if the operators had reacted differently. This led ultimately to the development of various 'accident scenarios', which could later be incorporated into plant simulator computers, which would be used to benefit operator training. The application of artificial intelligence could further enhance this support.[xi]

It was clear that a LOCA had taken place. The root cause of this was a PORV that failed to close, causing the RCS to depressurise and, hence, the coolant water to escape and flash into steam, resulting in the absence of core cooling, to permanent damage to the reactor so that the unit was a 'write off.' All the different events that took place illustrated the progress of the accident. Artificial intelligence can help to identify faulty components. [xii]

In the 1950s, reliability engineers working for the US Armed Forces developed a Failure Modes and Effects Analysis (FMEA) programme to study problems that might arise from malfunctions of military systems. These techniques were developed and used by other industries, including the nuclear, space, airline, automotive industry, etc. The methods were mainly for testing component failures and would have been appropriate for the accident at TMI-2. The technique was also used for criticality analysis FMECA, which would have been very apt in this circumstance. A Military Standard document, MIL-STD-1629, was issued in 1949 and re-issued in 1980. Artificial Intelligence has been used to enhance these techniques further. [xiii]

Whilst FMECA techniques were mainly used to establish the reliability and criticality of components, Bell laboratories developed a programme in the 1960s known as Fault Tree Analysis for following failures of entire systems. Both FME(C)Axiv and FTA are used extensively in Safety and Reliability Engineering and Quality Assurance in the design, manufacturing and operation of complex systems. Both can be incorporated into plant simulators for engineers and operators.xv Since these techniques are incorporated in the computer software, they can also be used for Artificial Intelligence (AI), which can be incorporated into the plant computer, giving not only a 'real' time assessment of the plant operations but also a 'learning' feature which can be unique to each plant.

In the author's opinion, such inclusion would greatly improve plant performance and would have prevented the TMI-2 reactor from being damaged, as timely actions could have prevented this from becoming a reality.

CONCLUSION

AI could be built into all nuclear plant operating computers, ensuring greater safety and reliability. It would be an additional expense for the owners, but as more plants use the technique, one would assume that the cost will decrease. It could be used to identify potential problems before they develop into plant failures, especially concerning plant maintenance.[xvi]

REFERENCES wn

MEMBERSHIP FEES EFFECTIVE 1 DECEMBER 2023

The Council meeting held on 1 September 2023 approved subscription & entrance fees as from 01 December 2023 as per schedule indicated below.

PLEASE NOTE: In terms of Bylaw 3.2 annual subscriptions are due on 1st December 2023

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Council agreed to a discount for fees paid before 31 March 2024. Members are therefore encouraged to pay promptly to minimize increase impact.

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Student	173	150	208	180	208	180
After 6 yrs study	1 800	1 565	2 160	1 878	2 160	1 878
Associate	1 800	1 565	2 160	1 878	2 160	1 878
Member	1 989	1 730	2 387	2 076	2 387	2 076
after 6 years	2 325	2 021	2 789	2 426	2 789	2 426
after 10 years	2 433	2 116	2 919	2 539	2 919	2 539
Senior Member	2 433	2 116	2 919	2 539	2 919	2 539
after 6yrs/age 40	2 637	2 293	3 164	2 751	3 164	2 751
Fellow	2 637	2 293	3 164	2 751	3 164	2 751
Retired Member (By-law B3.7.1)	1 118	972	1 342	1 167	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 R3337.00 which includes an entrance fee of R950.00. On election to the applicable grade of membership the new member's account will be adjusted accordingly and refunds/additional payment made on request. Entrance fee for Students is free and new Student applicants require payment of R208.00.

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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".

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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 2024.

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MAY 2024

07/05/2024	Hack Lab
08/05/2024	SANS 10142-1 Edition 3
08/05/2024	Pumped Storage Developments in China
15/05/2024	Fundamentals of Financial Evaluation for Projects
15/05/2024	ECSA Road to Registration webinar
16/05/2024	Writing Good Technical Specification
18/05/2024	Biomedical Chapter webinar
20/05/2024	Cable Jointing, Termination and Testing
21/05/2024	An Intro to Artificial Intelligence for Professionals
22/05/2024	Planning Feasibility Studies in IR 4.0: An Engineer's Perspective
22/05/2024	Nuclear Chapter webinar
23/05/2024	Rotating Machine Section webinar
28/05/2024	Technical Report Writing

JUNE 2024

05/06/2024	ARC Flash
06/06/2024	Photovoltaic Solar Systems
11/06/2024	Fundamentals of Medium Voltage Protection
11/06/2024	Design of Economical Earthing Systems for Utility Installations
19/06/2024	Operating Regulations For HV/MV Systems - ORHVS
25/06/2025	Project Management For Engineers

SAIEE Sections, Chapter & Centre Events

SAIEE Academy Online Training

SAIEE Academy Classroom Training

SAIEE TELEVISION

View past events & webinars on SAIEE TV here.


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