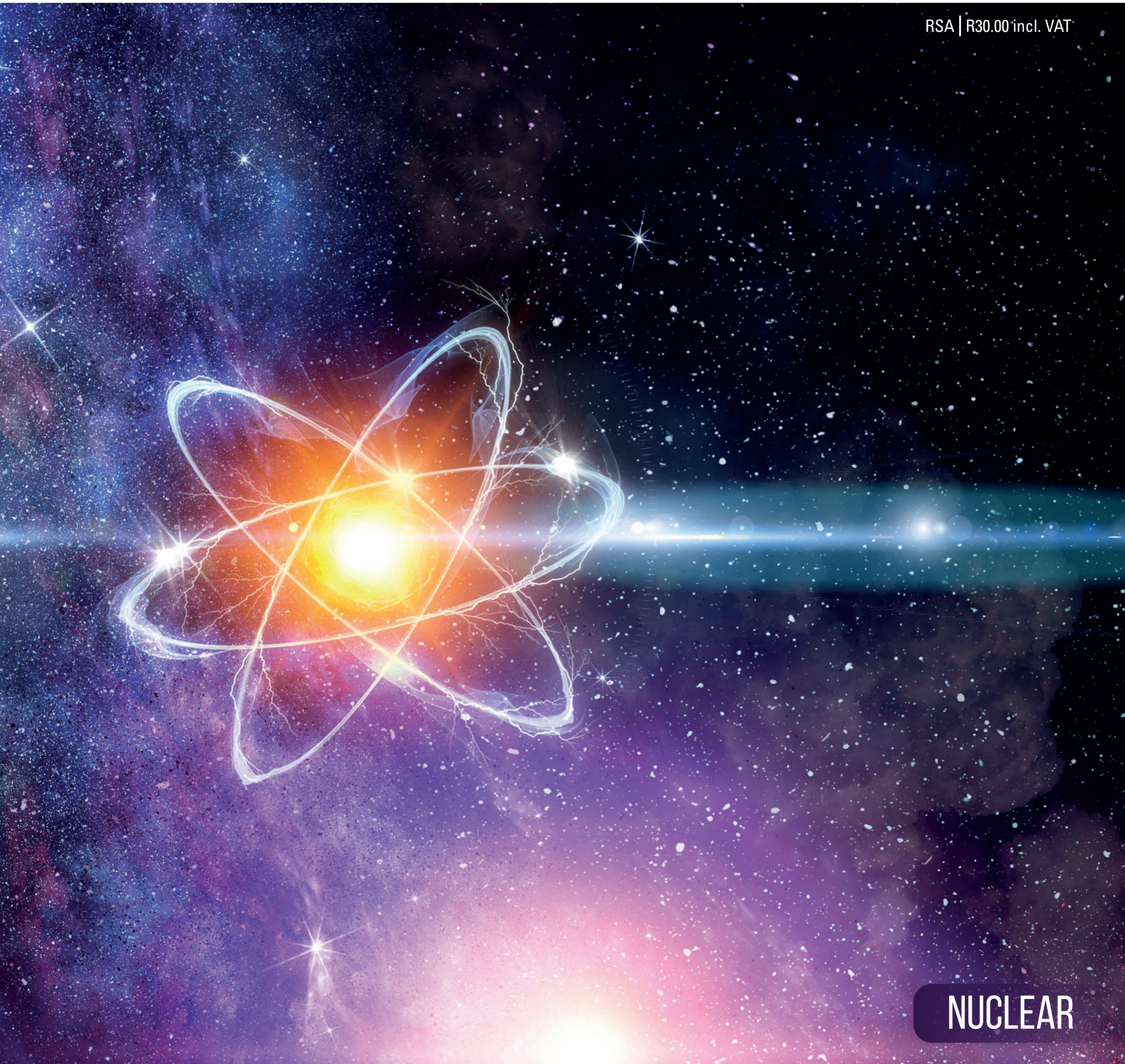
wattnow

POSSIBILITIES OF THE 5TH INDUSTRIAL REVOLUTION



SAIEE THE OFFICIAL PUBLICATION OF THE SOUTH AFRICAN INSTITUTE OF ELECTRICAL ENGINEERS | JANUARY 2021

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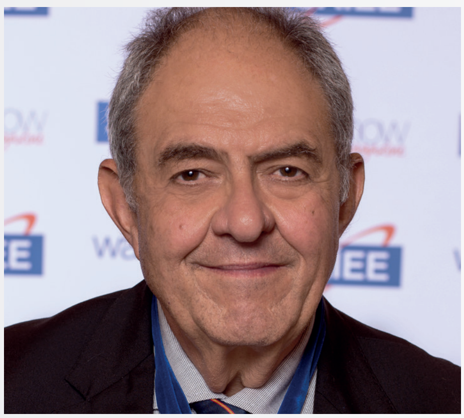

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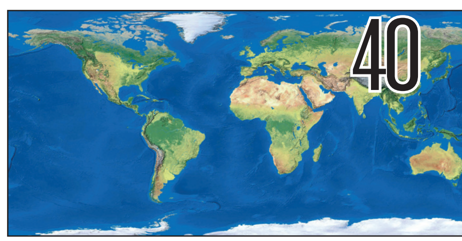

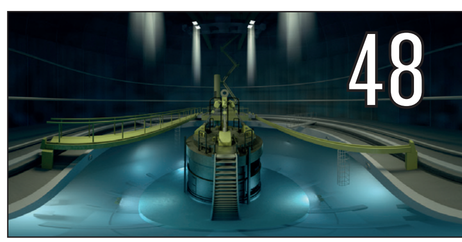

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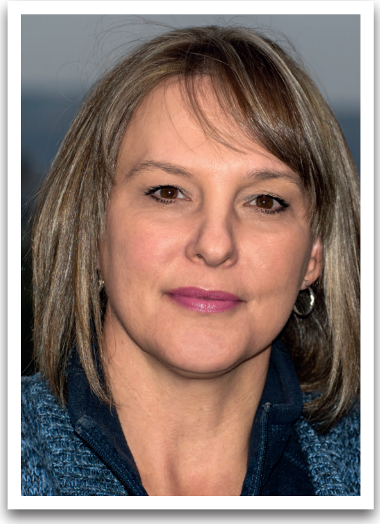


Welcome to January 2021. Trust that you had a relaxing break and are bright-eyed and bushy-tailed to start this year with a bang.

This issue of **watt**now focuses on Nuclear Technologies.

During November 2020, the National Energy Regulator of South Africa (Nersa) invited comment on government's plans to add 2,500MW in nuclear power to South Africa's electricity mix by 2030.

Currently, Africa's only nuclear station, Koeberg, which has been running since 1984, delivers only 1,940MW – around 3.6% of South Africa's electricity output. The government wants to increase nuclear to represent 5.6% of power production.

So, firstly, I will introduce the SAIEE Nuclear Chapter, their purpose and various Study Committees. Read more on page 24.

On page 40, find an article that paints the latest picture of Nuclear Power in the World today. Over 50 countries utilise nuclear energy in about 220 research reactors. In addition to research, these reactors are used to produce medical and industrial isotopes and training.

Our last feature article, "Advanced Nuclear Power Reactors" explains the improved designs of nuclear power reactors, which are continually being developed internationally. The first so-called Generation III advanced reactors have been operating in Japan since 1996. These have now evolved further. Find it on page 48.

The next issue of wattnow features Mining, and the deadline is 8 January 2021. Please send your contributions to minx@saiee.org.za.

Herewith the January issue - enjoy the read!

Minx


IEC 61850
TRANSDUCER
XRIO
IEEE
CALIBRATION
PTL
8,7 KG
COMTRADE
PROTECTION
ACCURACY
METER TESTING
CONTROL INTERFACE
ANALOG BINARY INPUT
DC INPUT
VOLTAGE OUTPUT
CURRENT OUTPUT
AUX DC OUTPUT
BINARY OUTPUT
PC
USB
EXTERNAL INTERFACE
EXPANSION PORTS
CMC 430
OMICRON
POWER

Dear Valuable SAIEE member,

SAIEE CHARGE REWARD PROGRAMME

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

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

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

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

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

Yours faithfully,

Leanetse Matutoane
Operations Manager

CHARGE REWARD PROGRAMME

MEMBER LOYALTY

We appreciate our Member's support for 110 years

REWARD

A unique reward programme exclusive to SAIEE Members

FEEDBACK

We received your feedback and we listened to added benefits

LOYALTY CARD

Earn Charge Rewards by attending events, courses or writing articles

SATISFACTION

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

LOYALTY PROGRAM

Redeem your Charge Points towards CPD credits

QUALITY

We guarantee top quality events, courses, and services

SERVICE

We are here to serve you, our Valued Member better

RESPECT

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

SUPPORT

We are here to answer any queries you might have

For more information:

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

Alternatively, call Connie on 011 487 3003.

SAIEE CHARGE rewards programme

3D-printed part loaded into plant for first time; Rolls Royce to sell nuclear I&C business

A 3D printed safety component, manufactured at the U.S. Department of Energy's Oak Ridge National Laboratory (ORNL), will be loaded into a U.S. commercial nuclear plant for the first time, Framatome said in a statement at the beginning of December.

The stainless-steel fuel assembly channel fasteners will be inserted in the Tennessee Valley Authority's (TVA) Browns Ferry Nuclear Plant during the spring 2021 refueling outage, Framatome said.

The components, which secure the fuel channel to the boiling water reactor (BWR) fuel assembly, were printed at the ORNL using additive-manufacturing techniques as part of the lab's Transformational Challenge Reactor Program and installed on ATRIUM 10XM fuel assemblies at Framatome's nuclear fuel manufacturing facility.

The channel fasteners are usually made from expensive castings and require precision machining.

"Our use of additive-manufacturing techniques is a major advancement for Framatome and the nuclear energy industry," said Ala Alzaben, senior vice president of the Commercial and Customer Center of the Fuel Business Unit at Framatome.

Additively manufactured channel fasteners for Framatome's boiling water reactor fuel assembly. (Source: Oak Ridge National Laboratory)

"Working with industry leaders at ORNL and TVA, our team developed a new, innovative way to manufacture components that will help to reduce costs while maintaining plant safety and reliability."

Data collecting from developing the component using additive manufacturing and from inspections during the refueling outages will help in future efforts to certify the components' quality, Framatome said. wn

Rolls Royce to sell civil nuclear I&C business

Engineering company Rolls Royce has agreed to sell its civil nuclear instrumentation and control (I&C) business to Framatome, the group said in a statement December 7.

The business includes all of Rolls Royce activities and teams based in Grenoble (France), Prague (Czech Republic), Beijing and Shenzhen (China).

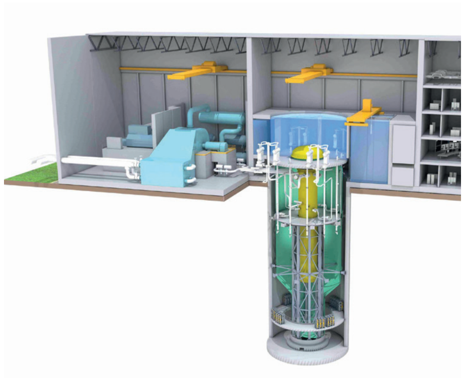
"This transaction marks a further simplification of our business and contributes towards our target to generate over £2bn from disposals, as announced on 27 August 2020. We also believe it represents the best outcome for this part of our civil nuclear operations and its people," Rolls Royce Chief Executive Officer Warren East said.

The sale is expected to be finalized in the middle of next year, subject to closing conditions including regulatory approvals, the group said. Work at both companies will continue as normal until the transaction is complete, it said.

The business being sold had 550 employees and reported revenues of 94 million euros ($113 million), which were consolidated within the results of Rolls Royce's Power Systems business.

The accord does not impact UK-based employees or small modular reactor (SMR) activities, it said.

NRC issues report for GE Hitachi Nuclear SMR



The U.S. Nuclear Regulatory Commission (NRC) has issued a Final Safety Evaluation Report for the first of several licensing topical reports (LTRs) that have been submitted for GE Hitachi Nuclear Energy's BWRX-300, the company confirmed at the end of November.

The LTR forms the basis for the dramatic simplification of the BWRX-300 and was submitted to the NRC in December last year, GEH said.

"The BWRX-300 will leverage much of the existing licensing basis of the NRC-certified ESBWR and this LTR will accelerate our commercialization efforts as we remain laser focused on making the first SMR operational later this decade," said President and CEO of GEH Jay Wileman in a statement.

GEH expects the review of two other LTRs, submitted to the NRC early this year, to be completed in the next few months while it has submitted a fourth LTR in September.

The company expects the LTRs to serve as a foundation for the development of a Preliminary Safety Analysis Report that could, potentially, be submitted to the NRC by a utility customer, the statement said.

OPG defuels 2nd reactor ahead of schedule

Ontario Power Generation (OPG) has successfully defueled the second unit to undergo refurbishment at the Darlington Nuclear Generating Station ahead of schedule, the Canadian company said in a statement at the end of November.

The defueling allows the next phase of the Darlington Refurbishment Project to begin and OPG and its project partner CanAtom Power Group have begun to prepare the reactor for disassembly, it said.

Defueling involves the removal of 6,240 fuel bundles from the reactor after which they are placed in water-filled bays where they remain in storage for 10 years.

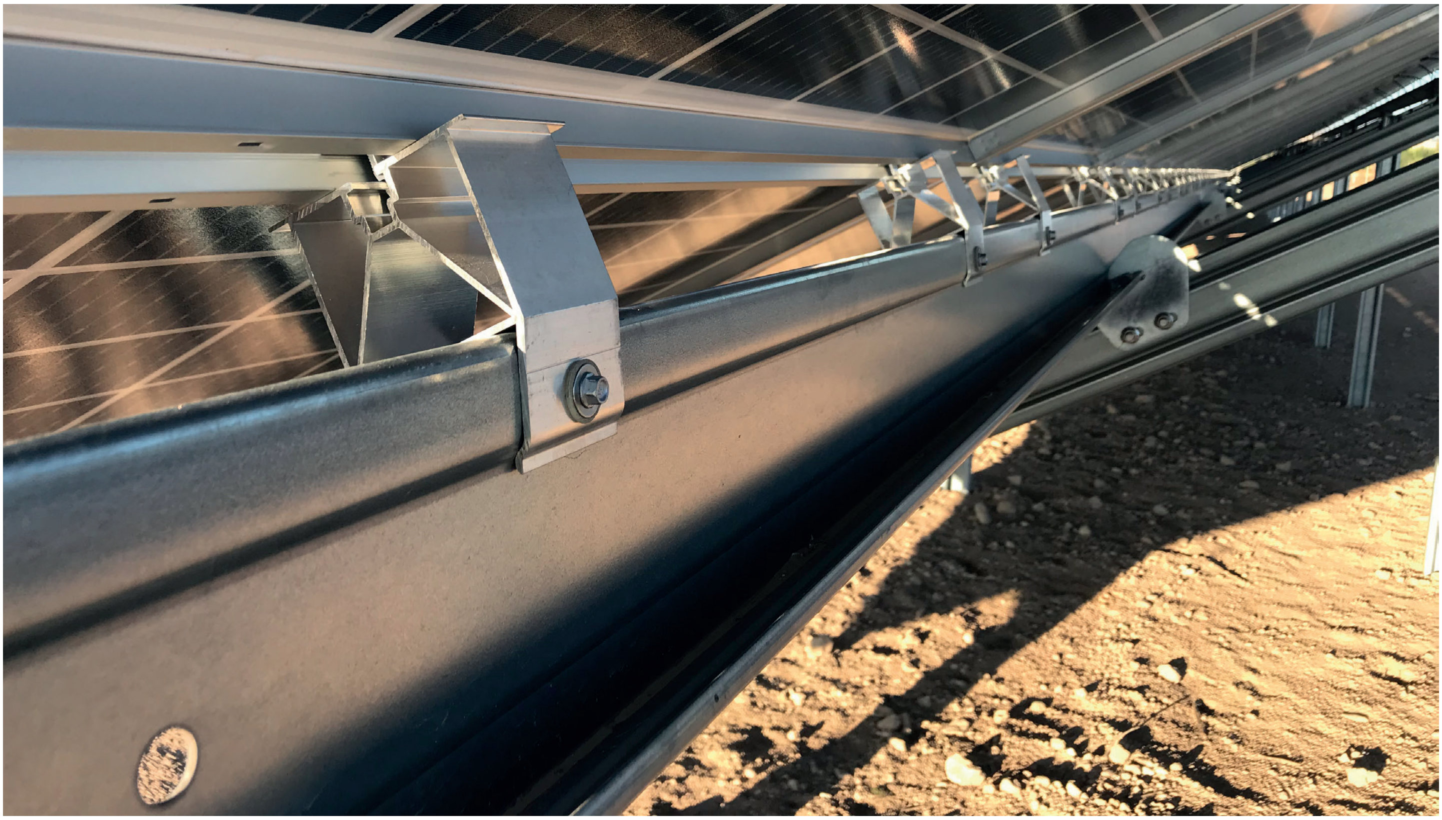
"Once again, the Darlington Fuel Handling team has demonstrated their knowledge, skills and expertise, defuelling Unit 3 safely and with quality ahead of the targeted completion date," said Steve Gregoris, Senior Vice President, Darlington Nuclear GS.

The next step in the process begins with islanding, in which, over the course of 55 days, the unit being refurbished is separated from the operating units by implementing controls and installing steel bulkheads, OPG said.

The company noted that it was able to improve efficiency and quality performance with the second unit after its experience with refurbishment of the first unit.

The Darlington Refurbishment Project, where four units of the plant will be refurbished, is scheduled to be completed by 2026.

Schletter: Bifacial 2 MW Plant in Spain with new Module Clamp Adapter



The trend towards bifacial modules continues: The Schletter Group has supplied the mounting systems in Spain for a 2 MW open area plant of Spanish project developer Atersol. To optimize the yield from the plant, Schletter developed a new module clamp adapter for the project. This reduces shading on the underside of the module considerably.

"To allow bifacial modules to develop their full yield potential, they must be matched to the mounting system", emphasized Hans Glaser, who is in charge of Schletter Group's Spanish operation. "This is what we did in this project, and we developed a new component specially for it". The new module clamp adapter, which is 60 mm high, allows for a higher energy yield on the module underside. It can be used for all fixed mount Schletter open area systems and will also be used in future for other bifacial projects.

Normally, the module is fixed directly on the purlin using module clamps or – if traditional module clamp adapters are used – just a few millimeters above it. This means that a blind spot is created on the side of the purlin facing away from the light where almost no light hits the underside of the module. The photovoltaic cells in this shaded area therefore produce practically no energy. The new module clamp adapter, on the other hand, acts as a spacer. It creates a light gap about 80 to 90 mm wide between the purlin and the module. Consequently, the shaded area due to the purlin is much smaller, which means that the yield on the module underside is improved.

The 2 MW plant is near the town of Caudete in the south-east of Spain. It produces 2 MWp with 5,000 type STK Risen RSM 144-6-400 bifacial modules. The Schletter FS Duo twin-post system with pile-driven foundations was used for assembly. The system is very easy to assemble and can be used with almost any ground conditions and site incline. Thanks to its adjustable tilt head, even steep slopes can be compensated with the FS Duo system.

The plant, including the pile-driving plan and measurements for installation of the foundations, was planned and supported by the Schletter branch in Spain. wn

ECSA Announcement: COVID Exemption

Following an outbreak of the Coronavirus (COVID-19) and the impact of the lockdown in South Africa from March 2020, the Engineering Council of South Africa (ECSA) resolved to relax the Continuing Professional Development (CPD) requirements and to exempt all Registered Persons from complying with the requirements for the current year, 2020.

This exemption is automatic and will be implemented by Council as follows: the twenty-five (25) credits for the five (5) year cycle required in order to renew your registration(s) and will be distributed amongst the three CPD categories as stipulated below:

In terms of Section 22(1) of the Engineering Professions Act, the Registered Person must still apply in the prescribed manner to Council for the renewal of his or her registration.

CPD CATEGORIES	ACTIVITY	NUMBER OF EXEMPTED CREDITS
Category 1	Developmental Activities	1
Category 2	Work-based Activities	2
Category 3	Individual Activities	2
Total		5

All practitioners registered in the professional or specified categories will be exempted from obtaining five (5) credits for the year 2020. These credits make up five (5) credits of

ECSA would like to wish all Registered Persons good health during these trying times and to express our gratitude for the continued support. wn

Save the Date...

The SAIEE is happy to announce that the dates for the 2021 SAIEE Annual Conference have been confirmed!

2021 promises to be a year where all will adapt to the 'new normal', and it is therefore that the SAIEE decided to host a two-day virtual conference, with an international flair, on the 17th & 18th of November 2021.

Not only is 'digital' the new buzz-word, but virtual conferencing delivers a fantastic experience to everyone. We will offer virtual exhibition stands which drives local and international attendees directly to your website, virtual networking events, virtual private meeting rooms, a digital programme and many changes for digital networking.

Not only will the attendance fee dramatically reduced compared to a physical event, but your chances to meet international visitors and decision-makers are ten-fold. Watch this space!

SA approaches 25,000 Covid-19 deaths, with 216 in 24 hours

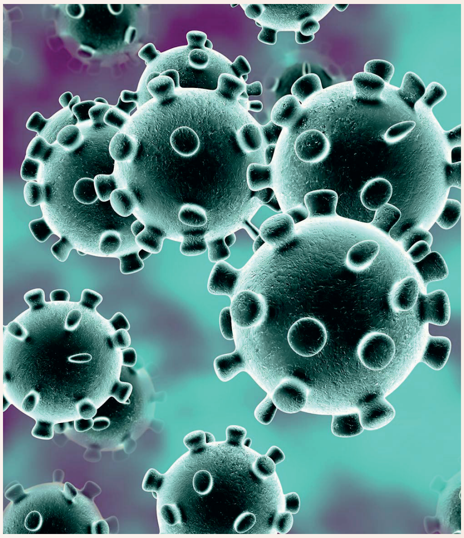
SA's death toll climbed to just shy of 25,000 Covid-19 related deaths, as the total number of confirmed infections moved past 930,000.

Health minister Dr Zweli Mkhize confirmed that 216 new coronavirus-related deaths in the past 24 hours, taking the total number of fatalities from the respiratory illness to 24,907.

Of these, the Eastern Cape (97) and the Western Cape (84) accounted for 83.8% of the deaths. Gauteng accounted for 16 deaths, KwaZulu-Natal 15 and the Free State four.

Mkhize also reported that there were 8,789 new cases. This means there are now 930,711 confirmed infections to date. The new infections came from 35,844 tests, at a positivity rate of 24.5%.

So far, 796,346 recoveries have been recorded. wn



IBC SOLAR SA: Installers and Project of the Year Awards

From left: Daniel Haitzler, Managing Director of IBC SOLAR South Africa and Darryl Claasen, Ultimate Solar IS of the Year.

From left: Daniel Haitzler, Managing Director of IBC SOLAR South Africa and Fil Wolfs, Windstrom IS of Year.

From left: Daniel Haitzler, Managing Director of IBC SOLAR South Africa and Jason Cockerill, Bespoke Energy PJ of Year.

IBC SOLAR South Africa, subsidiary of IBC SOLAR AG, a global leader in photovoltaic (PV) systems and energy storage has awarded their Premium Partners 2020 at year-end functions. The partners were honored amongst others with the awards "installers of the year" and "project of the year".

During events held at two outside venues in Johannesburg and Cape Town, in-line with COVID regulations, Daniel Haitzler, Managing Director of IBC SOLAR South Africa, awarded its best system clients with Premium Partner Certificates for loyalty and great work. It is now the second year in a row, that IBC SOLAR SA has awarded system partners for their excellent SOLAR PV installations. "An IBC SOLAR Premium Partner is not only assessed by a certain level of sales volume but by the number of complete systems and the frequency of business interactions with us throughout the year. The success comes from partnership and that is what we are targeting with our clients to build a win-win relationship for all of us", Haitzler points out. "Our Premium Partners are exactly that".

In addition to the Premium Partner Certificates, the clients Daisy Energy in cooperation with Bespoke Energy won the Award "Project of the Year South Africa". In a joint effort, the two companies installed and commissioned a 60kWp plant and a 259kWh Microgrid. The solar part is managed by three Fronius Symo 20 inverter, connected to six Victron Quattro 10 with a Solar MD Li-Iron battery bank to providing 60 kVA of power output. The project was installed with most DC components coming from IBC SOLAR and commissioned flawlessly in an extremely confined space. In addition, it presents an outlook for the future, how to power Africa in a sustainable and self-sufficient manner.

The "Installer of the Year Awards" went to Ultimate Solar for Gauteng and Windstrom for the Western Cape. Both customers have come a long way with IBC SOLAR and are both highly skilled and experts in their field. They have installed and commissioned numerous systems by using the whole range of IBC SOLAR's product portfolio.

Furthermore, the long-standing clients Solsquare in Namibia, Synergy Contracting in Zambia and Renewvia Kenya were awarded with the "Installer of the Year Awards" as customers in the export markets.

Even during the very challenging year of 2020, IBC SOLAR South Africa managed to grow their track record and further strengthen their market position in the Sub-Saharan region. wn

BI plans strategic acquisitions, new products and services for 2021

BI carries the standard Masta range.

Craft single direction thrust ball bearings.

The current economic situation might offer excellent opportunities for acquisitions within its field of operation, comments Bearings International (BI) Managing Director Bart Schoevaerts.

This comes off the back of increased collaboration within the Hudaco Group, of which BI forms part. Plans for next year also include expanding and optimising BI's branch and franchise network across Africa.

Looking at recent developments, BI has focused on its motor strategy, announcing a new partnership agreement that will see it distributing IE2 and IE3 motors from ABB in 2021.

Initial stocks will arrive in late December 2020, with more to follow in the New Year. "We are incredibly excited about the future of this partnership and look forward to offering the market a premium brand motor of choice," highlights Schoevaerts.

Also introduced in 2020, the CRAFT range of bearings has been well-accepted by the market and will be added to in 2021. On the power transmission side, BI will add a heavy-duty vee belt to its offer. "There are a few other products and services we plan to launch in 2021, so watch this space," adds Schoevaerts.

"We are looking at developing a total on-line customer experience, in addition to further digitalisation," reveals Schoevaerts. This focus has emerged from the learning curve introduced by the Covid-19 pandemic, which highlighted the need to automate and introduce more paperless processes.

"The IT skills of our employees are crucial, so we will invest more in training and development in this regard. Customer and supplier contact is equally important, and therefore we will give this even more attention going forward. We shall evaluate and embrace new technologies continuously and not wait until a situation forces us to do so."

The main challenges facing the distribution sector in South Africa at present are product supply, logistics capacity and a hesitancy to enter into long-term commitments. What gives BI the leading edge in such a tough trading environment at present are the resilience and willingness of its staff to embrace change and its existing long-standing relationships with both customers and suppliers.

"The hard lockdown certainly made it more difficult to visit and win new customers, while the various lockdowns around the world have impacted the availability of some products. In addition, the cost of logistics has seen an increase, while customers have postponed or even cancelled some key planned projects," notes Schoevaerts.

In terms of the future, he concludes: "I am confident that we have learned a lot, made the necessary changes and will continue to make future changes to become more resilient against future crises. I would like to thank our customers and employees for their continuous support and trust in the BI brand." wn

Connect with BI on Social Media to receive the company's latest news.
Facebook LinkedIn

NEWS

INTERNATIONAL HUMAN RIGHT'S DAY:

How Nuclear Science Helps Countries Guarantee Basic Rights to Water, Food and Health

As we mark International Human Rights Day (10 December 2020) with a hopeful look towards the end of the COVID-19 pandemic, it strikes me as an excellent time to highlight the often-underappreciated ways the atom supports the attainment of our fundamental human rights.

BY MARIANO GROSSI
IAEA DIRECTOR-GENERAL RAFAEL

The International Atomic Energy Agency's (IAEA) role as the world's "nuclear watchdog" is essential to global peace and security and needs no preamble. By guarding against nuclear proliferation, the Agency supports peace and freedom from oppression. But the IAEA also contributes significantly to social and economic rights around the world. By ensuring that everyone can benefit from nuclear science, the IAEA underpins rights enshrined in the International Covenant on Economic, Social and Cultural Rights in 1976. These include the right to benefit from scientific progress; the right to an adequate standard of living, and the highest-attainable standard of health.

The Agency does this by using nuclear science to combat zoonotic diseases; bolster food safety; protect fruits from pests; strengthen water management; treat cancer; and of course, to help countries mitigate climate change.

Supporting these fundamental human development areas is at the core of the IAEA's technical cooperation assistance. More than 140 countries – including many least developed nations, 26 in Africa – come to the IAEA seeking science-based solutions to manage resources, tackle a growing incidence of chronic and infectious diseases, and boost productivity through clean and reliable industrial processes.

Just last year, the IAEA supported 2081 fellows and trained more than 3,400 scientists and specialists. These learned, among others, to use isotopic techniques to check the origin and quality of freshwater, develop heat-resistant varieties of tomatoes, and protect patients so that they receive

just the right dose of radiation beat a tumour.

Supporting countries to prosper has been at the heart of our work since the IAEA was created in 1957 with the statutory mission to "accelerate and enlarge the contribution of atomic energy to peace, health and prosperity throughout the world."

This mandate could not be more timely. Nuclear Science and Technology contribute directly to several Sustainable Development Goals – from zero hunger to life on land. And their contribution will continue to grow as countries seek to address the significant challenges of our time.

Let's take zoonotic diseases, like COVID-19. Many countries turned to the IAEA for support during the pandemic, as nuclear-derived PCR tests are the most accurate and reliable way to detect viruses. The Agency shipped more than 1,873 consignments of virus detection equipment to 126 countries and territories. And looking to the future, we launched the Zoonotic Disease Integrated Action (ZODIAC) initiative to build the human, infrastructure and scientific capacity in countries to enhance global preparedness against zoonotic disease outbreaks and prevent future health crisis brought upon by diseases that transition from animals to humans.

Climate change is another major current threat to humanity, where nuclear technology is part of the solution. Efforts to avert the devastating effects of burning fossil fuels require immediate reductions in greenhouse gas emissions, particularly in the energy sector. As a reliable source of low-carbon electricity, nuclear power can significantly contribute to this. The IAEA helps countries in the efficient, safe and secure use of this sustainable energy. It supports existing and new nuclear programmes worldwide, serving as a catalyst for innovation and building capacity from energy planning and analysis to design, construction, operation, and knowledge management.

As we emerge from the pandemic facing economic uncertainty, sustainable development is high on the world agenda. This requires that we provide all available tools to help countries safeguard their people's fundamental rights, such as access to safe food, water, adequate health care, energy and the benefits of scientific progress. Nuclear science and technology are powerful tools that will be indispensable to drive this progress. wn

UK nuclear plan seen as tentative step in the right direction

The British government's energy plan, as laid out in recent policy papers, is a step in the right direction for nuclear, but lacks key details, say industry insiders.

BY PAUL DAY

The UK government's 'Ten-Point plan for a Green Industrial Revolution', which includes sections on advancing offshore wind, building on hydrogen production, zero emission vehicles and carbon capture, calls for the deliverance of new and advanced nuclear power through investment of some £600 million ($800 million).

The plan announced £385 million for an Advanced Nuclear Fund, which includes £215 million for small modular reactors (SMRs), and aims to unlock up to £300 million in private sector match-funding, and another £170 million for a research and development program on Advanced Modular Reactors.

It adds another £40 million to develop the regulatory frameworks and support UK supply chains.

Meanwhile, the Treasury's 'Response to the National Infrastructure Assessment', which was released in November, rejected the advice of the National Infrastructure Commission (NIC) two years earlier that the government should not provide support for more than one nuclear power station beyond Hinkley Point C (HPC) before 2025.

Since the NIC assessment, the UK has set a target of net zero greenhouse gas emissions by 2050 against a backdrop of an expected doubling of electricity demand in the same period.

These factors prompted the government to state *"it is important to maintain options by pursuing additional large-scale nuclear projects, subject to clear value for money for both consumers and taxpayers and all relevant approvals."*

Those within the British nuclear industry consider the turn around by the British government as a positive, if initial, move.

"It is a good start. Nuclear is essential to supporting achieving the targets of net-zero and it is undeniably required if we are to enable a clean energy system … The commitment in the 10-point plan is the first steppingstone to getting this target achieved," says Mike Drury, Account Director Newbuild and

Advanced Nuclear Technology at the UK National Nuclear Laboratory (NNL).

The government is poised to release two further papers which should help to clear up its intentions for the industry; an energy white paper, which is expected before the end of the year, and an outstanding consultation on financing and the regulated asset base (RAB).

"The direction we are heading in is very positive and investors are seeing the opportunity and now starting to get very interested. However, for this to really land, commitment on the market size for the UK is needed to enable the fleet approach to be committed to," says Drury, adding that it was also important to hear a firm position on energy demand from the white paper, as well as a clear statement on siting options and a strategy for a fleet of reactors.

UK NUCLEAR NEW BUILD

Around of fifth of all electricity generated in Britain comes from nuclear power, but almost half of the current capacity is to be retired by 2025 and, apart from EDF's and China's CGN's HPC in Somerset, plans to replace it have been patchy.

"It's pretty much an accident of history really, but because our fleet is old and coming to end of its life in the next few years, there's probably been a bit more focus in the UK than other places in Europe where they're a bit further behind and also struggling with how to decarbonize," says CEO of the Nuclear Industry Association Tom Greatrex.

HPC and a planned near-replica, Sizewell C, will produce some 6.4 GWe of electrical power once they are up and running, later this decade for HPC and, if given the final green light, Sizewell C in the early 2030s.

Meanwhile, the Wylfa and Oldbury projects, which together would have generated over 5 GWe, were dropped by Hitachi after failing to reach an agreement on financing and on concerns over the country's plan to leave the European Union. A BBC report claims the government is in talks with a consortium of Westinghouse and others to save Wylfa, though to date, plans for the project remain uncertain.

A 3.3 GWe Moorside project has also been put on hold after Westinghouse was forced into a Chapter 11 bankruptcy in 2017, while the 2-3 GWe Bradwell site, which has reached stage four of the UK's Generic Design Assessment, may still go ahead despite worsening relations between the Chinese, who have been offered to build on the site, and the UK government.

A 10-year plan by Rolls Royce to install 16 SMRS, each with a capacity of 440MWe, as head of the UK SMR consortium will take advantage of a whole series of nuclear license sites, such as old Magnox stations or sites previously occupied by coal-fired power stations.

Proponent	Reactor/site	Locality	Type	Capacity (MWe gross)	Construction start
EDF Energy[n]	Sizewell C1	Suffolk	EPR	1670?	
	Sizewell C2	Suffolk	EPR	1670?	
Total planned	**2 units**			**3340 MWe**	
China General Nuclear	Bradwell B1	Essex	Hualong One	1150	
China General Nuclear	Bradwell B2	Essex	Hualong One	1150	
Total proposed	**2 units**			**2300 MWe**	
Horizon	*Wylfa Newydd 1&2*	*Wales*	*ABWR*	*2760*	
Horizon	*Oldbury B1&B2*	*Gloucestershire*	*ABWR*	*2760*	
GE Hitachi	*Sellafield*	*Cumbria*	*2 x PRISM*	*2 x 311*	*Cancelled*
Candu Energy	*Sellafield*	*Cumbria*	*2 x Candu EC6*	*2 x 740*	*Cancelled*
NuGeneration	*Moorside 1-3*	*Cumbria*	*3x AP1000*	*3 x 1135*	*Cancelled*

Table 1: Power reactors in the UK, planned and proposed

ENCOURAGING BUT LIMITED

The ten-point plan is an encouraging framework when working toward net zero by 2050, but it lacks detail, Greatrex says, adding that the need for a solid path toward a functioning nuclear industry is well understood but the means for delivering it is still not in place.

The one-off nature of the in-construction HPC reactor means the strike price of £92.5 per MWh is heavily inflated and is a stark illustration of why the UK nuclear industry needs to adhere to a financing structure more tailor made to nuclear power and greater commitment by the government of where the industry is heading.

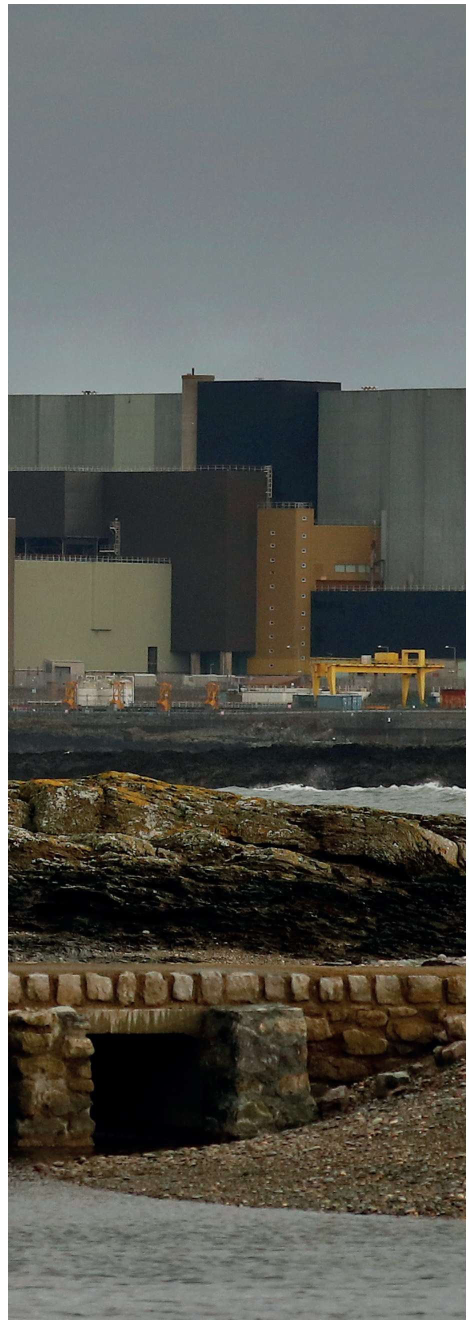
"When two-thirds of the price ticket for Hinkley is the cost of financing and taxation, as opposed to the cost of construction . . . if there are ways of reducing that then really it's pretty obvious thing you want to address. And that's the rationale behind the consultation the government held on RAB, or potentially taking an equity stakes, or a mix of elements of the two - which is probably where we'll end up," says Greatrex.

The government's at-times unclear approach to nuclear power is part of the problem as state-support, both financial and regulatory, siting options and plans for a nuclear fleet remain undecided. *"(The government) is working on all of these, but as with all financial investments, these considerations have to be balanced with current COVID recovery plans, long term security of supply surety, contributions to economic recovery and for this type of investment, clear communication on the advantages and contributions that will be made towards meeting a legal obligation for Net-Zero,"* says Drury.

There are still many important stakeholders in the industry that may not be fully convinced, says Andrew Storer, CEO, Nuclear AMRC who added that the UK must move on from *"a conversation about proving ourselves to one of delivery."*

While, the most important thing is to ensure the UK has a program that the sector can coalesce around, nuclear companies in Britain need to show they can work better as one in order to provide requisite confidence to agree a program, says Storer.

"We need to be better at working as one industry. It is a commercial business, but we do need to come together if we really want to tackle the challenges that affect us all. After all, if there is to be a huge contribution from nuclear to achieve net zero by 2050, then there will be enough work for everyone and then some," he said. wn



Zest WEG – 40 Years And Growing In Africa

Zest WEG's four decades in Africa have produced a powerful local manufacturing base, and a growing footprint across sub-Saharan Africa – strengthening supply chains and local economies.

"Progress in skills development has been significant in the past few years, as we have invested heavily in technology and skills transfer between the company and our holding company WEG in Brazil," says Juliano Vargas, chief executive officer of Zest WEG. "Leveraging WEG's global manufacturing productivity logic, we have also installed the latest equipment and systems to pave the way for a sustainable future."

As a result, local content in the company's manufacture of transformers is now nearly 90%, while for products like E-Houses and electrical panels has exceeded 70%. Vargas highlights the strategic importance of local content not just in terms of the mining industry's commitment to the Mining Charter, but for the sustainability of the South African economy as a whole.

"Our local manufacturing capability has helped to strengthen the supply chain for our customers, making businesses more secure," he says. "The value of this has been well demonstrated by the economic impact of border closures during the Covid-19 pandemic."

Vargas emphasises that Zest WEG's own supply chain has been actively nurtured through enterprise development initiatives, fostering the sustainability of local businesses. This local manufacturing ecosystem shields the company from market fluctuations and gives it a competitive cost advantage on locally manufactured products.

Success in South Africa has fostered growth into 47 other African countries, where customers are not only supported by wholly-owned operations but also by Zest WEG's Value Added Resellers (VARs) in over 20 countries around the continent.

"These VARs understand their local markets and are skilled practitioners in their fields," he says. "This ensures that they can apply Zest WEG solutions appropriately and optimally to customers' specific needs."

VARs are a key aspect of the company's strategy to become rooted all over sub-Saharan Africa, collaborating with in-country experts and enhancing technical expertise and local capacity for economic development.

Vargas notes that WEG's range of products serve many industrial sectors, allowing Zest WEG and its VARs to explore opportunities not only in mining, but also in oil and gas, agriculture, water, cement and general industry. wn

Booyco expands PDS footprint to Namibian mine

Proximity detection leader Booyco Electronics is equipping 19 mechanised mining machines with its latest Booyco CXS proximity detection solution to enhance safety during the development phase of underground operations at Namibia's largest gold mine.

According to Anton Lourens, Booyco Electronics CEO, the order was placed by long-time customer Murray & Roberts Cementation, who will be establishing the underground stoping horizon for the Wolfshag zone of B2Gold's Otjikoto mine.

The contract also includes sensing devices for 120 underground personnel on the operation, which will be located in the employee's cap lamp to provide an alarm.

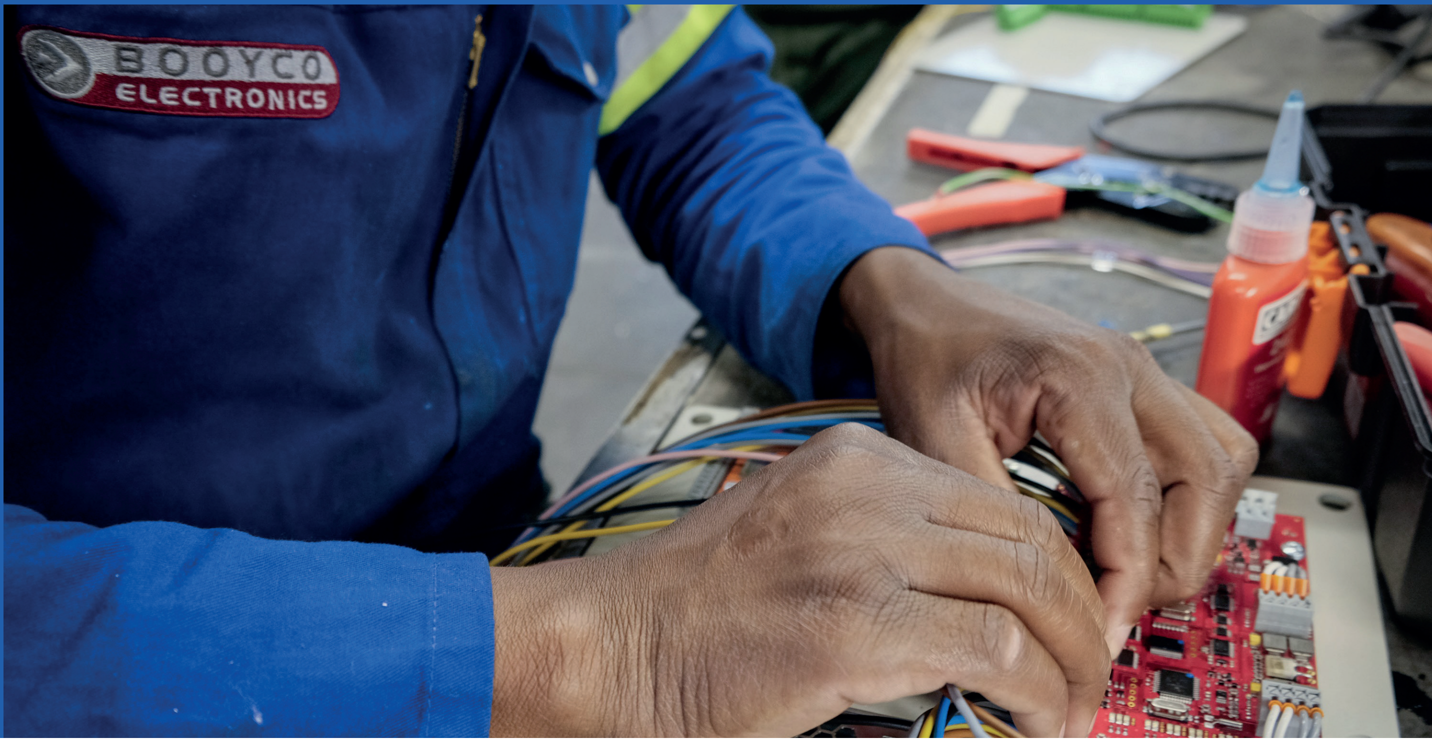
"Our equipment will help achieve the highest level of safety by mitigating the risk of collisions between pedestrians and vehicles, and between vehicles, on this project," says Lourens. "The installation of our CXS units is in line with the commitment by the mine and the contractor to zero harm in the workplace."

Murray & Roberts Cementation's project will take 28 months and will be conducted with local company Lewcor Mining. The contract will include a decline of 5 metres wide by 5,5 metres high being driven to the orebody from a portal in one of Otjikoto's depleted open pits. The operation will be highly mechanised, with equipment including drill rigs, dump trucks, load-haul-dumpers and utility vehicles, as well as shotcreting and ancillary equipment.

Lourens highlights that Booyco Electronics' latest generation CXS system being used on the project is a comprehensive and integrated proximity detection solution. The technology takes a step beyond being just a warning system to becoming a true collision avoidance system.

"The CXS system on this project will deliver Level 7 and Level 8 capability in terms of the Earth Moving Equipment Safety Roundtable (EMESRT), and can also accommodate Level 9," he says. "Although there is not yet a legal requirement for collision avoidance systems in Namibia, our customer and the mine adopt a global best practice approach to all aspects of safety in mining operations."

With the mine's location more than 300 km north of Windhoek, it was



Booyco Electronics is at the forefront of fit-for-purpose proximity detection technology.

important that the equipment is robust and reliable to ensure maximum uptime, he says.

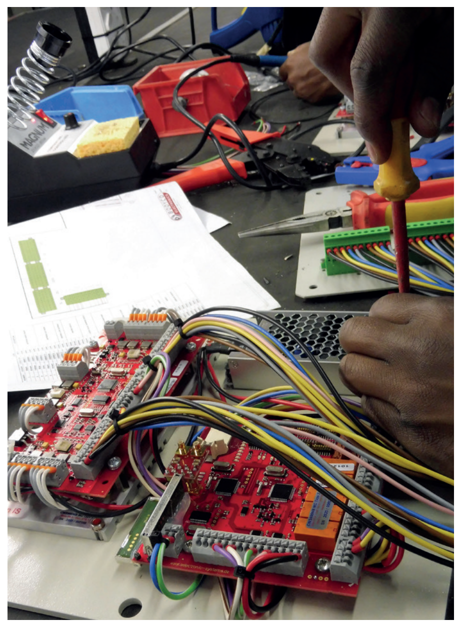
"To ensure that the equipment performs optimally, we have trained the customers' artisans on how to look after it," Lourens says. "A qualified serviceman from Booyco Electronics will also visit the site regularly to audit performance, assess the equipment and conduct any necessary maintenance."

A pioneer of proximity detection systems in South Africa, Booyco Electronics' home-grown technology has seen wide take-up in underground operations – both hard rock and coal – as well as in the opencast environment, plants and warehouses.

"Since our inception in 2006, safety regulations have changed significantly," he says. "An important strength of our technology is that it has constantly evolved to meet the needs of the industry."

The company now has a footprint of over 100 mining customers in South Africa, and this Namibian project is part of its gradual expansion into other countries in Southern Africa. He highlights that collision avoidance systems are likely to become increasingly mandatory in neighbouring states as these countries usually follow South African regulations. Major miners are also driving change through the globally recognised EMESRT guidelines.

"The International Council on Mining and Metals is also an important stakeholder in this process," Lourens says. "The ICMM highlights that transport and mobile equipment accidents were highest cause of fatalities at their members' operations in 2018, accounting for 30% of fatalities." wn



Booyco Electronics proximity detection solution will enhance safety during the development phase of Wolfshag.

The Booyco CXS allows end users to achieve Level 9 compliance.

Our purpose...

DEVELOPING SUSTAINABLE AND CLEAN ENERGY RESOURCES TO POWER SOUTH AFRICA'S INDUSTRIALISED ECONOMY

The International Energy Association (IEA), engaged in shaping a secure and sustainable energy future for all, records in their 2020 Global Energy Outlook, that for South Africa, coal is the mainstay of the South African energy system, meeting around 70% of primary energy demand.

BY THE SAIEE NUCLEAR CHAPTER

IEA states that "the government will face complex choices as it pursues its objectives of diversifying and reducing the environmental impact of the country's energy mix, and needs to pursue an active policy of public engagement in the debate.

But South Africa's combination of integrated policymaking, strong regulation, well-designed incentives for low carbon investment including private investment, greater efficiency and regional integration gives it enviable strength for the task."

IEA records South Africa's key energy data as follows:

ELECTRICITY GENERATION (2019) IN GWH:	
Coal	221 303
Nuclear	13 595
Wind	6 624
Hydro	5 610
Solar PV	3 255
Solar Thermal	1 554
Bio Fuels	443
Oil	183

CO_2 EMISSIONS IN $MTCO_2$ (2018):	
Coal	350
Oil	73
Natural Gas [428 $MtCO_2$]	5

ENERGY CONSUMPTION PER SECTOR (2018 KTOE)*:	
Industry	24 551
Transport	19 214
Residential	13 360
Commercial and Public Sectors	6 096
Non-Energy Use	4 790
Agriculture and Forestry	2 198
Not Specified	1 072
Fishing	63

The 2019 IEA Global Energy Outlook records the trends for each of the contributing energy sectors as follows:

- Renewables: "at the centre of the global energy transition."
- Hydrogen: "versatile energy carrier to manage critical energy challenges."
- Coal: "centre of the debate on energy and climate policy."
- Oil: "markets are characterised by volatility and extraordinary change."
- Gas: "cleanest burning and fastest-growing fossil fuel."
- Wind: "renewable energy with major potential."
- Solar: "on track to meet global climate targets."
- CCUS – Carbon Capture, Utilisation and Storage: "key emission reduction technology."

- Nuclear: "largest contributor of carbon-free electricity."
- Electric Vehicles: "electric mobility gaining momentum across cars, trucks and beyond."

In synchronism with the International Energy Association, the South African Institute of Electrical Engineers explores all of the energy sectors in the energy mix. Chapters and Study Committees have been launched to provide a platform for member participation and voluntary contribution of fact-based content, contributing to the National Energy Dialogue.

The January 2021 Issue of **watt**now has focused on Nuclear Energy. We introduce the SAIEE Power and Energy Section's Nuclear Chapter.

NEXT PAGE:
INTRODUCING THE COMMITTEE...

* - ktoe: kilotonnes of oil equivalent

CHAIRMAN

Professor David Richard Nicholls
Pr.Eng., C.Eng., FSAIEE, MINucE, BSc(Hons), Dip.Nuc.
Professor of Practice
Faculty of Engineering and the Built Environment
University of Johannesburg
Non-Executive Chairman: Nuclear Energy Corporation of SA (NECSA)

Mr Nicholls started his career in the Royal Navy, joining at the age of 17 in 1971. He gained his engineering degree and postgraduate nuclear qualifications before serving as an engineer officer in nuclear submarines. Nicholls left the navy in 1982 to manage a small family manufacturing company for two years before emigrating to South Africa in 1984 to join Eskom. He arrived in Eskom as the Koeberg nuclear reactors were commissioned and started his Eskom career in the Safety and Licensing section of the Nuclear Engineering department at the head office in Megawatt Park.

During most of his 34 years in Eskom, he remained in the nuclear field up to his retirement in December 2018. He retired from Eskom as the Chief Nuclear Officer, responsible for all nuclear activities in the company. The significant highlights of Mr Nicholls time in Eskom were the creation and management of the Pebble Bed Modular Reactor (PBMR) project, the establishment of the corporate nuclear safety oversight organisation and the technical leadership of the program for nuclear new-build from 2007. Mr Nicholls was appointed as the Chairperson of the South African Nuclear Energy Corporation (NECSA) in January 2020 by the Minister of Mineral Resources and Energy. Internationally Mr Nicholls was the Chairman of the IAEA Technical Working Group on Light Water Reactors from 2010 to 2016 and is currently the Co-Chair of the IAEA Technical Working Group on Nuclear Power Plant Operations. He was a member of WANO's Post-Fukushima Design Review Team from 2012 to 2018.

SECRETARIAT

Professor Simon Connell FSAIEE, FSAIP
Research Professor and SA Representative CERN
Department of Mechanical Engineering Science
Faculty of Engineering and the Built Environment
University of Johannesburg

Prof Connell is professor of physics at the University of Johannesburg. He has research interests in Particle Physics, Nuclear Physics, Nuclear Energy, Materials Science, Quantum Physics, High-Performance Computing and Applied (innovation) Physics. His rating by the SA Research Funding Agency (NRF) cites him as having "considerable international recognition". He is a past president of the South African Institute of Physics.

He is the founding member of the South African participation in High Energy Physics at the ATLAS Experiment at CERN, wherewith his group he participates in a Beyond Standard Model search and engineering and technical activities. He has published over 150 papers in International Journals and is also an ATLAS author. He has worked for many years at the European Synchrotron Research Facility (ESRF). He is interested in technology for competitive industry and innovation and has a project on the intelligent sensor-based sorting of diamond in kimberlite, which is now being commercialised.

He is a passionate supporter of Nuclear Energy and performs research in this area, particularly the modelling of power reactors. He is currently active in the discipline's service is developing the South African user base for Light Sources, (these are premier international multi-disciplinary research tools) and the implementation of the roadmap towards the African Light Source.

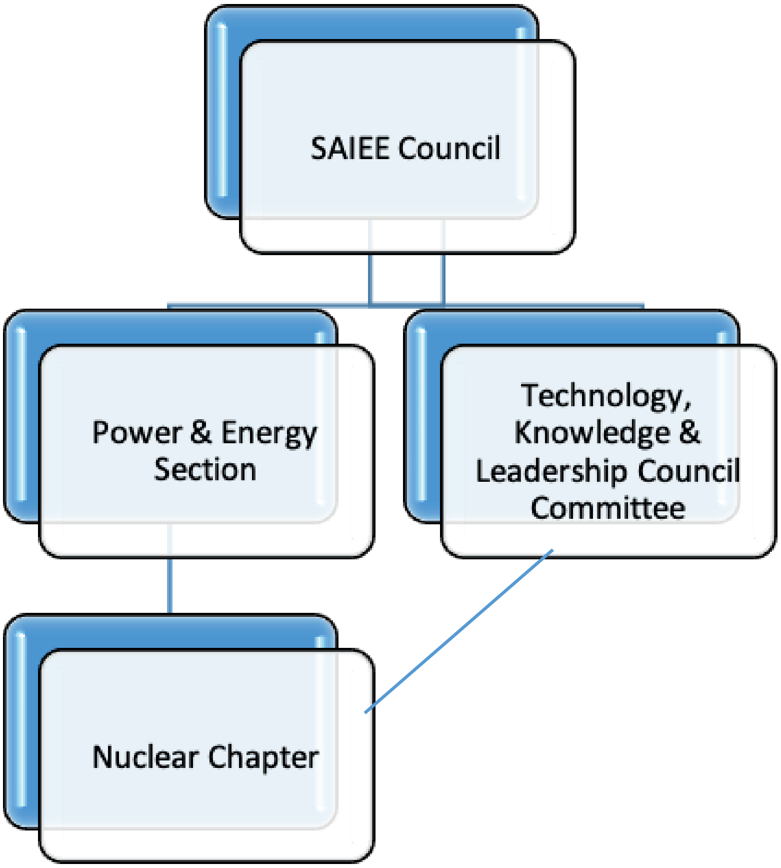
The Objectives of the Nuclear Chapter

1. To integrate and develop South Africa's Nuclear Capabilities as part contribution to South Africa's National Development Plan.
2. To promote scientists, engineers, and technologists' employability and create new quality jobs in advanced national industrialisation.
3. To stimulate sustainable and resilient national economic development in academic research, energy security and medical sciences.
4. To share and debate engineering and scientific information through webinars, short online learning and continuous development programmes, panel discussions and publications.
5. To promote a wider community and democratic participation in the merits and boundary conditions of Nuclear Science, Engineering and Technology applications in the national interest.

SAIEE LEADERSHIP ON NUCLEAR SCIENCE, TECHNOLOGY, ENGINEERING AND MATHEMATICS (NUCLEAR STEM)

The Chapter consists of Study Committees, they are:

- **The Energy Study Committee:** Electricity generation using conventional pressurised water reactors and next-generation modular and microreactors.
- **The Nexus of Applications Study Committee:** Applications of nuclear heat energy in sectors other than energy, such as water, waste, transport, industrial and mining processes, mineral beneficiation, and big data-driven solutions.
- **The Medical Applications Study Committee:** Private and public health applications.
- **The Science & Technology Study Committee:** Regulatory safety policies, practices and assurances; Advanced research and development of next-generation reactors and fuel preparation, beneficiation and management.
- **The Environmental Study Committee:** Environmental Impact Assessment and Management; Repository of Radioactive Materials for Short and Long Term Storage.
- **The Education Study Committee:** Custodian of Science, Engineering, Technology and Mathematics (STEM) for Scholars, Academic Training for Undergraduates and Postgraduates, Continuous Professional Development for Practicing Engineers and Scientists.



SAIEE Nuclear Chapter Structure

THE ENERGY STUDY COMMITTEE

CHAIRMAN
Mr Mmeli Fipaza
Pr. Eng. BSc(Eng),MSc(Eng) Cape Town MAP Wits MIET
Chief Engineer: Nuclear Operating Unit
Generation Group
Eskom

Mr Mmeli Fipaza is a Lead Chief Engineer in innovative nuclear technologies within the Nuclear Operating Unit of Eskom.

He is the South African member representative to the Expert Group of the Generation International Forum.

Since Industrial Revolution 1.0, global industrialised and developing economies have been powered by fossil fuels of coal, oil and gas. The increasing use of fossil fuel has contributed to increased carbon emissions. Rising concentrations of carbon in the atmosphere has directly promoted global warming and climate change.

The potential for irreversible environmental impact on life and the planet's sustainability now necessitates that all fossil fuel-based energy applications cease. The United Nations is leading the global effort to manage all carbon emissions downwards and to zero.

The potential for nuclear as a clean energy resource is gathering momentum. The International Energy Association (IEA) in their Global Energy Outlook of 2019 notes that nuclear has the potential to be the largest contributor to clean energy for sustainable development. In particular, global interest in Small Modular Reactors (SMRs) with seemingly several deployment advantages concerning aspects of costing, flexibility, modularity, scalability and so forth is gathering momentum.

SOUTH AFRICA'S OPTIONS:

- In 2024, Koeberg, South Africa's Pressurised Water Reactor Nuclear Power Station will be 40 years old. One option is to refurbish and extend the life of the power station. Add 20 years; the power station will operate to 2044.
- Add another 20 years; the power station will operate to 2084.
- Koeberg has provision to accommodate an additional two units; Units 3 and 4.
- Potential exists to expand Koeberg to a four-unit station; to add another 2500 MW to the existing 1860 MW.
- Small modular reactor technology is maturing; as advanced high-temperature gas-cooled reactors to serve as a heat source for industrial process plants and distributed electricity generation as municipal power stations and as renewal options for the ageing coal fleet.

The Energy Study Committee intends to provide profound solutions supporting the national strategic energy plans into the future. The primary focus areas of the initiative include desktop studies on:

- The feasibility of deploying modern nuclear technologies, including small modular reactors to surrogate generation due to decommissioned coal power stations. The project intends to renew or repurpose the power station sites to sustain economic activity in the areas.
- An economic evaluation of nuclear power plants will entail comparisons with other prominent power generation approaches including coal, gas, hydro and renewables to mention but a few. The primary focus will be on such key parameter as Capital Cost (Overnight), Levelised Cost of Electricity (LCOE), Job Creation and Supply Chain.
- The non-electrical applications of innovative nuclear reactors in South Africa - the applications may entail; cogeneration, Combine Heat and Power (CHP), Desalination and District Heating amongst others based on the power plant technology capability the applications may entail. Although some of the concepts are well documented in the IAEA TECDOC series, the services' regional applications may be subject to the specific needs, conditions, and stringent regulatory approvals.
- The team shall interface with other study committees on Koeberg Plant Life Extension programs and collaborate to share information on existing technical knowledge or experience(s) regarding nuclear developments.

THE NEXUS OF APPLICATIONS STUDY COMMITTEE

CHAIRMAN

Professor P Naidoo MBA Pr. Eng
Research Professor and City of Johannesburg Chair
Department of Mechanical Engineering Science
Faculty of Engineering and the Built Environment
University of Johannesburg

Dr Naidoo is Professor of Research in the Faculty of Engineering and the Built Environment, University of Johannesburg. He is a Fellow of the South African Academy of Engineers, a Fellow of the South African Institute of Electrical Engineers, a senior member of IEEE and a member of IET and Cigre. He is a registered professional engineer and a specialist consultant in electrical energy and power systems. His current research interests are in Sustainable Development as driven by the Green Economy and Industrial Revolution 4.0. Dr Naidoo's four-decade industrial career was with the Electricity Supply Commission of South Africa; from Engineer in Training to Non-Executive Director.

VICE CHAIRMAN

Dr. (Col.) Jean Marie Jullienne MBA
Governor: Mapungubwe Institute for Strategic Reflection
(MISTRA)

Dr. (Col.) Jullienne was born in Mauritius, studied Chartered Accountancy in the UK where he did his five-year articles with Robson Rhodes Lasser and Dunwoody. He moved to South Africa in 1979, where he fell in love with the country and its people. He has an MBA from Newport University, California and a PhD in Management of Technology & Innovation from the Da Vinci Institute.

He also obtained the Leonardo Da Vinci award the following year. He is the Honorary Colonel of Regiment President Kruger (Lenong) and a Governor of Mapungubwe's Institute for Strategic Reflection (MISTRA). He is an avid translator of ancient Hebrew and ancient Greek for the last thirty-four years. He published two books called "The Logic of God" and "the Cloud has Moved". He was the Managing Director of Environmental Resources Limited, a listed company on the Johannesburg Stock Exchange. He is the Chairman and Founder of the BEE Foundation which has been included as part of the BRICS flagship agricultural project. He is also the Chief Executive Officer of the Veterans Foundation. He is currently the Chairman of ART (African Remediation Technology) and the Chairman of BBSA (Biodegradable Bags SA) and Chairman of IC (Indigenous Capital). He was the advisor to the President and CEO of the French energy group, ENDEL/Engie for the last five years.

NEXUS OF APPLICATIONS OF NUCLEAR HEAT

Nexus of Applications' reference is the United Nations Sustainable Development Agenda 2030, "Transforming our World". Nuclear constitutes an ideal heat source; it is constant, predictable and controllable with zero environmental or air emissions.

The managing of Quality assurance, the safety of use and fuel spent. Nuclear has excellent potential to economically create and sustain long term jobs with socio and macroeconomic multiplier impacts in the following specialist and advanced industrialised sectors of the national economy. In addition to the established applications, we are expanding the application in the following sectors:

- Water Security: To Manufacture Fresh Water from Used, Waste, Sanitation or Salt Water Resources.
- Electric Transportation: To Manufacture Hydrogen in Bulk for Fuel Cell Powered Electric Vehicles of Rail and Road.
- Energy Intensive Heating, Cooling and Smelting: To Beneficiate National Mineral Resources of Iron, Steel, Platinum, Mineral Sands etc.
- Waste Beneficiation: To Manage and Extract Value from the Growing Quantities of Public Waste;

- Public Health: To contribute towards managing viruses and community diseases.
- Food Security: To support Agricultural Production, Food Processing, Beneficiation and Storage.
- IR4.0 and Big Data: To Promote Scanning, Imaging and Detection Technologies in Diamond Mining, Coal Quality Assurance, Security Intelligence and Medical Sciences

The Study Committee has launched, and the first assignments are commencing. As an example, the project on Enhancing the National Water Security is shared.

STUDY ASSIGNMENT: WATER SECURITY

To Manufacture Fresh Water from Used, Waste, Sanitation or Salt Water Resources.

VICE CHAIRMAN
Dr. Mandla Msibi MBA
Group Executive: Innovation and Impact
Water Research Commission of South Africa

Dr Mandla Msibi (Water Research Commission – South Africa) is an Environmental (Pollution) Scientist with PhD in Environmental Chemistry from the University of Birmingham, UK, and an MBA from the University of Pretoria. Mandla has over 24 years' experience as a Lecturer, Researcher, Research Manager, Knowledge Manager, Innovation and Technology Transfer Executive. He is currently the Group Executive: Innovation and Impact at the Water Research Commission (WRC). His experience includes Research Project Management: Potable Water Treatment, Head of the Information Technology Department, Knowledge Dissemination and leading Intellectual Property protection and the Technology Transfer Office.

He also worked for the Tshwane University of Technology as the Director: Research and Innovation, and later the University of Johannesburg as the Executive Director: Research and Postgraduate Studies.
"Every person deserves enough clean and safe water. We will achieve this by supporting the advancement (or promotion) and the use of innovative technologies and solutions to develop new products and services. We want to change practice so that we can meet current and future challenges and seize opportunities for economic development and job creation in the water sector, and aggressively communicate this position."

The Water Research Commission's workings refer: Graph 1 shows the relationship between available water (blue) and required water (green). Graph 2 maps the deterioration in the quality of freshwater resources.

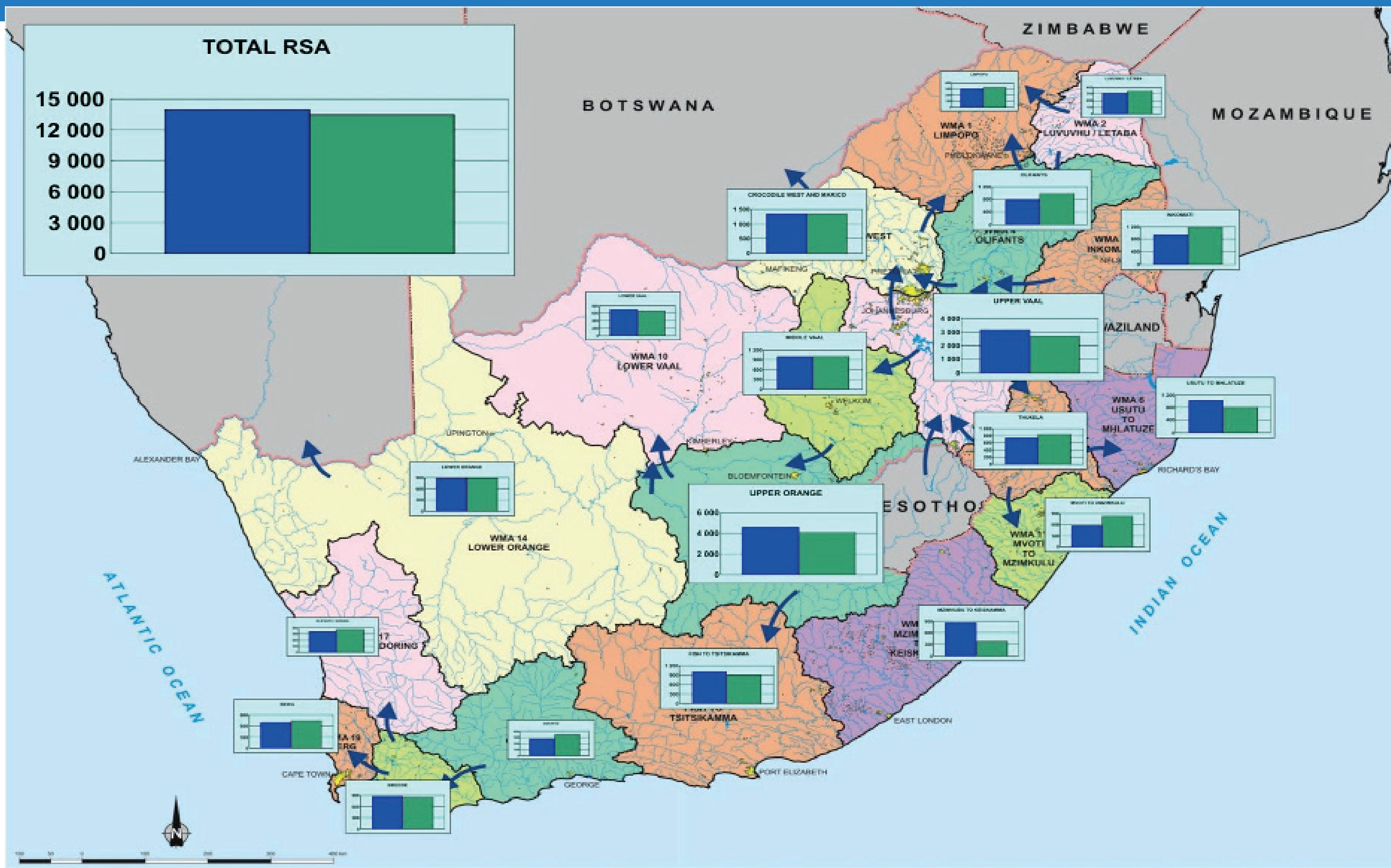
There exist too many variables surrounding rainfall. There are also many variables surrounding the collection and delivery of "rainfall" to customers.

In pursuit of water security, Utilities globally have developed and commissioned several "Clean Water" projects. Clean water projects include the engineering and development of desalination solutions plus purification and treatment of wastewater resources. Desalination consists of both "stand-alone" plants plus those that are integrated with power stations. The water treatment and purification plants include both large scale and mobile solutions.

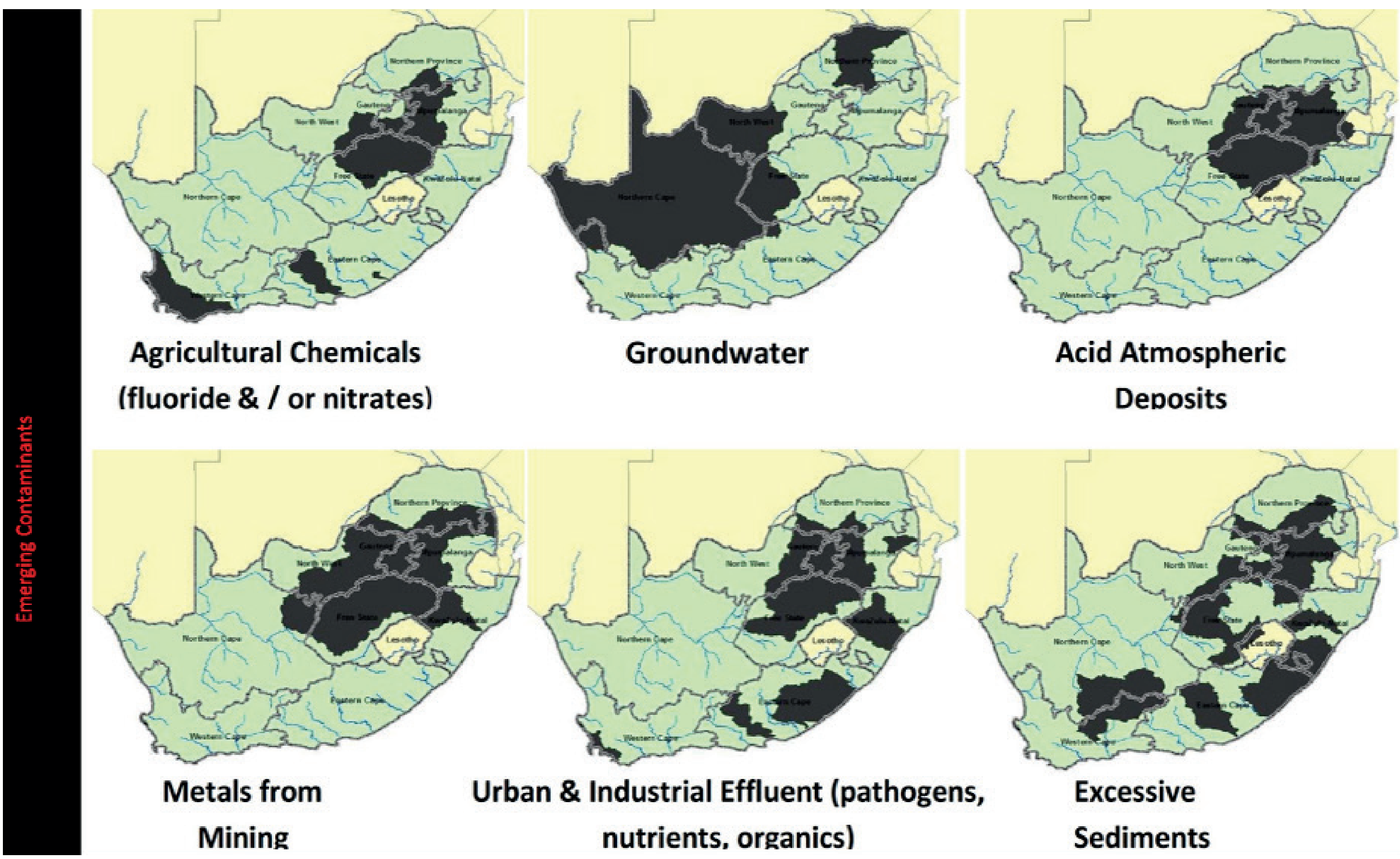
As Co-Chair of the Study Committee, Dr Mandla Msibi of the Water Research Commission of South Africa will explore the opportunity to manufacture clean water using nuclear heat as part-contribution towards National Water Security.

A first brownfield opportunity exists at the State-Owned Koeberg Nuclear Power Station outside Cape Town. The Western Cape had a recent "almost day zero experience" when the storage dams could not sustain the increasing demand for freshwater.

The two nuclear reactors at Koeberg employs the cold Atlantic seawater for cooling. Koeberg is a strategic water user and saves 22 billion litres of freshwater per annum. The condensers are cooled using seawater, which is returned to the sea after use. The seawater is not consumed. A coal-fired power station of the same size will use more than 50 million tons of coal and 160 000 million litres of scarce freshwater in a similar period. The freshwater will be entirely consumed. South Africa's freshwater resources are incredibly short and, at current economic and population growth rates, South Africa is expected to experience a permanent water shortage from 2020.



Graph 1: South African Map of Available vs Required Fresh Water



Graph 2: South African Map Showing the Deterioration in Fresh Water Quality

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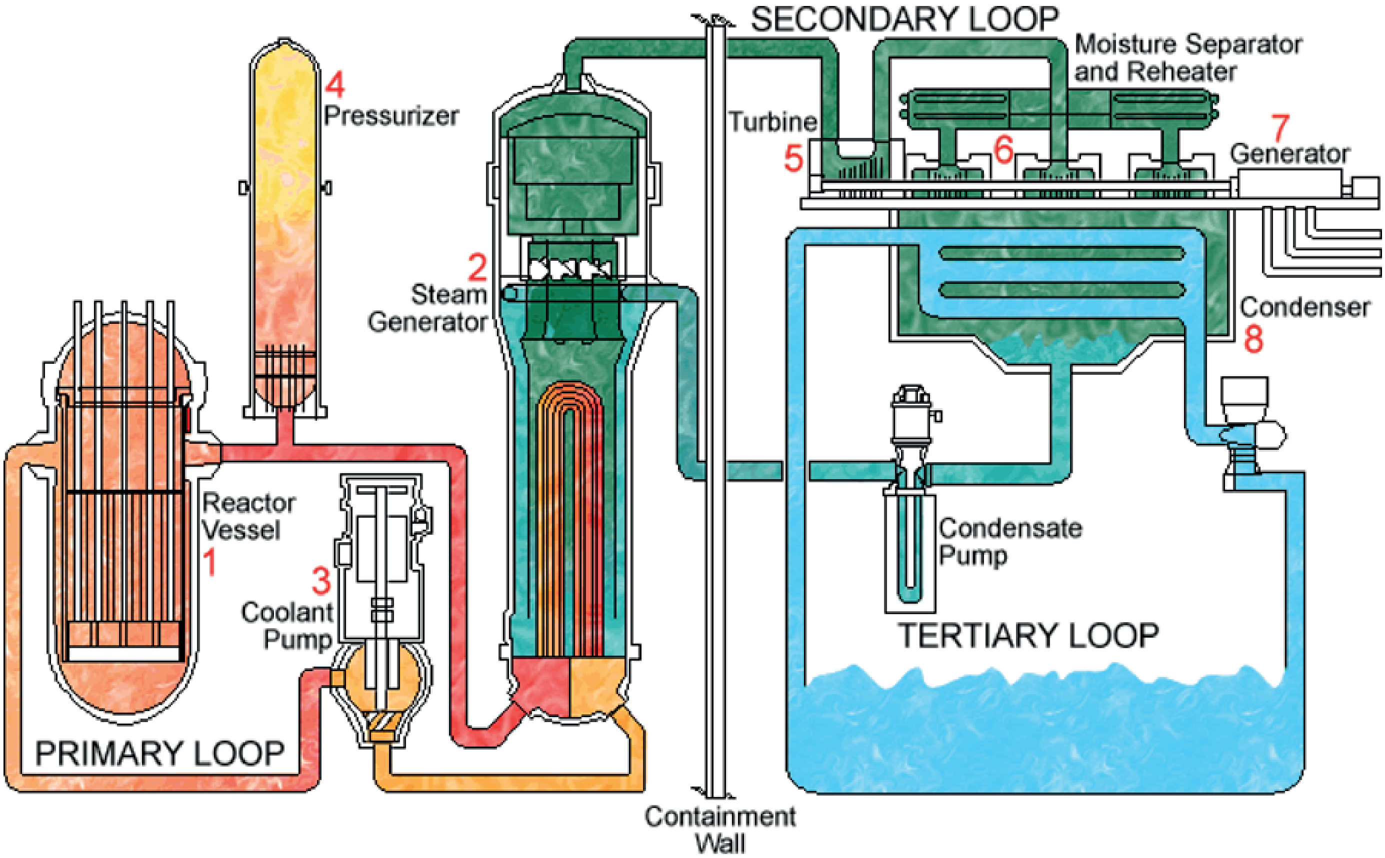


Koeberg operates on three separate water systems. The water is also known as the coolant. In other types of nuclear reactors, gas is used as the coolant. The fact that the three systems are separate is crucial because it means that the water in the reactor, which is radioactive but is in a closed system, does not come into contact with the other two systems and therefore does not contaminate the water in these systems.

The primary system takes heat away from the fuel in the (1) reactor to the tubes in the (2) steam generators. The water is then returned to the reactor using a (3) pump. In this primary system, Koeberg uses a three-loop system which is kept under pressure by a (4) pressuriser hence the name Pressurised Water Reactor or PWR. As we have said, this system is closed, and water from it does not come into contact with the secondary or tertiary system.

The secondary system is also closed. Water is pumped into the (2) steam generator. This water is allowed to boil and form steam which drives one (5) high-pressure turbine, three (6) low-pressure turbines and a (7) generator. The generator produces 921MW of electricity. Once the steam has driven the turbines, it flows to the (8) condensers where it is cooled back to water and circulated back to the (2) steam generator.

The tertiary system is used in the condensers. The condensers' cooling water system uses seawater at the rate of 80 tons/sec to cool the steam in the (8) condensers. Once it has cooled the steam down it is returned to the sea.

(The SAIEE acknowledges using the technical literature from the Eskom Technical Fact Sheet on Koeberg).

THE ENVIRONMENTAL STUDY COMMITTEE

CHAIRMAN

Prof Antoine F. Mulaba-Bafubiandi FSAIMM
Head: Mineral Processing and Technology Research Centre
Professor Hydrometallurgy, Dept of Metallurgy, Faculty of Engineering and the Built Environment,
University of Johannesburg

Professor Antoine F. Mulaba-Bafubiandi is the Head of Mineral Processing and Technology Research Centre and Professor of Hydrometallurgy at the Department of Metallurgy at the University of Johannesburg. He is the former Head of School of Mining, Metallurgy and Chemical Engineering.

He is a Fellow of the Southern African Institute of Mining and Metallurgy, and NRF rated scientist as "Established Researcher". His research interests encompass natural resources beneficiation and value addition, circular economy, strategic minerals, industry symbiosis, waste-to-energy, and nuclear waste engineering science.

VICE-CHAIRPERSON

Dr Suzan Bvumbi
Senior Physicist
National Radioactive Waste Disposal Institute

Dr Suzan Bvumbi is a Senior Physicist at the National Radioactive Waste Disposal Institute (NRWDI). She is one of the founding staff members of NRWDI. Her tasks include policies and practices for low and intermediate waste processing and disposal, spent fuel management and related research. Suzan is an Experimental Nuclear Physicist with special competence in Nuclear Structure, specialising in gamma-ray spectroscopy. She has taught and continued with nuclear research while lecturing at the University of Johannesburg from 2013 to 2016. She is currently in collaboration with ex-colleagues from the University of Johannesburg, partnerships with other academic institutions and iThembaLABS.

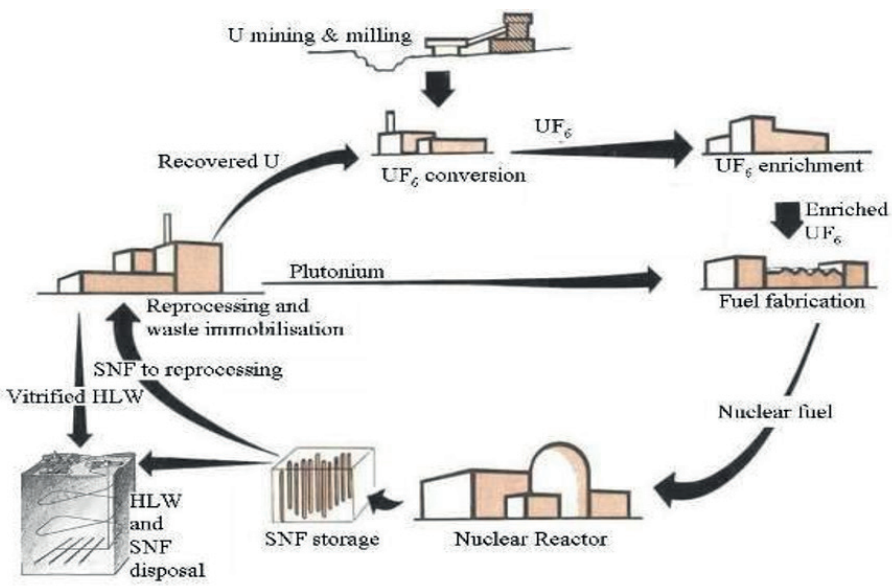
ENVIRONMENTAL MANAGEMENT OF URANIUM AND NUCLEAR MATERIALS

The Sun is the sole source of all energy; available in real-time and in inventory; carbon, hydrogen, uranium etc. Each resource has boundary conditions for application. In Uranium and Nuclear, regulatory policy and practice call for continuous safety assurance, impact and risk assessment, and management plus tight limits for radiation's impact on human health, flora, and fauna.

The liability of nuclear is infinite; by design and assurance, it is managed towards zero. These attributes of nuclear necessitate the employability of many specialists, resulting in constant and high administrative overheads. The overheads of nuclear must be read in conjunction with an industrialised economy, now in its 4th stage of evolution, in service of cities consisting of millions and countries of billions of citizens.

The Environmental Study Committee will focus on the full nuclear fuel cycle; from U mining and milling to low-level waste disposal, spent fuel management and long term storage. For the present and future day, reprocessing and uranium recovery is beyond the scope of the chapter. The Study Committee will invest in the ethical principles around nuclear waste and spent fuel, responsible for handling waste and safe long-term disposal in geological structures.

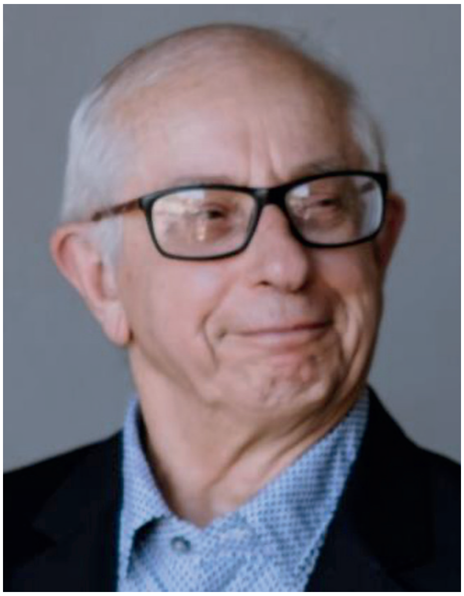
The Committee will prioritise South African capacity development for pre-processing before disposal; the development of appropriate technologies and education, training and skills development. We will explore the need for serving Africa as a regional long-term storage facility.



A Typical Nuclear Fuel Cycle from Mine to Low-Level Disposal and Long Term Storage

STUDY ASSIGNMENT: INVESTIGATIONS INTO GEOLOGICAL STRUCTURES FOR LONG TERM STORAGE OF SPENT FUEL

Koeberg's 40 years of electricity production has accumulated spent fuel that requires long term storage. Another 20-year life extension to Koeberg will produce more spent fuel that will need long term storage. The study committee's focus will be to investigate and report on the suitability of geological structures for long term spent fuel storage; as part contribution to knowledge production in the National Interest. Dr Marco Andreoli, a specialist consultant at the University of the Witwatersrand, will be led this work.



VICE-CHAIRMAN

Dr Marco Andreoli
Specialist Geological Consultant
University of the Witwatersrand

Marco Andreoli is a geologist and obtained his PhD in metamorphic petrology in 1982 from the University of the Witwatersrand (Wits). In the same year, he was employed by the Atomic Energy Board, later renamed the South African Nuclear Energy Corporation (Necsa), until his retirement in 2011. During this period, Dr Andreoli covered many aspects of nuclear geology investigations, spanning from uranium studies, thorium source rocks to the geological characterisation of proposed nuclear sites. He primarily focusses on those in the Quoin point area (Western Cape) and the Vaalputs National Radioactive Waste Disposal Facility (Northern Cape). As a result of these projects, Dr Andreoli matured a strong interest in studying natural analogues, the pathways of radioactivity through groundwater and problems of tectonics and neotectonics.

Since his retirement, Dr Andreoli has worked as a consultant on geological stability and neotectonics for Necsa (Vaalputs, Pelindaba) and other clients (Natal, Malawi). In 2009 Dr Andreoli was rated C1 by the South African National Research Foundation and provided with research funds primarily used to study the long term changes in tectonic stress across southern Africa.

This work continues to date with colleagues at the University of the Witwatersrand and of Johannesburg. In past years, with specialists from other Universities, in Los Angeles, Tel Aviv, and the GeoForschungsZentrum Potsdam, Germany. Dr Andreoli's collaborations led to numerous articles published in peer-reviewed Journals. As an additional interest, Dr Andreoli is also involved in multidisciplinary investigations of meteorite impacts in South Africa and Egypt.

THE SCIENCE AND TECHNOLOGY STUDY COMMITTEE

CHAIRMAN

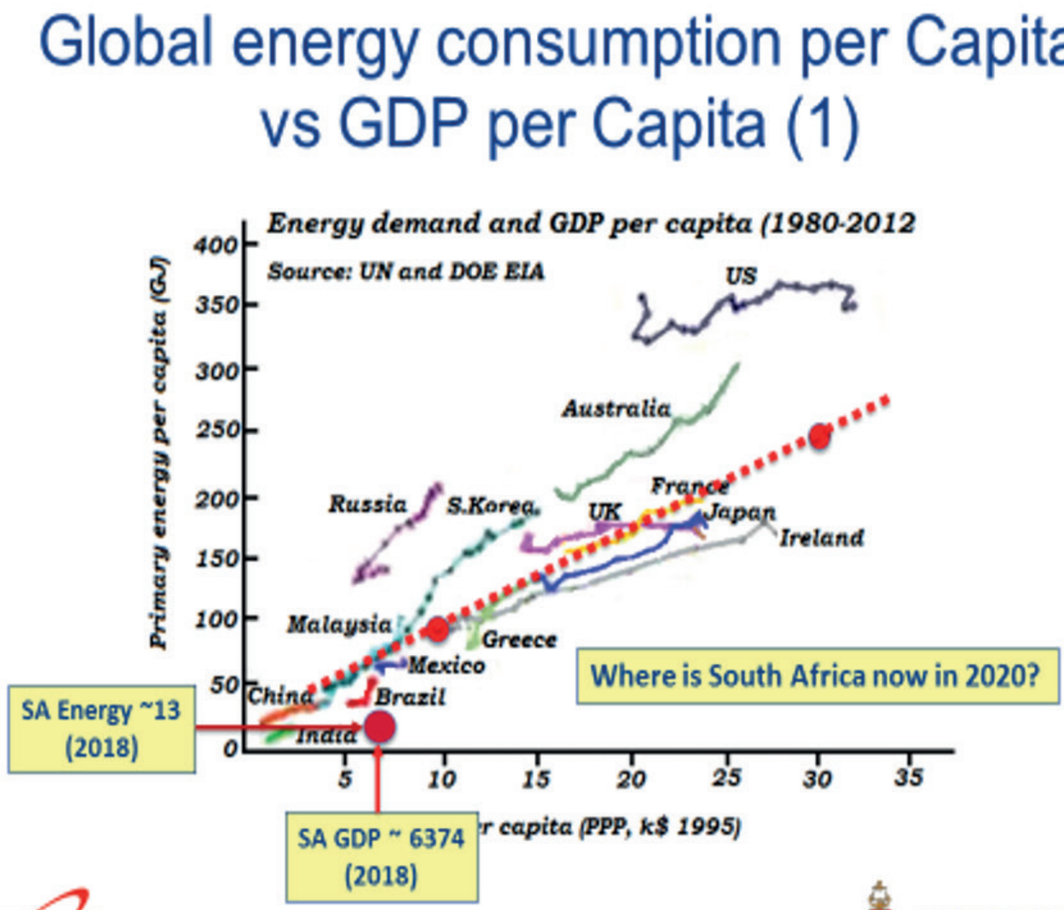
Professor Johan Slabber
National Nuclear Regulator Chair:
Nuclear Safety and Security
Department of Mechanical and
Aeronautical Engineering
Faculty of Engineering and the Built
Environment
University of Pretoria

Professor Johan Slabber is currently working in the Department of Mechanical and Aeronautical Engineering at the University of Pretoria. He is involved in giving the degree in Mechanical Engineering a nuclear flavour. He is also focusing his post-graduate research on studies to make Light Water Reactor fuel more accident tolerant. The University of Pretoria hosts a Nuclear Safety and Security (CNSS) Centre of the National Nuclear Regulator (NNR). In this regard, he holds the chair of Nuclear Safety and Security funded by the NNR and coordinates projects of importance to the NNR executed by the University of Pretoria and other similar national and international institutions. Before joining the University of Pretoria, he was the Chief Technology Officer of the company PBMR (Pty) Ltd. In his earlier career, he held General Manager, Reactor Technology at the Atomic Energy Corporation of South Africa (now Necsa). At Integrators of Systems Technology (IST), he was the Chief Systems Engineer.

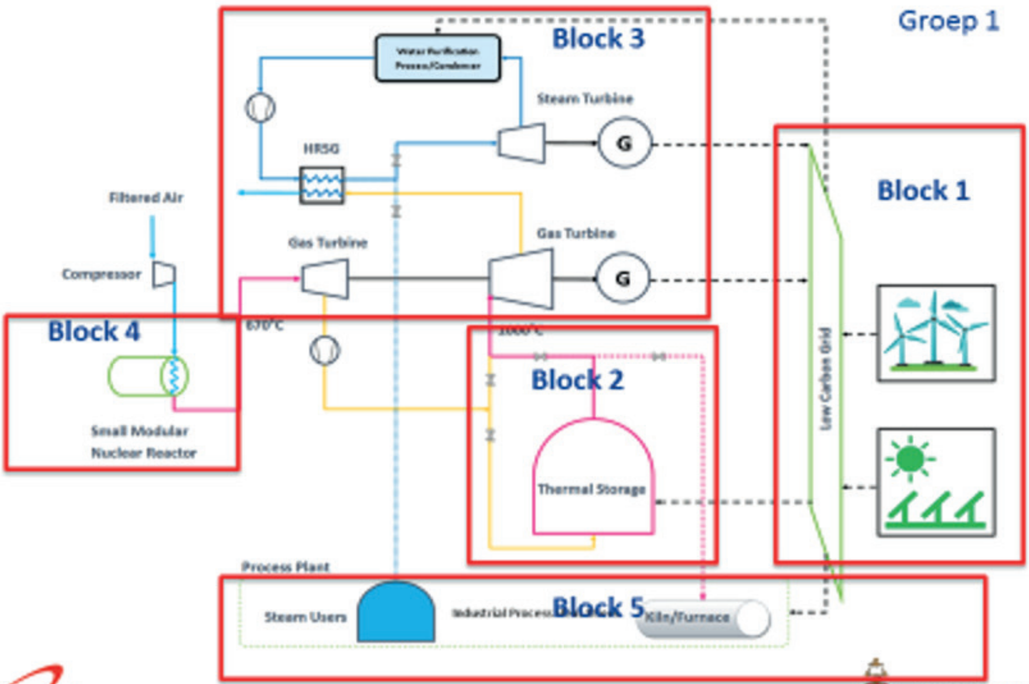
He led a small team which completed the first conceptual systems design of a small Demonstration High-Temperature Reactor. In 1994 he joined the Safeguards Department of the International Atomic Energy Agency (IAEA) in Vienna. He completed a contract period of 5 years before joining PBMR (Pty) Ltd in 1999. He is a former representative of South Africa on the International Nuclear Safety Group (INSAG) of the IAEA and a former member of the Senior Industry Advisory Panel (SIAP) of the Generation IV Industry Forum (GIF). He held a Doctorate in Mechanical Engineering from the University of Pretoria. He was introduced to and trained in nuclear engineering at the Oak Ridge School of Reactor Technology in the United States.

THE PRESENT AND FUTURE POWER NEEDS OF SOUTH AFRICA

The Science & Technology Study Committee has focused on the present and future power needs of South Africa specifically and the rest of Africa for a sustainable source of guaranteed electrical power that conforms to the "low carbon economy". The concept of the "Power Cell", a cohabitation between a small micro- nuclear reactor and renewable energy in the form of wind and solar power generation, is being explored to address this urgent need of power. The requirements as defined by the Generation IV roadmap is being overlaid on the design characteristics of the micro-reactor to show that it conforms well to those requirements; to result in strong interlinking between the South African manufacturing industry, the South African Nuclear Energy Development Corporation (NECSA) and other co-working institutions that will form a supply chain network during deployment and routine operation of the Power Cell system. We envisage the co-generation possibilities, such



Schematic diagram of the "Power Cell"



SAIEE

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Status of development

Block	Status of development
1	Relatively well developed and is being used but improvements may still be required;
2	Development of energy storage banks are being done on a worldwide basis;
3	No development required but some adaptations may be required to existing designs for optimum performance;
4	Micro-reactor development is being done in many countries world wide.

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as the supply of desalinated water and hydrogen production using high-temperature electrolysis.

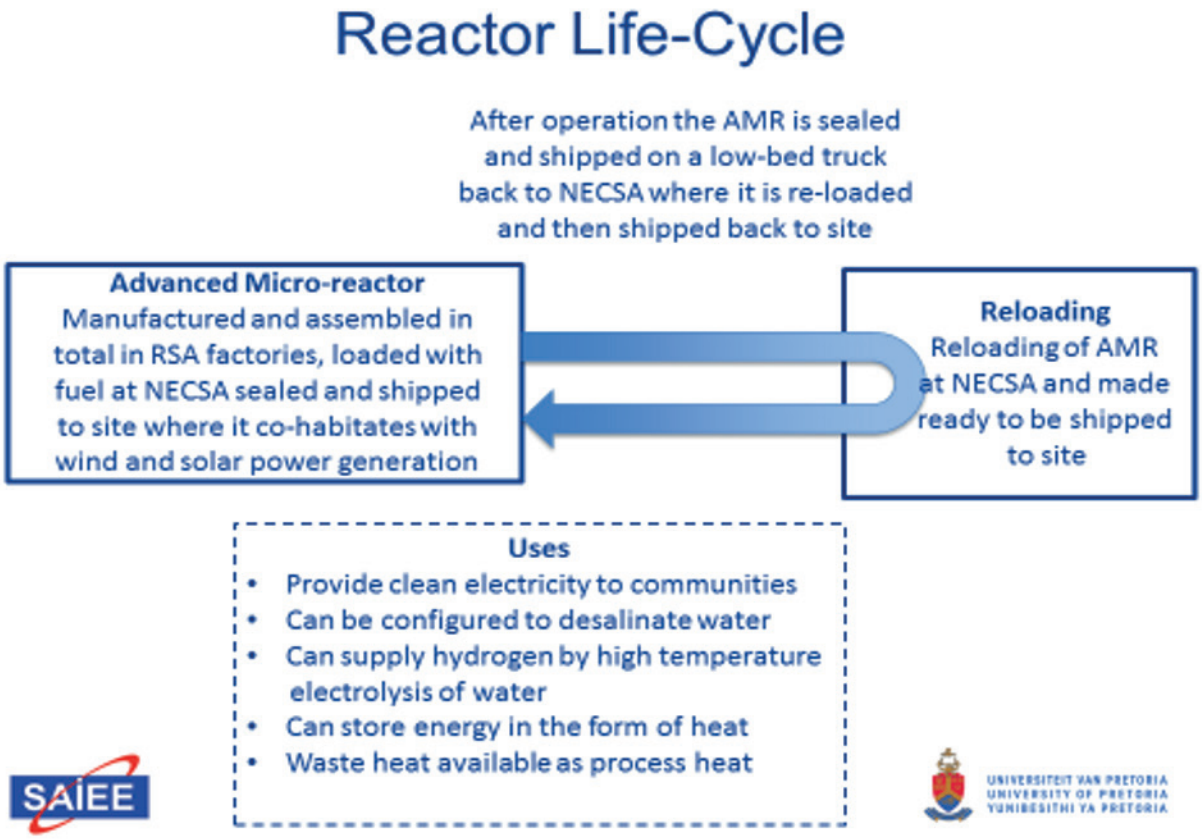
The backlog in electricity generation capacity in South Africa is BIG. Large blocks of generating capacity are urgently required if South Africa is serious about its objectives to grow at a rate that is at least aligned with the population growth rate. South Africa is committed to a greener economy with renewable energy listed as high on the priority list. It is realised in general that renewable energy does not offer a complete solution for users that is dependent on a guaranteed constant supply of electricity, such as operators of factories, mines, smelters etc. At the same time, homeowners may be somewhat more tolerant. Part of the solution will be to "eat the elephant in small bites" to use this phrase and adapt a plan to add reliable "green" generation capacity in tiny quanta. This small quanta is to be seen as "Power Cells".

DESCRIPTION OF THE MICRO REACTOR

The reactor is a small 10 MWt helium-gas cooled reactor that heats the air in a heat exchanger to around 700° C. The heated air then becomes the energy carrier to drive the rest of the thermodynamic cycle. The fuel is in the form of UO2. Microspheres coated with graphite and silicon carbide (SiC) that is the primary fission product containment. The microspheres are contained in SiC tubes in a Pb/Bi eutectic alloy that transfers heat from the coated particles to the tube wall. This tube forms then the fuel assembly of the reactor and the SiC tube wall functions as secondary containment of the fission products. The fuel assemblies are then loaded in a mono-block graphite structure that forms the core of the micro-reactor. The core design is for the use of high assay low enriched uranium (19%) and that the reactor can operate for five years between fuel reloads. It is still early days in the development of this type of reactor worldwide, but in the design, it is a requirement to stay as close to well tested and proved concepts that require mainly adaptation to a smaller format.

WHAT DOES THIS MEAN FOR SOUTH AFRICA?

It is suggested that NECSA becomes the hub for the development and research in collaboration with universities and the industry. This will infuse new life into the organisation since it will provide a joint research and development goal. In this way, South African universities will become involved in R&D in several areas. If managed properly, it will contribute synergistically to produce an excellent product and stimulate advanced



industrialisation. The South African industry will be enabled to form part of the supply chain in several technological areas. The establishment of new initiatives will be stimulated since constant power supply will now be guaranteed. The end product will form part of a grand plan to supply GREEN energy (and possibly also desalinated water) to some populations. The Power Cell provides the possibility to give energy to users of high-temperature process heat.

The following two study committees will formally launch in early 2021.

THE EDUCATION STUDY COMMITTEE

Chairman: Professor Simon Connell FSAIEE, FSAIP: University of Johannesburg
Co-Chair: Dr Rotondwa Mudau: Nuclear Energy Corporation of SA

With physics and mathematics associated with uranium and nuclear, there is unlimited scope for knowledge acquisition, sharing and development; from school, university to industry; from a graduate to a professional and onto continuous learning. Nuclear is an ideal career that can promote job security, employability, growth and professional development.

The Education Study Committee is currently developing its mandate:

- To encourage and invest in scholars to pursue careers in Science, Technology, Engineering and Mathematics (STEM); Nuclear is all about STEM.
- To promote Undergraduate and Post-Graduate development; from Bachelors to Masters, to Doctoral to Post-Doctoral Qualifications in Nuclear Science, Technology, Engineering and Mathematics.
- To manage Short Learning Programs and Continuous Professional Development courses for practising scientists and engineers.
- To participate in National and International Technical Societies to share experiences and set new agendas for knowledge production relevant to Nuclear STEM.

THE MEDICAL APPLICATIONS STUDY COMMITTEE

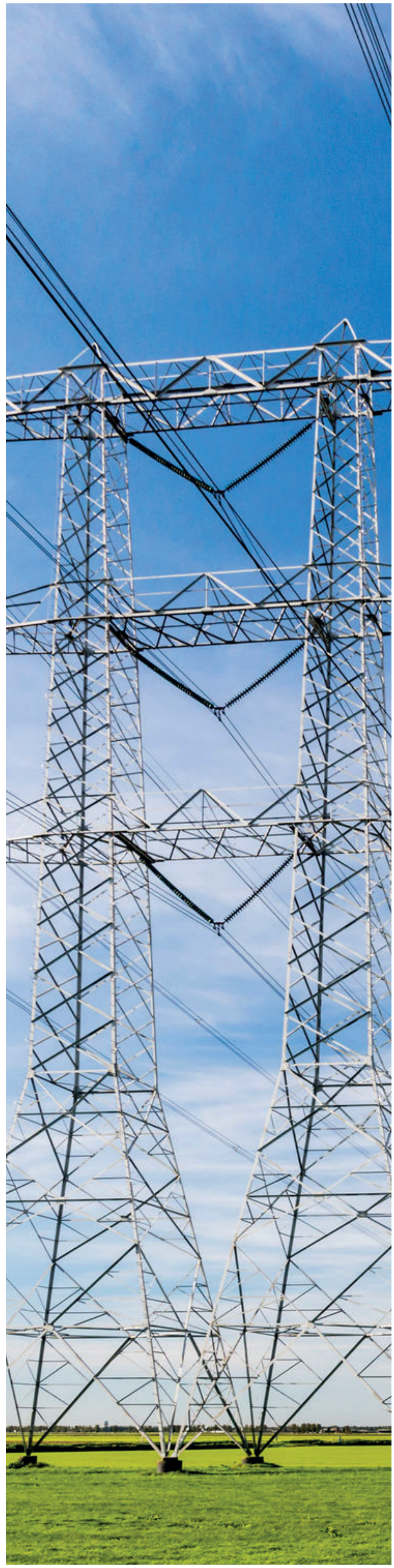
Chairman: Dr Sonwabile Ngcezu

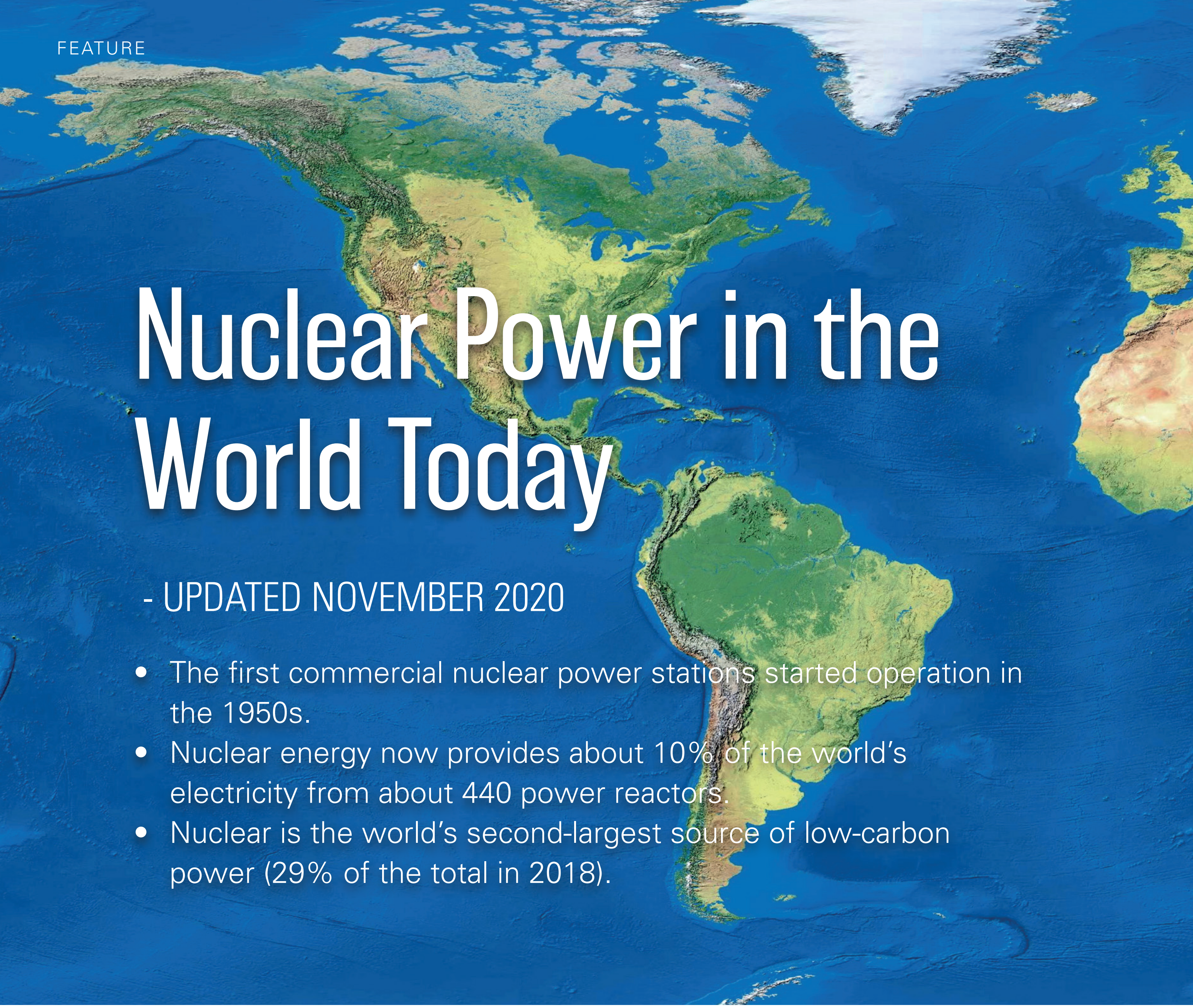
SA is a leading exporter of Medical Radioisotopes, earning the country valuable foreign exchange. NECSA and NTP Medical Radioisotopes work in the multibillion USD market. The global market was valued in 2016 at $11 b and is projected to grow to $ 20b in 2021. NECSA NTP is one of five global manufacturers of radioisotopes.

The medical applications study committee is currently developing its mandate to cover the broad field as defined by:

- Radioisotope Production: Molybdenum 99 (Mo-99)
- Nuclear Imaging (MRI, PET, SPECT)
- Diagnostic Radiation Medicine
- Therapeutic Nuclear Medicine
- Research into COVID 19, Virology Sciences and Public Health

We encourage members to join our Chapter. If you are interested to join any of these study committees, please send your CV and bio to nuclearchapter@saiee.org.za.





Nuclear Power in the World Today

- UPDATED NOVEMBER 2020

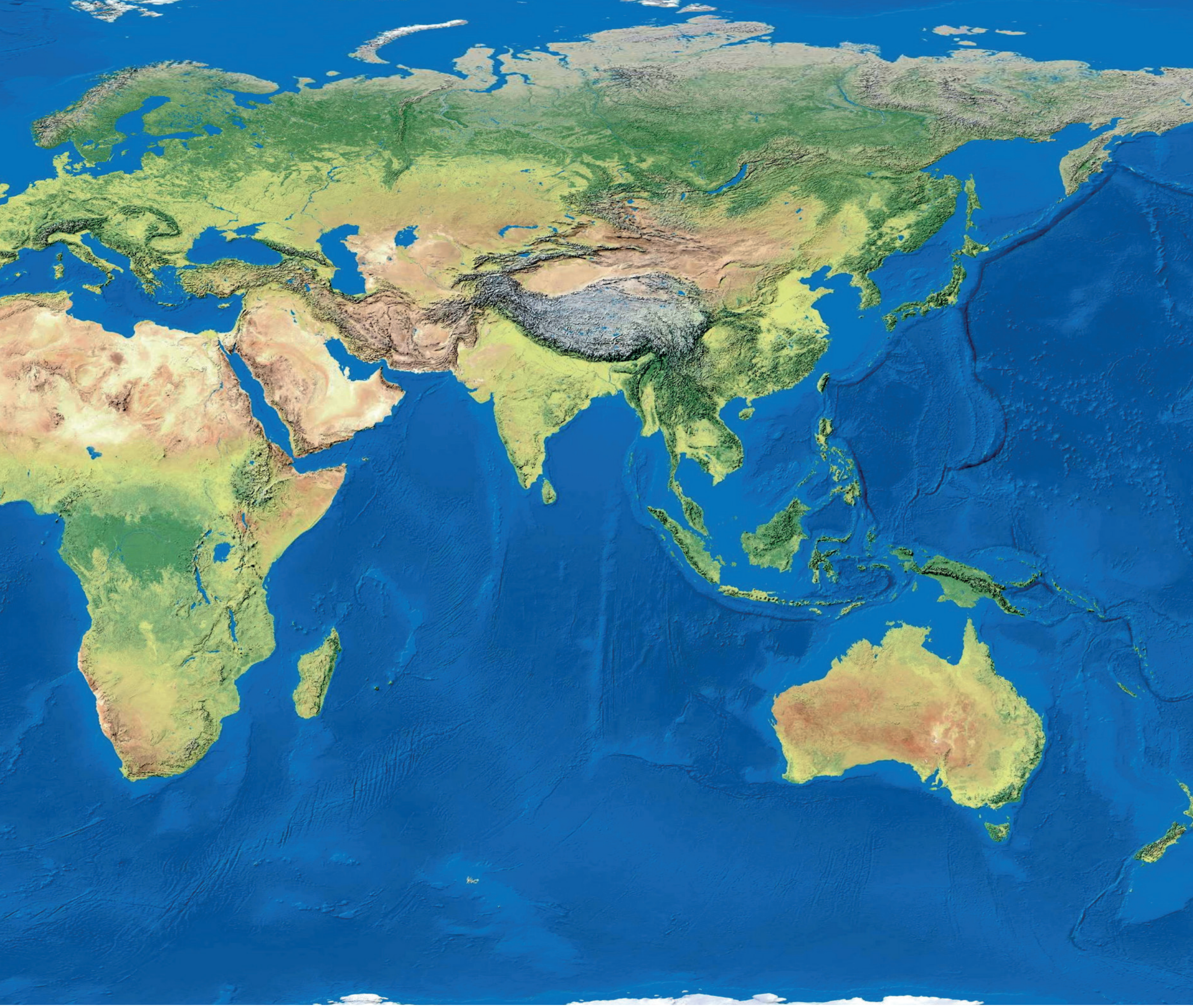
- The first commercial nuclear power stations started operation in the 1950s.
- Nuclear energy now provides about 10% of the world's electricity from about 440 power reactors.
- Nuclear is the world's second-largest source of low-carbon power (29% of the total in 2018).

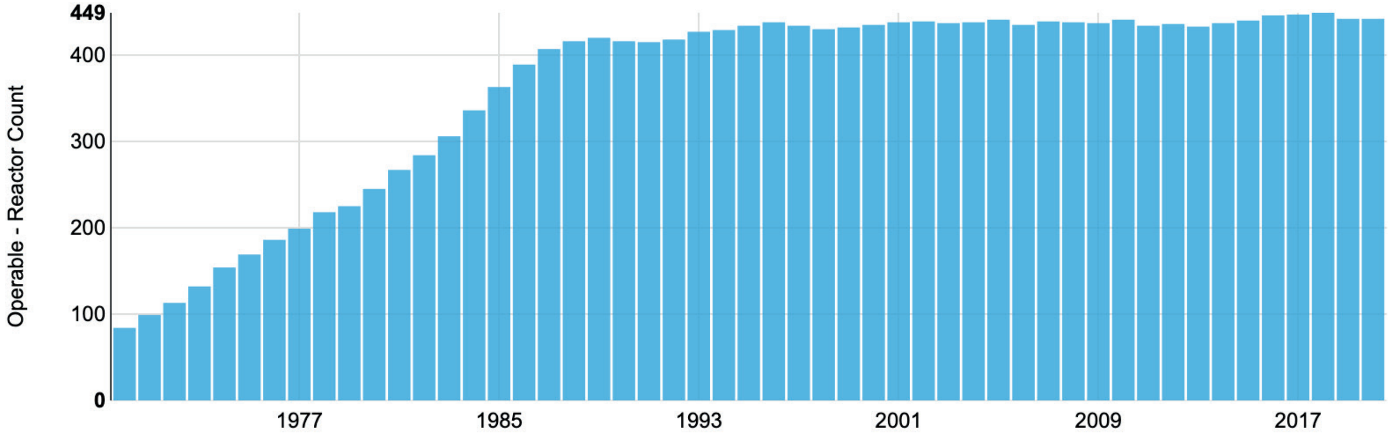
Over 50 countries utilise nuclear energy in about 220 research reactors. In addition to research, these reactors are used for the production of medical and industrial isotopes and training.

Nuclear technology uses the energy released by splitting the atoms of certain elements. It was first developed in the 1940s, and during the Second World War research initially focused on producing bombs. In the 1950s attention turned to the peaceful use of nuclear fission, controlling it for power generation.

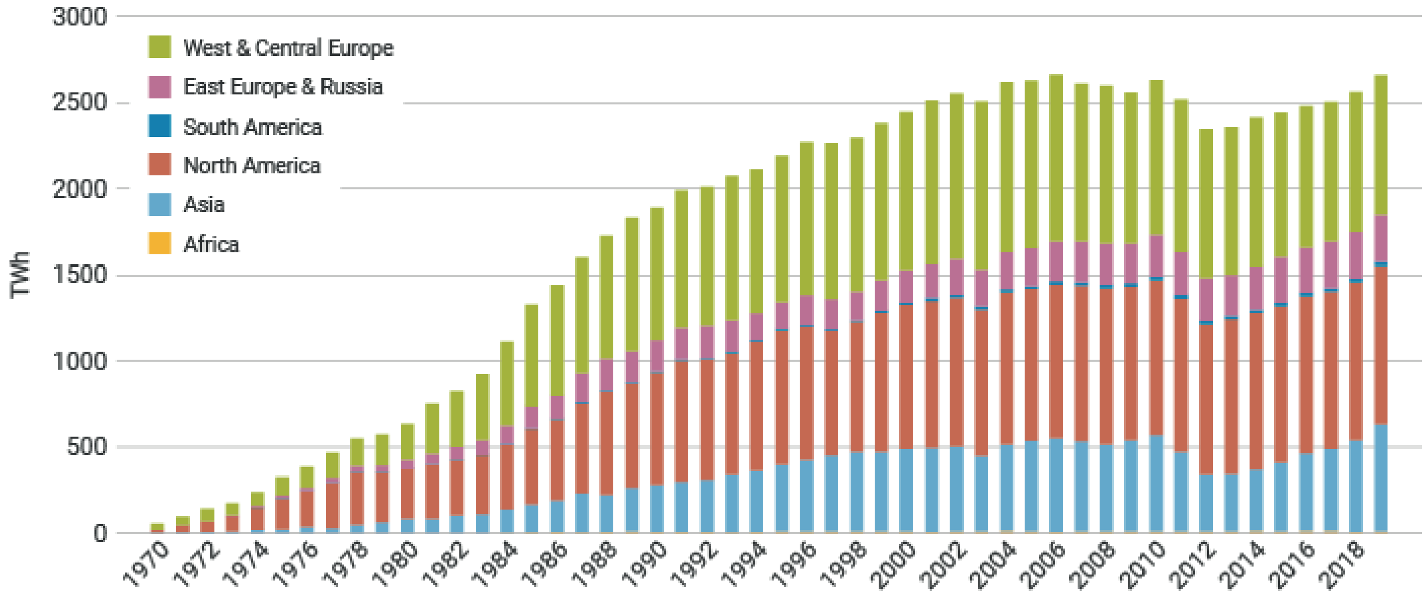
Civil nuclear power can now boast more than 17,000 reactor years of experience, and nuclear power plants are operational in 31 countries worldwide. In fact, through regional transmission grids, many more countries depend on nuclear-generated power; Italy and Denmark, for example, get almost 10% of their electricity from imported nuclear power. When the commercial nuclear industry began in the 1960s, there were clear boundaries between the East and West sectors. Today, the separate American and Soviet spheres no longer exist, and the nuclear industry is characterised by international commerce. A reactor under construction in Asia today may have components supplied from South Korea, Canada, Japan, France, Germany, Russia, and other countries.

Similarly, uranium from Australia or Namibia may end up in a reactor in the UAE, converted in France, enriched in the Netherlands, and deconverted in the UK and fabricated in South Korea. The uses of nuclear technology extend well beyond the provision of low-carbon energy. It helps control the spread of disease, assists doctors in diagnosing and treating patients, and





Graph 1: Number of Operable Reactors Worldwide



Source: World Nuclear Association and IAEA Power Reactor Information Service (PRIS)

Graph 2: Nuclear Electricity Production

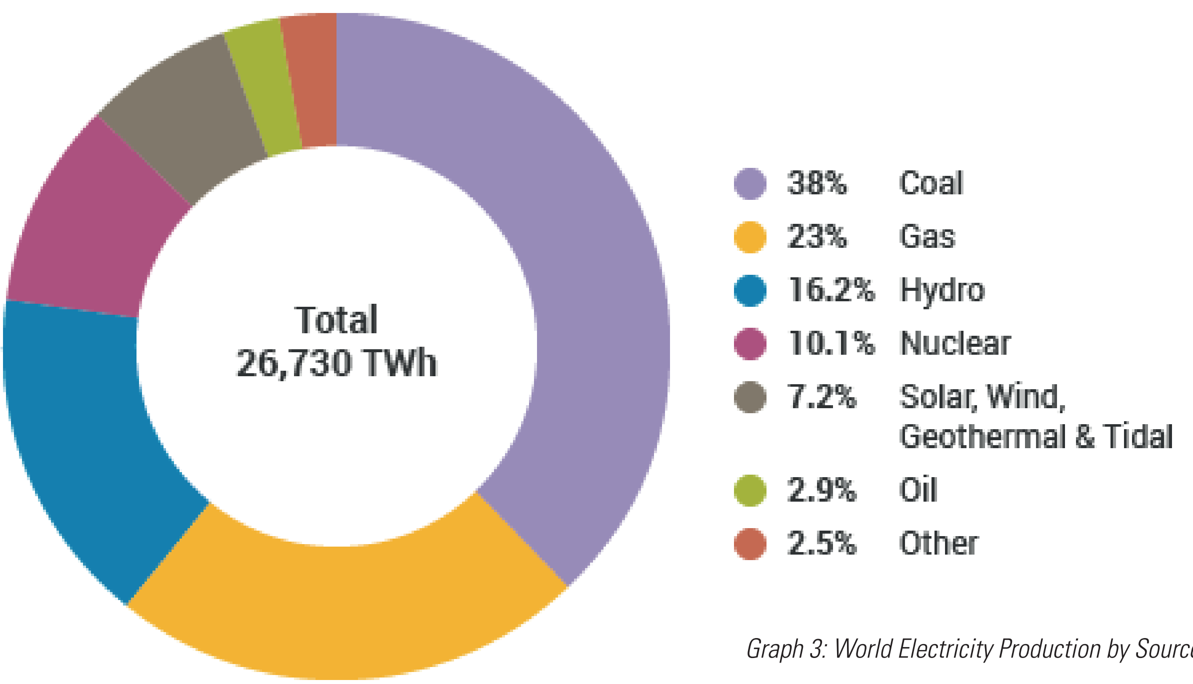
powers our most ambitious missions to explore space. These varied uses position nuclear technologies at the heart of the world's efforts to achieve sustainable development.

NUMBER OF OPERABLE REACTORS WORLDWIDE

About 440 nuclear power reactors generate around 10% of the world's electricity. About 50 more reactors are under construction, equivalent to approximately 15% of existing capacity.

In 2019 nuclear plants supplied 2657 TWh of electricity, up from 2563 TWh in 2018. This is the seventh consecutive year that global nuclear generation has risen, with output 311 TWh higher than in 2012.

Twelve countries in 2019 produced at least one-quarter of their electricity from nuclear. France gets around three-quarters of its electricity from nuclear energy. Slovakia and Ukraine get more than half from nuclear, whilst Hungary, Belgium, Sweden, Slovenia, Bulgaria, Switzerland, Finland and the Czech Republic get one-third or more. South Korea receives more than 30% of its electricity from nuclear, while in the



Graph 3: World Electricity Production by Source 2018

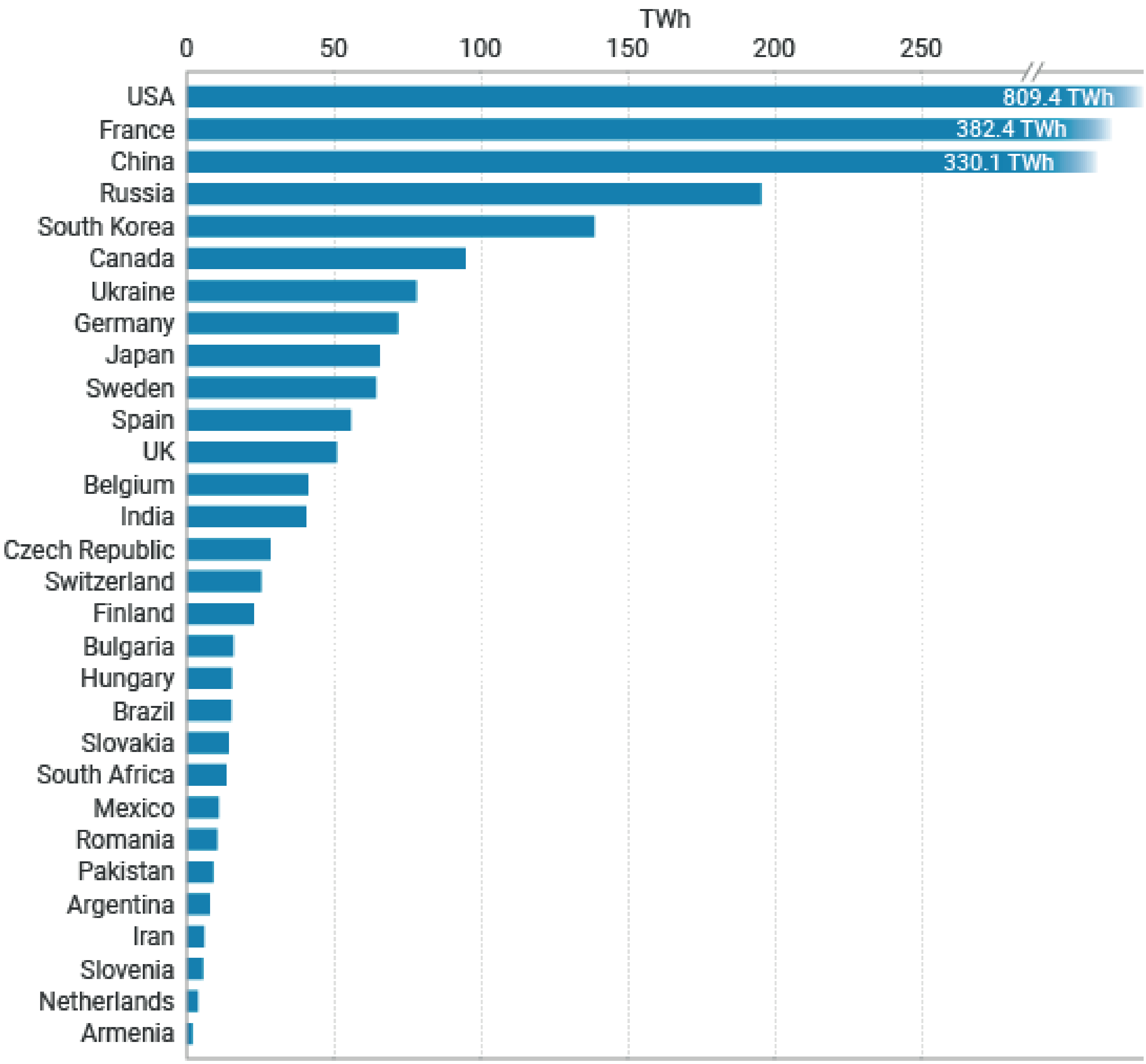
USA, UK, Spain, Romania and Russia about one-fifth of electricity is from nuclear. Japan was used to relying on nuclear power for more than one-quarter of its electricity and expected to return somewhere near that level.

NUCLEAR ENERGY AND COVID-19

Coronavirus disease 2019 (COVID-19) is an infectious disease caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). The spread of the novel coronavirus has required dramatic action to be taken in all aspects of life worldwide.

Maintaining a reliable electricity supply is vital. Nuclear energy provides about 10% of the world's electricity, so nuclear reactors have a crucial role. Reactor operators have taken steps to protect their workforce and have implemented business continuity plans to ensure the continuing function of their operations' key aspects.

Beyond power generation, nuclear technologies have medical applications that will help combat COVID-19. The International Atomic Energy Agency (IAEA) provides diagnostic kits, equipment and training in nuclear-derived detection techniques to



Graph 4: Nuclear Generation by Country 2019

countries asking for assistance in tackling the worldwide spread of the novel coronavirus causing COVID-19.

NEED FOR NEW GENERATING CAPACITY

There is a clear need for new generating capacity worldwide, both to replace old fossil fuel units, especially coal-fired ones, which emit a lot of carbon dioxide and meet the increased demand for electricity in many countries.

In 2018, 64% of electricity was generated from the burning of fossil fuels. Despite the strong support for, and growth in, intermittent renewable electricity sources in recent years, the fossil fuel contribution to power generation has remained virtually unchanged in the last ten years or so (66.5% in 2005).

The Organisation for Economic Co-operation and Development (OECD) International Energy Agency publishes annual scenarios related to energy.

In its World Energy Outlook 2020 there is an ambitious 'Sustainable Development Scenario' consistent with the provision of clean and reliable energy and a reduction of air pollution, among other aims. In this decarbonisation scenario, electricity generation from nuclear increases by almost 55% by 2040 to 4320 TWh, and capacity grows to 599 GWe.

The World Nuclear Association has put forward a more ambitious scenario than this – the Harmony programme proposes 1000 GWe of new nuclear capacity by 2050, to provide 25% of electricity then (about 10,000 TWh) from 1250 GWe of capacity (after allowing for retirements). This would require adding 25 GWe per year from 2021, escalating to 33 GWe per year, which is not much different from the 31 GWe added in 1984, or the overall record of 201 GWe in the 1980s. Providing one-quarter of the world's electricity through nuclear would substantially reduce carbon dioxide emissions and improve air quality.

WORLD OVERVIEW

All parts of the world are involved in nuclear power development, and some examples are outlined below.

For up-to-date data on operable, under construction and planned reactors worldwide, see the table of World Nuclear Power Reactors & Uranium Requirements.

For detailed country-level information, see the Country Profiles section of the World Nuclear Association's Information Library.

NORTH AMERICA

Canada has 19 operable nuclear reactors, with a combined net capacity of 13.6 GWe. In 2019, nuclear generated 15% of the country's electricity. All but one of the country's 19 nuclear reactors are sited in Ontario. Ten of those units – six at Bruce and four at Darlington – are to undergo refurbishment. The programme will extend the operating lifetimes by 30-35 years. Similar refurbishment work enabled Ontario to phase out coal in 2014, achieving one of the world's cleanest electricity mixes.

Mexico has two operable nuclear reactors, with a combined net capacity of 1.6 GWe. In 2019, nuclear generated 4.5% of the country's electricity.

The USA has 94 operable nuclear reactors, with a combined net capacity of 96.6 GWe. In 2019, nuclear generated 20% of the country's electricity. There had been four AP1000 reactors under construction, but two of these have been cancelled. One of the reasons for the hiatus in new-build in the USA has been an extremely successful evolution in maintenance strategies.

Over the last 15 years, improved operational performance has increased US nuclear power plants' utilisation, with the increased output equivalent to 19 new 1000 MWe plants being built.

2016 saw the first new nuclear power reactor enter operation in the country for 20 years. Despite this, the number of operable reactors has reduced in recent years, from a peak of 104 in 2012.

Early closures have been brought on by combining factors including cheap natural gas, market liberalisation, over-subsidy of renewable sources, and political campaigning.

SOUTH AMERICA

Argentina has three reactors, with a combined net capacity of 1.6 GWe. In 2019, the country generated 6% of its electricity from nuclear.

Brazil has two reactors, with a combined net capacity of 1.9 GWe. In 2019, nuclear generated 3% of the country's electricity.

WEST & CENTRAL EUROPE

Belgium has seven operable nuclear reactors, with a combined net capacity of 5.9 GWe. In 2019, nuclear generated 48% of the country's electricity.

Finland has four operable nuclear reactors, with a combined net capacity of 2.8 GWe. In 2019, nuclear generated 35% of the country's electricity. A fifth reactor – a 1720 MWe EPR – is under construction, and there are plans to build a Russian VVER-1200 unit at a new site (Hanhikivi).

France has 56 operable nuclear reactors, with a combined net capacity of 61.4 GWe. In 2019, nuclear generated 71% of the country's electricity. A 2015 energy policy had aimed to reduce the country's share of nuclear generation to 50% by 2025.

This target has now been postponed to 2035. The country's energy minister said that the target was not realistic. It would increase the country's carbon dioxide emissions, endanger the security of supply and put jobs at risk.

One reactor is currently under construction in France – a 1750 MWe EPR at Flamanville.

Six nuclear power reactors continue to operate in Germany, with a combined net capacity of 8.1 GWe. In 2019, nuclear generated 12.5% of the country's electricity. Germany is phasing out nuclear generation by about 2022 as part of its Energiewende policy. Energiewende, widely identified as the most ambitious national climate change mitigation policy, has yet to deliver a meaningful reduction in carbon dioxide (CO_2) emissions.

In 2011, the year after the policy was introduced, Germany emitted 731 Mt CO_2 from fuel combustion; in 2018, the country emitted 677 Mt CO_2 and was the world's seventh-biggest emitter of CO_2. The German government expects to miss its target of a 40% reduction in emissions relative to 1990 levels by a wide margin.

The Netherlands has a single operable nuclear reactor, with a net capacity of 0.5 GWe. In 2019, nuclear generated 3% of the country's electricity.

Spain has seven operable nuclear reactors, with a combined net capacity of 7.1 GWe. In 2019, nuclear generated 21% of the country's electricity.

Sweden has seven operable nuclear reactors, with a combined net capacity of 7.7 GWe. In 2019, nuclear generated 34% of the country's electricity. The government is closing down some older reactors but has invested heavily in operating lifetime extensions and uprates.

Switzerland has four operable nuclear reactors, with a combined net capacity of 3.0 GWe. In 2019, nuclear generated 24% of the country's electricity.

The United Kingdom has 15 operable nuclear reactors, with a combined net capacity of 8.9 GWe. In 2019, nuclear generated 16% of the country's electricity. A UK government energy paper in mid-2006 endorsed the replacement of the country's ageing fleet of nuclear reactors with the new nuclear build. Construction has commenced on the first of a new generation of plants.

CENTRAL AND EAST EUROPE, RUSSIA

Armenia has a single nuclear power reactor with a net capacity of 0.4 GWe. In 2019, nuclear generated 28% of the country's electricity.

Belarus has one operable nuclear power reactor, connected to the grid in November 2020, and a second reactor under construction. Almost all of the country's electricity is produced from natural gas.

Bulgaria has two operable nuclear reactors, with a combined net capacity of 2.0 GWe. In 2019, nuclear generated 38% of the country's electricity.

The Czech Republic has six operable nuclear reactors, with a combined net capacity of 3.9 GWe. In 2019, nuclear generated 35% of the country's electricity.

Hungary has four operable nuclear reactors, with a combined net capacity of 1.9 GWe. In 2019, nuclear generated 49% of the country's electricity.

Romania has two operable nuclear reactors, with a combined net capacity of 1.3 GWe. In 2019, nuclear generated 19% of the country's electricity.

Russia has 38 operable nuclear reactors, with a combined net capacity of 28.6 GWe. In 2019, nuclear generated 20% of the country's electricity. A government decree in 2016 specified construction of 11 nuclear power reactors by 2030, in addition to those already under construction. At the start of 2020, Russia had four reactors under construction, with a combined capacity of 4.8 GWe.

The strength of Russia's nuclear industry is reflected in its dominance of export markets for new reactors.

The country's national nuclear industry is currently involved in new reactor projects in Belarus, China, Hungary, India, Iran and Turkey, and to varying degrees as an investor in Algeria, Bangladesh, Bolivia, Indonesia, Jordan, Kazakhstan, Nigeria, South Africa, Tajikistan and Uzbekistan among others.

Slovakia has four operable nuclear reactors, with a combined net capacity of 1.8 GWe. In 2019, nuclear generated 54% of the country's electricity. A further two units are under construction.

Slovenia has a single operable nuclear reactor with a net capacity of 0.7 GWe. In 2019, Slovenia generated 37% of its electricity from nuclear.

Ukraine has 15 operable nuclear reactors, with a combined net capacity of 13.1 GWe. In 2019, nuclear generated 54% of the country's electricity.

Turkey commenced construction of its first nuclear power plant in April 2018, with the start of operation expected in 2023.

ASIA

Bangladesh started construction on the first of two planned Russian VVER-1200 reactors in 2017. Construction on the second began in 2018. It plans to have the first unit in operation by 2023. The country currently produces virtually all of its electricity from fossil fuels.

China has 48 operable nuclear reactors, with a combined net capacity of 46.5 GWe. In 2019, nuclear generated 5% of the country's electricity. The country continues to dominate the market for new nuclear build. At the start of 2020, 11 of the 53 reactors under construction globally were in China. In 2018 China became the first country to commission two new designs – the AP1000 and the EPR. China is commencing export marketing of the Hualong One, a largely indigenous reactor design. The strong impetus for developing new nuclear power in China comes from improving urban air quality and reducing greenhouse gas emissions. The government's stated long-term target, as outlined in its Energy Development Strategy Action Plan 2014-2020 is for 58 GWe capacity by 2020, with 30 GWe more under construction.

India has 22 operable nuclear reactors, with a combined net capacity of 6.3 GWe. In 2019, nuclear generated 3% of the country's electricity. The Indian government is committed to growing its nuclear power capacity as part of its massive infrastructure development programme. The government in 2010 set an ambitious target to have 14.6 GWe nuclear capacity on line by 2024. At the start of 2020, seven reactors were under construction in India, with a combined capacity of 5.3 GWe.

Japan has 33 operable nuclear reactors, with a combined net capacity of 31.7 GWe. At the start of 2020, only nine reactors had been brought back online, with a further 17 in the process of restart approval, following the Fukushima accident in 2011. In the past, 30% of the country's electricity has come from nuclear; in 2019, the figure was just 8%.

South Korea has 24 operable nuclear reactors, with a combined net capacity of 23.2 GWe. In 2019, nuclear generated 26% of the country's electricity. South Korea has four new reactors under construction domestically as well as four in the United Arab Emirates. It plans for two more, after which energy policy is uncertain. It is also involved in intense research on future reactor designs.

Pakistan has five operable nuclear reactors, with a combined net capacity of 1.3 GWe. In 2019, nuclear generated 7% of the country's electricity. Pakistan has two Chinese Hualong One units under construction.

AFRICA

South Africa has two operable nuclear reactors, with a combined net capacity of 1.9 GWe, and is the only African country currently producing electricity from nuclear. In 2019, nuclear generated 7% of the country's electricity. South Africa remains committed to plans for additional capacity, but financing constraints are significant.

MIDDLE EAST

Iran has a single operable nuclear reactor with a net capacity of 0.9 GWe. In 2019, nuclear generated 2% of the country's electricity. A second Russian-designed VVER-1000 unit is under construction.

The United Arab Emirates has one operable nuclear reactor with a capacity of 1.3 GWe. A further three units are under construction at the same plant (Barakah).

EMERGING NUCLEAR ENERGY COUNTRIES

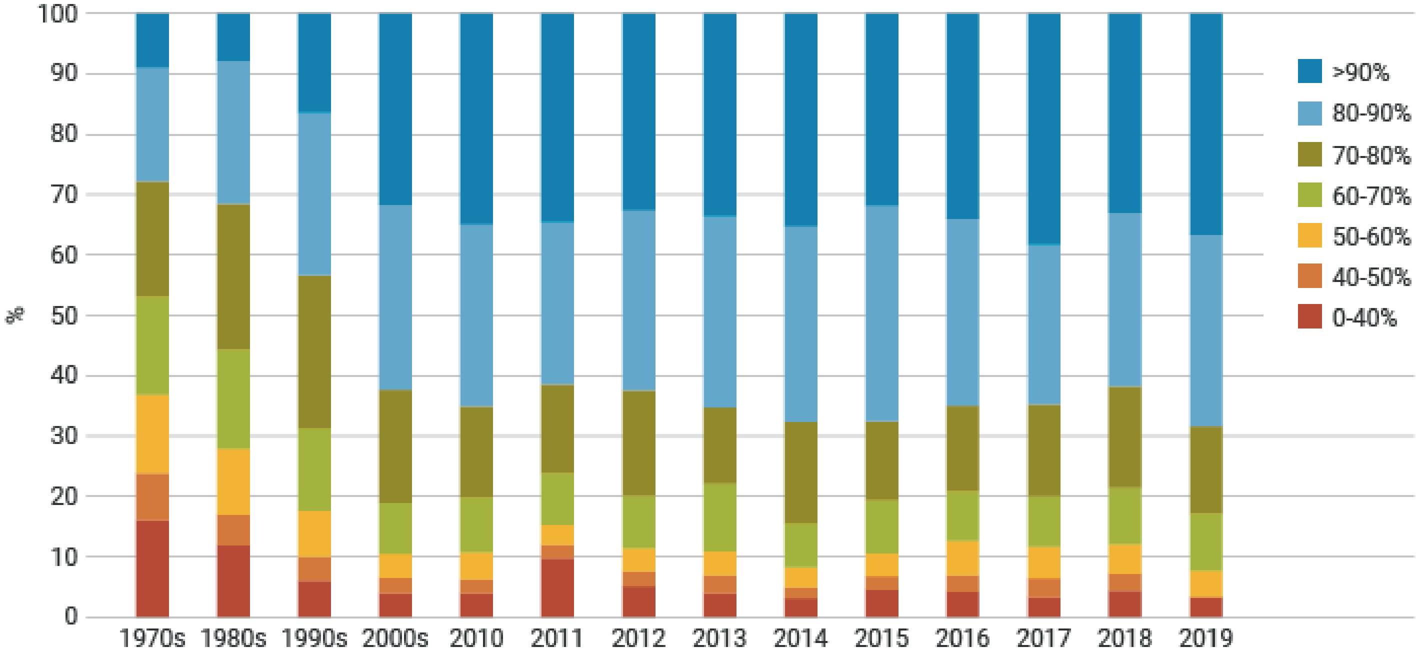
As outlined above, Bangladesh, Belarus, Turkey, and the United Arab Emirates are all constructing their first nuclear power plants. Several other countries are moving towards the use of nuclear energy for power production. For more information, click here.

IMPROVED PERFORMANCE FROM EXISTING REACTORS

The performance of nuclear reactors has improved substantially over time.

Over the last 40 years, the proportion of reactors reaching high capacity factors has increased significantly. For example, 62% of reactors achieved a capacity factor higher than 80% in 2018, compared to 28% in 1978, whereas only 7% of reactors had a capacity factor lower than 50% in 2018, compared to 20% in 1978.

It is also notable that there is no significant age-related trend in the mean capacity factor for reactors over the last five years.



Source: World Nuclear Association, IAEA PRIS

Graph 5: Long-term Trends in Capacity Factors

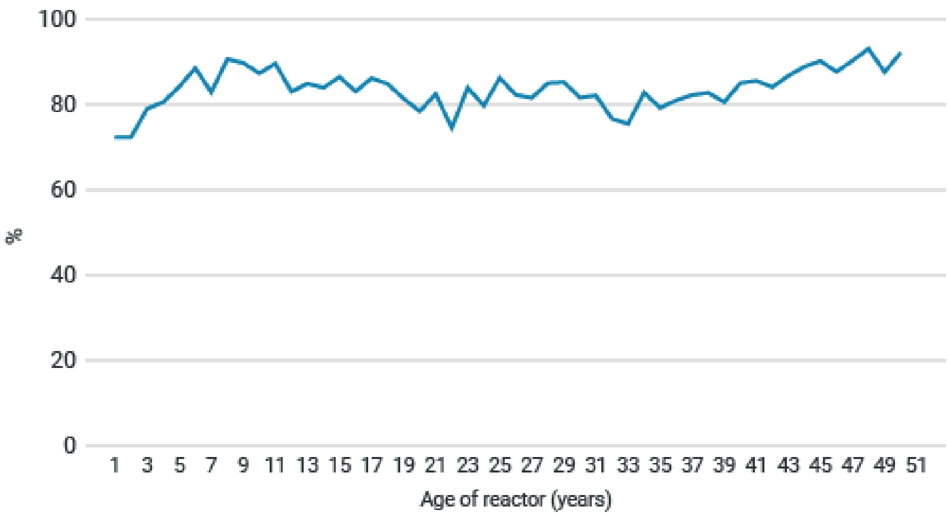
OTHER NUCLEAR REACTORS

In addition to commercial nuclear power plants, about 220 research reactors operate in over 50 countries, with more under construction. As well as being used for research and training, many of these reactors produce medical and industrial isotopes. The use of reactors for marine propulsion is mostly confined to the major navies. It has played an essential role for five decades, providing power for submarines and large surface vessels.

Over 160 ships, mostly submarines, are propelled by some 200 nuclear reactors and over 13,000 reactor years of experience have been gained with marine reactors. Russia and the USA have decommissioned many of their nuclear submarines from the Cold War era.

Russia also operates a fleet of large nuclear-powered icebreakers and has more under construction. It has also connected a floating nuclear power plant with two 32 MWe reactors to the grid in the remote arctic region of Pevek. The reactors are adapted from those powering icebreakers.

For more information, click here for The Many Uses of Nuclear Technology. wn

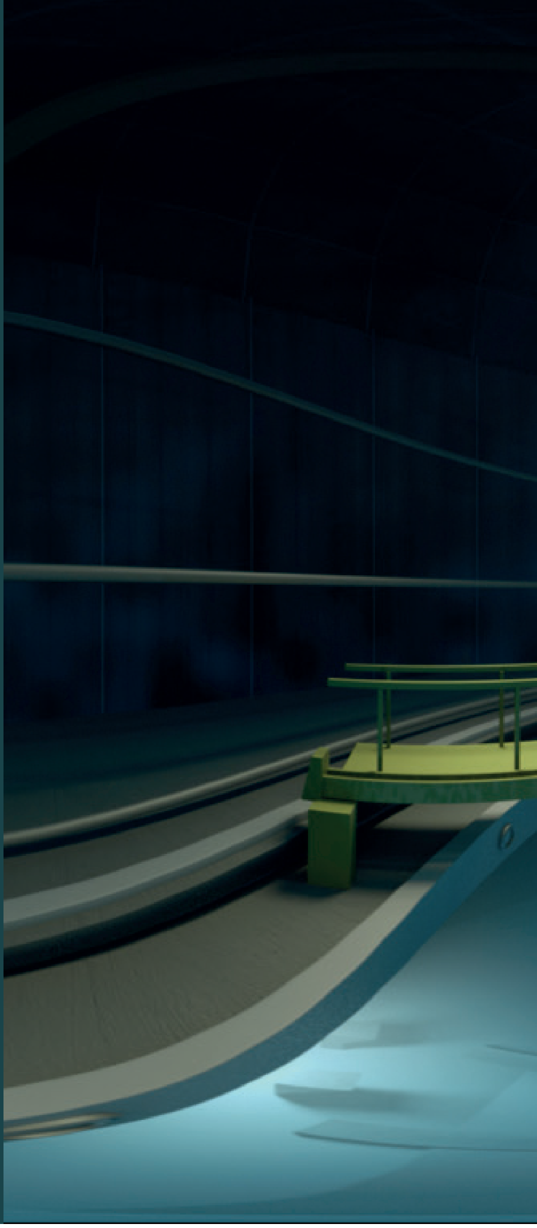


Source: World Nuclear Association, IAEA PRIS

Graph 6: Mean Capacity Factor 2015-2018 by the age of reactor

Advanced Nuclear Power Reactors

- UPDATED SEPTEMBER 2020

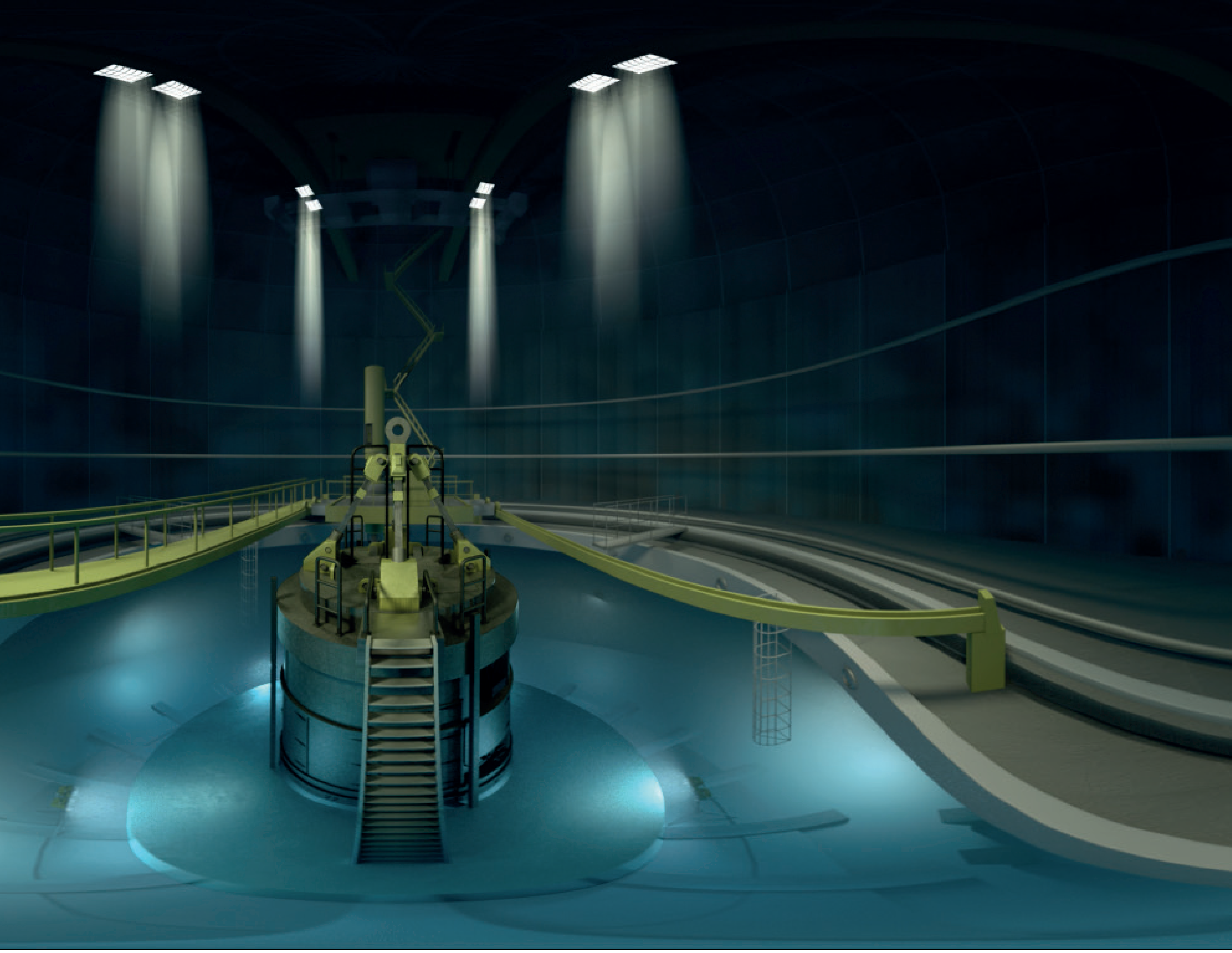


Improved designs of nuclear power reactors are continually being developed internationally. The first so-called Generation III advanced reactors have been operating in Japan since 1996. These have now evolved further.

Newer advanced reactors now being built have simpler designs which are intended to reduce capital cost. They are more fuel-efficient and are inherently safer.

Many new designs are small – up to 300 MWe. These are described in a separate information paper.*For smaller advanced reactors on Small Nuclear Power Reactors, click here.

The nuclear power industry has been developing and improving reactor technology for more than five decades. It is starting to build the next generation of nuclear power reactors to fill new orders. Several generations of reactors are commonly distinguished.



Generation I reactors was developed in 1950-60s, and the last one shut down in the UK in 2015.

Generation II reactors are typified by the present US and French fleets and most in operation elsewhere.

So-called Generation III (and III+) are the advanced reactors discussed in this paper, though Generation II's distinction is arbitrary. The first ones are in operation in Japan, and others are under construction in several countries.

Generation IV designs are still on the drawing board and will not be operational before the 2020s. Over 85% of the world's nuclear electricity is generated by reactors derived from designs initially developed for naval use. These and other nuclear power units operating are safe and reliable, but better designs are superseding them.

Reactor suppliers in North America, Japan, Europe, Russia, China and elsewhere have a dozen new nuclear reactor designs at advanced stages of planning or under construction, while others are at a research and development stage. Fourth-generation reactors are at the R&D or concept stage.

So-called third-generation reactors have:

- A more standardised design for each type to expedite licensing, reduce capital cost and reduce construction time.
- A more rugged design, making them easier to operate and less vulnerable to operational upsets.
- Higher availability and longer operating life – typically 60 years.
- Further reduced possibility of core melt accidents.*
- A substantial grace period, following shutdown the plant requires no active intervention for (typically) 72 hours.
- Stronger reinforcement against aircraft impact than earlier designs, to resist radiological release.

- Higher burn-up to use fuel more thoroughly and efficiently and reduce the amount of waste.
- Greater use of burnable absorbers ('poisons') to extend fuel life.

** The US NRC requirement for calculated core damage frequency (CDF) is $1x10^{-4}$, most current US plants have about $5x10^{-5}$ and Generation III plants are about ten times better than this. The IAEA safety target for future plants is $1x10^{-5}$. Calculated large release frequency (for radioactivity) is generally about ten times less than CDF.*

The most significant departure from most designs now in operation is that many incorporate passive or inherent safety features*. This requires no active controls or operational intervention to avoid accidents in the event of a malfunction and may rely on gravity, natural convection or resistance to high temperatures.

** Traditional reactor safety systems are 'active' because they involve electrical or mechanical operation on command. Some engineered systems operate passively, e.g. pressure relief valves. They function without operator control and despite any loss of auxiliary power. Both require parallel redundant systems. Inherent or full passive safety depends only on physical phenomena such as convection, gravity or resistance to high temperatures, not on engineered components' functioning. Still, these terms are not adequately used to characterise whole reactors.*

Another departure is that most will be designed for load-following. European Utility Requirements (EUR) since 2001 specify that new reactor designs must be capable of load-following between 50 and 100% of capacity. While most French reactors are operated in that mode, the EPR design has better capabilities. It will maintain its output at 25% and then ramp-up to full production at a rate of 2.5% of rated power per minute up to 60% output and 5% of rated output per minute up to full rated power. This means that the unit can potentially change its output from 25% to 100% in less than 30 minutes, though this may be at some expense of wear and tear. A feature of some new designs is modular construction. The means that many small components are assembled in a factory environment (offsite or onsite) into structural modules weighing up to 1000 tonnes, and these can be hoisted into place. Construction is speeded up.

Many are more extensive than predecessors. Increasingly they involve international collaboration. However, certification of designs is on a national basis and is safety-based – see the section below.

Another feature of some new designs is modular construction. Large structural and mechanical sections of the plant of up to 1000 tonnes are manufactured in factories or onsite adjacent to the plant and lifted into place, potentially speeding construction.

A contrast between the 1188 MWe Westinghouse reactor at Sizewell B in the UK and the modern Westinghouse AP1000 of similar power illustrates the evolution from 1970-80 types.

First, the AP1000 footprint is very much smaller – about one-quarter the size, secondly the concrete and steel requirements are lower by a factor of five*, and thirdly it has a modular construction. A single unit has 149 structural modules of five kinds, and 198 mechanical modules of four kinds: equipment, piping & valve, commodity, and standard service modules. These comprise one-third of all construction and can be built offsite in parallel with the onsite construction.

** Sizewell B: 520,000 m^3 concrete (438 m^3/MWe),*
65,000 t rebar (55 t/MWe);
AP1000: <100,000 m^3 concrete (90 m^3/MWe, <12,000 t rebar (11 t/MWe).

At Sanmen and Haiyang in China, where the first AP1000 units were grid-connected in August 2018, the first module lifted into place weighed 840 tonnes. More than 50 other modules used in the reactors' construction weigh more than 100 tonnes, while 18 weigh more than 500 tonnes.

THE US, EU AND UK DESIGN CERTIFICATION

In the USA, the federal Department of Energy (DOE) and the commercial nuclear industry in the 1990s developed four advanced reactor types. Two of them fell into the category of large 'evolutionary' designs which build directly on the experience of operating light water reactors in the USA, Japan and Western Europe. These reactors are in the 1300 megawatt range.

One was an advanced boiling water reactor (ABWR) derived from a General Electric design and then promoted both by GE Hitachi and Toshiba as a proven design, which is in service in Japan and was being built in Taiwan.

Four are planned in the UK. The other type, System 80+, was an advanced pressurised water reactor, which was ready for commercialisation but was never promoted for sale.

It was the basis of the Korean Next Generation Reactor programme. Many of its design features are incorporated into eight South Korean reactors, specifically the APR1400, which operates in South Korea and built in South Korea and the UAE and marketed worldwide.

The US Nuclear Regulatory Commission (NRC) gave final design certification for both in May 1997, noting that they exceeded NRC "safety goals by several orders of magnitude". The ABWR has also been certified as meeting European utility requirements for advanced reactors and is undergoing the generic design assessment process in the UK.

Another, more innovative US advanced reactor was smaller – 600 MWe – and had passive safety features (its projected core damage frequency is more than 100 times less than NRC requirements). The Westinghouse AP600 gained NRC final design certification in 1999 (AP = Advanced Passive).

These NRC approvals were the first such generic certifications to be issued and were valid for 15 years. As a result of an exhaustive public process, safety issues within the certified designs' scope were fully resolved. Hence, they are not open to a legal challenge during licensing for particular plants. Using such certified designs, US utilities can obtain a single NRC licence to construct and operate a reactor before construction begins.

Both GE Hitachi and Toshiba in 2010 submitted separate applications to renew the US design certification for their respective versions of the ABWR (Toshiba's incorporating design changes already submitted to the NRC in connection with the South Texas Project combined construction and operating licence application). The Japanese version of it differs in allowing modular construction, so is not identical to that licensed in the USA. In mid-2016 Toshiba withdrew its design certification renewal application, and in August 2017 GE Hitachi put its review by the NRC on hold.

Separate from the NRC process and beyond its immediate requirements, the US nuclear industry selected one standardised design in each category – the large ABWR and the medium-sized AP600, for detailed first-of-a-kind engineering (FOAKE) work.

The US$ 200 million program was half funded by DOE and meant that prospective buyers then had fuller information on construction costs and schedules.

The 1100 MWe-class Westinghouse AP1000, scaled-up from the AP600, received final design certification from the NRC in December 2005 – the first Generation III+ type to do so.

It represented the culmination of a 1300 person-year and $440 million design and testing program. In May 2007 Westinghouse applied for UK generic design assessment (GDA, pre-licensing approval) based on the NRC design certification, and expressing its global standardisation policy. The application was supported by European utilities and was granted in 2017.

Overnight capital costs were projected to be very competitive with older designs, and modular design is expected to reduce construction time eventually to 36 months. The AP1000 generating costs are also likely to be very competitive, and it has a 60-year operating life. It is being built in China (four units under construction, with many more to follow) and in the USA (initially four units at two sites). It is planned for building in the UK. It is capable of running on a full MOX core if required.

In February 2008 the NRC accepted an application from Westinghouse to amend the AP1000 design, and this review was completed with revised design certification in December 2011.

The NRC chairman said that the revised AP1000 design is one that seems to most fully meet the expectations of the commission's policy statement on advanced reactors. "The design provides enhanced safety margins through the use of simplified, inherent, passive or other innovative safety and the security functions, and also has been assessed to ensure it could withstand damage from an aircraft impact without significant release of radioactive materials." This design change increased capital cost.

In December 2016 Westinghouse requested the NRC to extend its AP1000 reactor's design certification for five years from 2021 to 2026. In the light of the operational experience of the first few reactors, it would then apply for renewal of US design certification.

The ESBWR from GE Hitachi received US design certification in September 2014. The South Korean APR1400 received US design certification in August 2019.

In January 2017 NuScale submitted its small modular reactor design to the NRC for design certification. The application consisted of nearly 12,000 pages of technical information. The certification process is expected to take 40 months. See information on Small Nuclear Power Reactors for reactor details.

Longer-term, the NRC expected to review the Next Generation Nuclear Plant (NGNP) for the USA (see US Nuclear Power Policy information) – essentially the Very High-Temperature Reactor (VHTR) among the Generation IV designs. It will also focus on small reactor designs.

In Europe, there are moves towards harmonised requirements for licensing. Since 1991, reactors may also be certified according to compliance with European Utility Requirements (EUR) of 12 generating companies with stringent safety criteria. The EUR are essentially a utilities' wish list of some 5000 items needed for new nuclear plants. Designs certified as complying with EUR include Westinghouse's AP1000, Gidropress's AES-92 and VVER-TOI, Areva's EPR, Mitsubishi's EU-APWR and in 2017 KHNP's APR1400 (EU-APR). GE's ABWR, Areva's Kerena, and Westinghouse's BWR 90 also have some measure of EUR approval. China's Hualong One is under review.

European regulators increasingly require large new reactors to have some core catcher or similar device. This is so that there is enhanced provision for cooling the bottom of the reactor pressure vessel or simply catching any material that might melt through it in a full core-melt accident. The EPR and VVER-1200 have core-catchers under the pressure vessel, the AP1000 and APWR have provision for enhanced water cooling.

The UK's Office for Nuclear Regulation (ONR) undertakes generic design assessment (GDA) of nuclear reactors. A GDA of each type can then be followed by site- and operator-specific licensing. ONR made initial assessments of four designs submitted in 2007: UK EPR for Areva, AP1000 for Westinghouse, ESBWR for GE Hitachi, and ACR-1000 for AECL in Canada.

The latter two were withdrawn from the process in 2008, and in 2013 the GE Hitachi ABWR was added.

The ONR and Environment Agency jointly issued design acceptance confirmations (DAC), statements on design acceptability (SODA) for the EPR December 2012, and the AP1000 in March 2017. In 2013 Hitachi-GE applied for UK generic design approval for the ABWR, and after some design changes were granted at the end of 2017.

As the GDA for the EPR design proceeded, issues arose which were in common with new capacity being built elsewhere, particularly the EPR units in Finland and France. This led to international collaboration and a joint regulatory statement on the EPR instrumentation and control among ONR, US NRC, France's ASN and Finland's STUK. More broadly, it relates to the Multinational Design Evaluation Programme and will help improve the harmonisation of regulatory requirements internationally.

In 2012 Rosatom announced that it intended to apply for design certification for its VVER-TOI reactor design of 1200 MWe, with a view to Rusatom Overseas building them in the UK.

In 2016 China General Nuclear Power Group (CGN) applied for GDA for the 1150 MWe Hualong One (HPR1000) reactor design, intending to build it at Bradwell. General Nuclear Systems, a joint venture with EDF holding 33.5% and CGN 66.5%, was formed for progressing the GDA, which commenced in January 2017 and moved to its fourth and final stage in February 2020.

Small modular reactors (SMRs) are another GDA task impending for the ONR.

JOINT INITIATIVES AND COLLABORATION

Three major international initiatives have been launched to define future reactor and fuel cycle technology, mostly looking further ahead than this paper's main subjects.

The Multinational Design Evaluation Programme (MDEP) was launched in 2006 by the US NRC and the French Nuclear Safety Authority (ASN) to develop innovative approaches to leverage the resources and knowledge of national regulatory authorities reviewing new reactor designs. It is led by the OECD Nuclear Energy Agency and involves the IAEA. Ultimately it aims to develop global regulatory standards for the design of Gen IV reactors. The US Nuclear Regulatory Commission (NRC) has proposed a three-stage process culminating in international design certification for new reactor types, notably Generation IV types. Twelve countries are involved so far: Canada, China, Finland, France, India (from 2012), Japan, Korea, Russia, South Africa, Sweden (from 2013), UK, USA, and others which have or are likely to have firm commitments to building new nuclear plants may be admitted – the UAE is an associate member.

The MDEP pools the resources of its member nuclear regulatory authorities for:

1) co-operating on safety reviews of designs of nuclear reactors that are under construction and undergoing

licensing in several countries; and
2) exploring opportunities and potential for harmonisation of regulatory requirements and practices. It also produces reports and guidance documents that are shared internationally beyond the MDEP membership.

The Generation IV International Forum (GIF) is a US-led grouping set up in 2001 which has identified six reactor concepts for further investigation to commercial deployment by 2030. See Generation IV Nuclear Reactors information.

The IAEA's International Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO) is focused more on developing country needs, and initially involved Russia rather than the USA. However, the USA has now joined it. It is currently funded through the IAEA budget.

At the commercial level, by the end of 2006 three major Western-Japanese alliances had formed in the world reactor supply market, and since then another has become prominent:

- Areva with Mitsubishi Heavy Industries (MHI): in a significant project and subsequently in fuel fabrication;
- General Electric with Hitachi as a close relationship: GE Hitachi Nuclear Energy (GEH), 60% GE; and Hitachi-GE Nuclear Energy based in Japan, 80% Hitachi; and
- Westinghouse had become a 77%-owned subsidiary of Toshiba (with The Shaw Group 20%). Toshiba is now an 87% owner, having sold 10% to Kazatomprom and bought the 20% share.

Ten years later, in 2016, Westinghouse collaborated with China's State Nuclear Power Technology Corporation (SNPTC) in developing the AP1000 design to a CAP1000 and a larger CAP-1400, and China is gaining a high profile as reactor vendor alongside Russia's Rosatom. Areva was substantially restructured due to substantial cost overruns on two EPR projects, and Electricite de France (EDF) took over the nuclear power plant part.

The after-effects of the Fukushima accident overshadow Japanese vendors. South Korea's KEPCO through KHNP is building its APR1400 on budget and schedule in the United Arab Emirates but faces new political challenges at home.

There have also been several other international collaborative arrangements initiated among reactor vendors and designers, but it remains to be seen which will be most significant.

WHO IS MARKETING WHAT?

Apart from small reactors, the following are the main models actively being marketed:

- EDF (Framatome): EPR2, Atmea1, Kerena

DEVELOPER	REACTOR	SIZE – MWE GROSS	DESIGN PROGRESS, NOTES
GE Hitachi, Toshiba	ABWR	1380	Commercial operation in Japan since 1996-7. US design certification 1997. UK design certification application 2013. Active safety systems.
KHNP	APR1400 (PWR)	1450	Shin Kori 3&4 operating in South Korea. Under construction: Shin Hanul 1&2 in South Korea, Barakah in UAE. Korean design certification 2003. US design certification August 2019.
Gidropress	VVER-1200 (PWR)	1200	Novovoronezh II, from mid-2016, Leningrad II from 2018, as AES-2006. Under construction at Akkuyu in Turkey and Rooppur in Bangladesh.
OKBM	BN-800	880	Beloyarsk 4, demonstration fast reactor and test plant.
Westinghouse	AP1000 (PWR)	1250	Four units operating in China and under construction in the USA; many units planned in China (as CAP1000).
Areva (& EdF)	EPR (PWR)	1750	Two units operating in China, under construction in Finland and France.

Table 1: Advanced power reactors operational

DEVELOPER	REACTOR	SIZE – MWE GROSS	DESIGN PROGRESS, NOTES
Gidropress	VVER-TOI (PWR)	1300	Under construction at Kursk II, planned for Nizhny Novgorod and many more in Russia.
CNNC & CGN (China)	Hualong One (PWR)	1170	Main Chinese export design, under construction at Fangchenggang and Fuqing, also Pakistan.
INET & CNEC (China)	HTR-PM, HTR-200 module	2x105 (one module)	Demonstration plant being built at Shidaowan.
SNPTC	CAP1400	1500	Demonstration plant being built at Shidaowan.

Table 2: Advanced power reactors under construction

DEVELOPER	REACTOR	SIZE – MWE GROSS	DESIGN PROGRESS, NOTES
GE Hitachi	ESBWR	1600	Planned for Fermi and North Anna in USA. Developed from ABWR, but passive safety systems. Design certification in USA Sept 2014.
Mitsubishi	APWR	1530	Planned for Tsuruga in Japan. US design certification application for US-APWR, but delayed. EU design approval for EU-APWR Oct 2014.
Areva & Mitsubishi	Atmea1 (PWR)	1150	Originally designed for Sinop in Turkey. French design approval Feb 2012. Canadian design certification in progress.
Candu Energy	EC6 (PHWR)	750	Improved CANDU-6 model. Canadian design certification June 2013.
OKBM	VVER-600	600	Planned for Kola.

Table 3: Advanced power reactors ready for deployment

- Westinghouse: AP1000
- GE Hitachi: ABWR, ESBWR, PRISM
- KHNP: APR1400, EU-APR
- Mitsubishi: APWR, Atmea1
- Rosatom: AES-92, AES-2006, VVER-TOI
- SNC-Lavalin: EC6
- CNNC & CGN: Hualong One
- SNPTC: CAP1400

LIGHT WATER REACTORS

- Power reactors moderated and cooled by water

EPR

Areva NP (formerly Framatome ANP) developed a large (4590 MWt, typically 1750 MWe gross and 1630 MWe net) European pressurised water reactor (EPR), which was accepted in mid-1995 as the new standard design for France and received French design approval in 2004. It is a four-loop design derived from the German Konvoi types with features from the French N4 and was expected to provide power about 10% cheaper than the N4. It will operate flexibly to follow loads, have fuel burn-up of 65 GWd/t and high thermal efficiency of 37%, and a net efficiency of 36%. It is capable of using a full core load of MOX. Availability is expected to be 92% over a 60-year service life.

It has double containment with four separate, redundant active safety systems, and boasts a core catcher under the pressure vessel. The safety systems are physically separated through four ancillary buildings on the same concrete raft, and two of them are aircraft crash protected. The primary diesel generators have fuel for 72 hours, the secondary back-up ones for 24 hours, and tertiary battery back-up lasts 12 hours. It is designed to withstand a seismic ground acceleration of 600 Gal without safety impairment.

The first EPR unit commenced construction at Olkiluoto in Finland, the second at Flamanville in France, the third European one was to be at Penly in France. However, the first EPR to be grid-connected was at Taishan in China. It entered commercial operation at the end of 2018. The EPR has undergone UK generic design assessment, with some significant changes to instrumentation and control systems being agreed with other national regulators. Two are being built at Hinkley Point C in the UK.

Questions arose regarding the steel quality in the top and bottom reactor pressure vessel heads for Flamanville, forged by Areva's Creusot Forge plant. The pressure vessel for Olkiluoto was developed in Japan and those for Taishan by MHI and Dongfang Electric.

A US version, the US-EPR quoted as 1710 MWe gross and about 1580 MWe net, was submitted for US design certification in December 2007, but this process is suspended. The first unit (with 80% US content) was expected to be grid-connected by 2020. It is now known as the Evolutionary PWR (EPR). Much of the one million person-hours of work involved in developing this US EPR was said to be making the necessary changes to output electricity at 60 Hz instead of the original design's 50 Hz. The main development of the type was to be through UniStar Nuclear Energy.

Areva NP is working with EdF on a 'new model' EPR, the EPR NM or EPR2, "offering the same characteristics" as the EPR but with simplified construction and significant cost reduction – about 30%. The basic design was to be completed in 2020, and in mid-2019 the French regulator ASN said it was happy with most aspects of the design. Emergency core cooling is significantly different from the EPR. EdF noted that it, not the complex EPR being built at Flamanville, would be the model that replaced the French fleet from the late 2020s. Poland appears to be a candidate for the demonstration plant.

AP1000

The Westinghouse AP1000 is a two-loop PWR which has evolved from the smaller AP600, one of the first new reactor designs certified by the US NRC. Simplification was a primary design objective of the AP1000. In overall safety systems, standard operating systems, the control room, construction techniques, and instrumentation and control systems provide cost savings with improved safety margins. It has a core cooling system including passive residual heat removal by convection, improved containment isolation, passive containment cooling system to the atmosphere and in-vessel retention of core damage (corium) with water cooling around it. No safety-related pumps or ventilation systems are needed.

The AP1000 gained US design certification in 2005, and UK generic design assessment approval in 2017. However, the USA and the UK's structural design was significantly modified from 2008 to withstand aircraft impact.

It has been built in China at Sanmen and Haiyang and is under construction at Vogtle in the USA. The units are being assembled from modules. It is 1250 MWe gross and 1110-1117 MWe net in the USA, 1157 or 1170 MWe net in China (3415 MWt). Westinghouse earlier claimed a 36-month construction time to fuel loading. The first ones built in China were on a 57-month schedule to grid connection but took about 110 months. Progress was delayed, particularly by re-engineering the 91-tonne coolant pumps, of which each rector has four. After the first four units in China, the design is known as the CAP1000 there.

CAP1400

SNPTC and SNERDI in China have jointly developed a passively safe 1500 MWe (4040 MWt) two-loop design from the AP1000, the CAP1400, or Guohe One, with 193 fuel assemblies and improved steam generators, operating at 323°C outlet temperature, 60-year design lifetime, and 72-hour non-intervention period in the event of an accident.

The average discharge burn-up is about 50 GWd/t, with a maximum of 59.5 GWd/t. Operation flexibility includes extra control rods for MOX capability for an 18 to 24-month cycle and load-following. The seismic rating is 300 gal. The CAP1400 project may extend to a larger, three-loop CAP1700 or CAP2100 design if the passive cooling system can be scaled to that level. Westinghouse has agreed that SNPTC will own the intellectual property rights for any AP1000 derivatives over 1350 MWe. Construction of the first unit at Shidaowan started without public announcement in 2019. Exports are intended.

ABWR

The advanced boiling water reactor (ABWR) is derived from a General Electric design in collaboration with Toshiba. Two examples built by Hitachi and two by Toshiba have been in Japan's commercial operation (1315 MWe net), with another two under construction and two in Taiwan. More are planned in Japan, and four are planned in the UK. The ABWR has been offered in slightly different versions by GE Hitachi, Hitachi-GE and Toshiba so that 'ABWR' is now a generic term. It is a 1380 MWe (gross) unit (3926 MWt in Toshiba version), though GE Hitachi quotes 1350-1600 MWe net. Toshiba outlines development from its 1400 MWe class to a 1500-1600 MWe class unit (4300 MWt). Tepco was funding the design of a next-generation BWR, and the ABWR-II is quoted as 1717 MWe.Toshiba promoted its EU-ABWR of 1600 MWe with core catcher and filtered vent, developed with Westinghouse Sweden.

The Hitachi UK-ABWR may have similar features but be a similar size to Japanese units. The first four ABWRs were each built in 39-43 months on a single-shift basis. Though GE and Hitachi have subsequently joined up, Toshiba retains some rights over the design, as does Tepco. The design can run on full-core mixed oxide (MOX) fuel, as for the Ohma plant built in Japan. Design operating lifetime is 60 years. Unlike previous BWRs in Japan, the external recirculation loop and internal jet pumps are replaced by coolant pumps mounted at the reactor pressure vessel's bottom. Safety systems are active – GEH describes it as "the pinnacle of the evolution of active safety." Both Toshiba and GE Hitachi have applied separately to the NRC for design certification renewal, though these are respectively withdrawn or on hold. The initial certification in 1997 was for 15 years, and in 2011 the NRC certified for GE Hitachi an evolved version which allows for aircraft impacts. UK generic design assessment approval for Hitachi's version of the ABWR is expected at the end of 2017. GE Hitachi was also designing a 600-800 MWe version of the ABWR, with five instead of ten internal coolant pumps, aiming at Southeast Asia. In addition, a 400 MWe version was envisaged.

ESBWRGE

Hitachi Nuclear Energy's ESBWR is an improved design "evolved from the ABWR" but utilises passive safety features including natural circulation principles. The ninth evolution of the original BWR design was licensed in 1957 and was developed from a predecessor design, the SBWR at 670 MWe. GEH says it is safer and more efficient than earlier models, with 25% fewer pumps, valves and motors, and can maintain cooling for seven days after shutdown with no AC or battery power. The emergency core cooling system has eliminated the need for pumps, using passive and stored energy. The used fuel pool is below ground level.

The ESBWR (4500 MWt) will produce approximately 1600 MWe gross, and 1520 MWe net, depending on site conditions, and has a design operating lifetime of 60 years. It is more fully known as the Economic Simplified BWR (ESBWR) and leverages proven technologies from the ABWR.

GE Hitachi gained US NRC design certification for the ESBWR in September 2014, following design approval in March 2011. It was submitted for UK generic design assessment in 2007 but withdrawn a year later.GEH is selling this alongside the ABWR, which it characterises as more expensive to build and operate, but proven.

The ESBWR is more innovative, with lower building costs due to modular construction, lower operating costs, 24-month refuelling cycle and a 60-year operating lifetime. The USA plans to build as Detroit Edison's Fermi 3 and Dominion's North Anna 3 are not proceeding.

APWR

Mitsubishi's large APWR – advanced PWR of 1538 MWe gross (4451 or 4466 MWt) – was developed in collaboration with four utilities (Westinghouse was earlier involved). The first two are planned for Tsuruga, initially to come online from 2016. It is a four-loop design with 257 fuel assemblies and neutron reflector, is simpler, combines active and passive cooling systems in a double containment, and has over 55 GWd/t fuel burn-up. It is the basis for the next generation of Japanese PWRs. The planned APWR+ is 1750 MWe and has full-core MOX capability.

The US-APWR is 4451 MWt, about 1600 MWe net, due to longer (4.3m instead of 3.7m) fuel assemblies, higher burn-up (62 GWd/t) and higher thermal efficiency (37%) (2013 company description). It has a 24-month refuelling cycle. Its emergency core cooling system (ECCS) has four independent trains, and its outer walls and roof are 1.8 m thick.

US design certification application was in January 2008 with certification expected in 2016 but halted. In March 2008 MHI submitted the same design for EUR (European Utility Requirements) certification, as the EU-APWR, and this certification of compliance was granted in October 2014. MHI planned to join with Iberdrola Engineering & Construction in bidding for sales of this in Europe. Iberdrola would be responsible for building the plants.

The Japanese government was expected to provide financial support for US licensing of the US-APWR.

Washington Group International was to be involved in US developments with Mitsubishi Heavy Industries (MHI). The US-APWR was selected by Luminant for Comanche Peak, Texas, a merchant plant.

APR1400, EU-APR, APR+, APR100

South Korea's APR1400 advanced PWR design has evolved from the US System 80+ with enhanced safety and seismic robustness and was earlier known as the Korean Next Generation Reactor. Design certification by the Korean Institute of Nuclear Safety was awarded in May 2003. According to an IAEA status report, it is 1455 MWe gross in Korean conditions, 1350-1400 MWe net (3983 – nominal 4000 MWt) with two-loop primary circuit. The first of these are operating in Korea – Shin Kori 3&4 – with Shin Hanul 1&2 under construction. It was chosen for the United Arab Emirates (UAE) nuclear programme based on cost and reliable building schedule. Four units are under construction there, with the first expected online in 2020.

Fuel in 241 fuel assemblies has burnable poison and will have up to 55 GWd/t burn-up, refuelling cycle around 18 months, outlet temperature 324ºC. It is designed "not only for the base-load full power operation but also for a part load operation such as the load following operation. A standard 100-50-100% daily load follow operation has been considered in the reactor core design as well as in the plant control systems." Ramp up and down between 100% and 50% takes two hours. Plant operating lifetime is 60 years, seismic design basis is 300 Gal. A low-speed (1800 rpm) turbine is used. An application for US design certification was lodged in 2013 and a revised version accepted in March 2015. The NRC confirmed its safety in September 2018, and design certification was approved in May 2019 and formally awarded in August.

Based on this, KOPEC has developed an EU version (APR1400-EUR or EU-APR) with double containment and core-catcher, which was given EUR approval in October 2017. It is 4000 MWt, 1520 MWe gross, with a design lifetime of 60 years and 250 Gal seismic rating.

KHNP is also developing a more advanced 4308 MWt, 1560 MWe (gross) version of the APR1400, the APR+, which gained design approval from NSSC in August 2014. It was "developed with original domestic technology", up to 100% localised, over seven years since 2007, with export markets in view. It has a modular construction expected to give 36-month construction time instead of 52 months for the APR1400. It has 257 fuel assemblies of a new design, 18- to a 24-month fuel cycle, and passive decay heat removal. Also, it is more highly reinforced against aircraft impact than any earlier designs. Seismic rating is 300 Gal.

In addition, some of the APR features are being incorporated into an exportable APR-1000 intended for overseas markets, notably the Middle East and Southeast Asia. They will operate with an ultimate heat sink of 40°C, instead of 35°C for the OPR-1000. Improved safety and performance will raise the capital cost above that of the OPR, but this will be offset by reduced construction time (40 months instead of 46) due to modular construction.

ATMEA1

The Atmea1 has been developed by the Atmea joint venture established in 2007 by Areva NP and Mitsubishi Heavy Industries to produce an evolutionary 1100-1150 MWe net (3150 MWt) three-loop PWR using the same steam generators as EPR. This has 37% net thermal efficiency, 157 fuel assemblies 4.2 m long, 60-year operating lifetime, and the capacity to use mixed-oxide fuel for full core load. Fuel cycle is flexible 12 to 24 months with short refuelling outage, and the reactor has load-following (100-25% range) and frequency control capability. The first units are likely to be built at Sinop in Turkey.

Following an 18-month review, the French regulator ASN approved the general design in February 2012. The reactor is regarded as mid-sized relative to other modern designs and will be marketed primarily to countries embarking upon nuclear power programs. It has three active and passive redundant safety systems and an additional back-up cooling chain, similar to EPR. It has a core-catcher and is available for high-seismic sites. Canadian design certification is underway.

KERENA

Together with German utilities and safety authorities, Areva NP has also developed another revolutionary design, the Kerena, a 1290 MWe gross, 1250 MWe net (3370 MWt) BWR 60-year design life formerly known as SWR 1000. Based on Siemens' Gundremmingen plant, the design was completed in 1999, and US certification was sought, but then deferred. It has not yet been submitted for accreditation anywhere but is otherwise ready for commercial deployment. It has two redundant active safety systems and two passive safety systems, including a core-catcher, similar to EPR. The reactor is simpler overall and uses high-burnup fuels (to 65 GWd/t) enriched to 3.54%, giving it refuelling intervals of up to 24 months. It can take a 50% MOX load and uses flow variation to improve fuel usage. It has 37% net efficiency and can load-follow down to 70% using recirculation pumps only, and down to 40% with control rods.

AES-92, V-392

Gidropress late-model VVER-1000 units with enhanced safety (AES-92 & -91 power plants) have been built in India and China. Two more (V466B variant) were planned for Belene in Bulgaria. The AES-92 is certified as meeting EUR, and its V-392 reactor is considered state of the art. They have four coolant loops, 163 fuel assemblies, and are rated 3000 MWt.

AES-2006, MIR-1200

A third-generation standardised VVER-1200 (V-392M and V-491) reactor of 1198 MWe gross (with cool water) and 3212 MWt is in the AES-2006 plant. It is an evolutionary development of the well-proven VVER-1000 in the AES-92 and AES-91 plants, with longer life (60 years for non-replaceable equipment), greater power, and greater efficiency (34.8% net instead of 31.6%) and 60 GWd/t burn-up.

Cogeneration heat supply capacity is 300 MWt. It retains four coolant loops and has 163 FA-2 fuel assemblies, each with 534 kg of UO2 fuel enriched to 4.95%.

The Core outlet temperature is 329°C. The lead units are being built at Novovoronezh II (V-392M) and Leningrad (V-491), the first starting operation in 2016. The Novovoronezh units provide 1114 MWe net each, and the Leningrad II units 1085 MWe net each. Two steam turbines are offered: Power Machines (Silmash) full-speed; and Alstom Arabelle half-speed, as proposed for MIR-1200 and Hanhikivi in Finland.

An AES-2006 plant will consist of two of these OKB Gidropress reactor units expected to run for 60 years with a capacity factor of 90%.

Overnight capital cost was said to be US$ 1200/kW (though the first contract was about $2100/kW) and serial construction time 54 months. They have enhanced safety, including earthquakes and aircraft impact (V-392M especially) with some passive safety features, double containment, and core-catcher planned for Akkuyu in Turkey (V-509).

While Gidropress is responsible for the actual 1200 MWe reactor, Moscow AEP and Atomproekt St Petersburg are going different ways on the cooling systems, and the V-392M version is the basis of the VVER-TOI. Passive safety systems prevail in Moscow's V-392M design, while St Petersburg's V-491 design focuses on active safety systems based on the Tianwan V-428 design. In both, long-term decay heat removal does not rely on electrical power or ultimate heat sink. (Click here for information on Nuclear Power in Russia.) Atomenergoproekt says that the AES-2006 conforms to both Russian standards and European Utilities Requirements (EUR).

In Europe, the V-491 technology is called the Europe-tailored reactor design, MIR-1200 (Modernised International Reactor) or AES-2006E, with some Czech involvement. Those bid for Temelin is quoted as 1158 MWe gross, 1078 MWe net. That for Hanhikivi is 1250 MWe gross, due to cold water.

VVER-TOI

In 2010 Atomenergoproekt announced the VVER-TOI (typical optimised, with enhanced information) design based on V-392M. The primary Gidropress reactor is V-510. It has upgraded pressure vessel, increased power to 3300 MWt and 1255 MWe gross (nominally 1300, hence VVER-1300), improved core design still with 163 fuel assemblies to increase cooling reliability, larger steam generators.

Further development of passive safety with a 72-hour grace period requires no operator intervention after shutdown, lower construction and operating costs, and 40-month construction time. It will use a low-speed turbine-generator and can undertake daily load-following down to 50% of power. The project was initiated in 2009 and, the design was completed at the end of 2012. In June 2012 Rosatom said it would apply for design certification in the UK through Rusatom Overseas, with the VVER-TOI version. The first units are planned for Kursk II and Smolensk II in Russia.

VVER-600

Gidropress has developed the VVER-600/V-498 for sites such as Kola, where larger units are not required. It is a two-loop design based on the V-491 St Petersburg version of the VVER-1200 and using the same equipment without core-catcher (corium retained within RPV). It will have a 60-year life and is capable of load-following. Export potential is anticipated. It supersedes the VVER-640/V-407 design.

HUALONG ONE, HPR1000

In China, there are two indigenous designs based on a French predecessor but developed with modern features. CNNC developed the ACP1000 design, with 1100 MWe nominal power and load-following capability, and 177 fuel assemblies. In parallel but somewhat ahead, China Guangdong Nuclear Power Corporation, now China General Nuclear Power (CGN), led the 1100 MWe ACPR-1000, with 157 fuel assemblies (same as the French M-310 predecessor), and about 30 of these have been built. However, due to rationalisation over 2011-13, this design has been dropped in favour of the Hualong One, essentially the ACP1000 with some ACPR features.

The Hualong One thus has 177 fuel assemblies 3.66 m long, 18-24 month refuelling interval. It has three coolant loops delivering 3050 MWt, 1170 MWe gross, 1090 MWe net (CNNC version). It has double containment and active safety systems with some passive elements, and a 60-year design lifetime. Average burnup is 45,000 MWd/tU, thermal efficiency is 36%. A seismic shutdown is at 300 gals. Instrumentation and control systems will be from Areva-Siemens. Estimated cost in China is $3500/kWe. The first units under construction are Fangchenggang 3&4 (CGN) and Fuqing 5&6 (CNNC). Pakistan is also building one. CNNC and CGN in December 2015 formed a 50-50 joint venture company – Hualong International Nuclear Power Technology Co – to market it. The version promoted on the international market is called HPR1000 (Hualong Pressurized Reactor 1000), based on the CGN version, with Fangchenggang as the reference plant. In October 2015 CGN submitted the HPR1000 for certification of compliance with European Utility Requirements (EUR).

VBER-300

OKBM's VBER-300 PWR is a 295-325 MWe unit (917 MWt) developed from naval power plants and was initially envisaged in pairs as a floating nuclear power plant. It is designed for 60-year life and 90% capacity factor. It now planned to develop it as a land-based unit with Kazatomprom, with a view to exports, and Kazakhstan will build the first one.

HEAVY WATER REACTORS

- Moderated and mostly cooled by heavy water

In Canada, the government-owned Atomic Energy of Canada Ltd (AECL) had two designs under development based on its reliable CANDU-6 reactors, the most recent of which are operating in China. In 2011 the reactor division of AECL was sold and became Candu Energy Inc, a subsidiary of SNC-Lavalin. One of these earlier designs continues, with associated fuel cycle innovation.

The CANDU-9 (925-1300 MWe) was developed from the CANDU-6 also as a single-unit plant. It had flexible fuel requirements which have been taken forward to the EC6. A two-year licensing review of the CANDU-9 design was completed early in 1997, but the plan was shelved.

EC6

The innovation of the CANDU-9 was put back into the Enhanced CANDU-6 (EC6). This is to be built as twin units – with a power increase to 740-750 MWe gross (690 MWe net, 2084 MWt) and flexible fuel options, plus a 4.5-year construction 60-year plant life (with mid-life pressure tube replacement). EC6 is presented as a third-generation design based on Qinshan Phase III in China and is under consideration for new build in Ontario and overseas.

Phase 2 of CNSC's vendor pre-project design review was completed in April 2012, with phase 3 on target for 2013. The versatility of fuel is a claimed feature of the EC6 and its derivatives. As well as natural uranium, it can use direct recovered/reprocessed uranium (RU) from used PWR fuel, natural uranium equivalent (NUE – DU + RU), MOX (DU + Pu), fertile fuels such as LEU + thorium and Th with Pu, and closed-cycle fuels (Th + U-233 + Pu). The NUE fuel cycle with full-core NUE is being demonstrated at Qinshan in China in CANDU-6 units*. There is also a program for the Advanced Fuel Candu Reactor (AFCR) – an adaptation of EC6 – on direct use of RU and LEU + thorium-based CANDU fuel. Finally, a CANMOX fuel is proposed with EC6 for disposal of the UK's plutonium stock

** RU with 0.9% U-235 plus DU gives 0.7% NUE, which is burned down to about 0.25% U-235.*

The EC6 has design features. Notably, it is an automated refuelling, which enables third-party process monitoring concerning non-proliferation concerns.

AFCR

The Advanced Fuel CANDU Reactor (AFCR) is a 740 MWe development of the EC6, designed to use recycled uranium and thorium-based fuels.

Candu Energy has developed it with CNNC's Third Qinshan Nuclear Power Corp, which plans to convert the two Qinshan CANDU-6 PHWR units to AFCRs. Then new-build AFCRs are envisaged in China. The recycled uranium can fully fuel one AFCR from four LWRs' used fuel. Hence deployment of AFCRs will significantly reduce the task of managing used fuel and disposing of high-level waste and could reduce China's new uranium requirements. Late in 2014, CNNC and Candu Energy signed a joint venture framework agreement to build AFCR projects domestically and develop opportunities for them internationally. In September 2016 an agreement among SNC-Lavalin, CNNC and Shanghai Electric Group set up a joint venture in mid-2017 to design, market and build the AFCR, with NUE fuel.

AHWR

India is developing the Advanced Heavy Water Reactor (AHWR) as the third stage to utilise thorium to fuel its overall nuclear power program. The AHWR is a 300 MWe gross (284 MWe net, 920 MWt) reactor moderated by heavy water at low pressure.

The calandria has about 450 vertical pressure tubes, and the coolant is pressurised light water boiling at 285ºC and circulated by convection. A large heat sink – 'gravity-driven water pool' – with 7000 cubic metres of water is near the top of the reactor building. Each fuel assembly has 30 Th-U-233 oxide pins and 24 Pu-Th oxide pins around a central rod with a burnable absorber. Burn-up of 24 GWd/t is envisaged.

It is self-sustaining compared to U-233 bred from Th-232 and has a low Pu inventory and consumption, with a slightly negative void coefficient of reactivity. It is designed for 100-year plant life and is expected to utilise 65% of the fuel's energy, with two-thirds of that energy coming from thorium via U-233. A co-located fuel cycle facility is planned, with remote handling for the highly-radioactive fresh fuel. At the end of 2016, the design was complete, and large-scale engineering studies validated the design's innovative features. No site or construction schedule had been announced for the demonstration unit.

Once it is fully operational, each AHWR fuel assembly will have the fuel pins arranged in three concentric rings:

- Inner: 12 pins Th-U-233 with 3.0% U-233.
- Intermediate: 18 pins Th-U-233 with 3.75% U-233.
- Outer: 24 pins Th-Pu-239 with 3.25% Pu.

The fissile plutonium content will decrease from an initial 75% to 25% at equilibrium discharge burn-up level.

As with the U-233, some U-232 is formed, and the highly gamma-active daughter products confer a substantial proliferation resistance.

In 2009 an export version of this design was announced: the AHWR-LEU. This will use low-enriched uranium plus thorium as a fuel, dispensing with the plutonium input. About 39% of the power will come from thorium (via in situ conversion to U-233), and burn-up will be 64 GWd/t. Uranium enrichment level will be 19.75%, giving 4.21% average fissile content of the U-Th fuel.

While designed for a closed fuel cycle, this is not required. Plutonium production will be less than in light water reactors, and the fissile proportion will be less and the Pu-238 portion three times as high, giving inherent proliferation resistance. The AEC says that "the reactor is manageable with modest industrial infrastructure within reach of developing countries." In the AHWR-LEU, the fuel assemblies will be configured:

- Inner ring: 12 pins Th-U with 3.555% U-235,
- Intermediate ring: 18 pins Th-U with 4.345% U-235,Outer ring: 24 pins Th-U with 4.444% U-235.

HIGH-TEMPERATURE GAS-COOLED REACTORS

- Graphite-moderated

These reactors use helium as a coolant at up to 950ºC, which either makes steam conventionally (Rankine cycle) or directly drives a gas turbine for electricity and a compressor to return the gas to the reactor core (Brayton cycle). Fuel is in the form of TRISO particles less than a millimetre in diameter. Each has a kernel of uranium oxycarbide, with the uranium enriched up to 17% U-235.

This is surrounded by layers of carbon and silicon carbide, giving a containment for fission products stable to 1600°C or more. These particles may be arranged: in blocks as hexagonal 'prisms' of graphite, or in billiard ball-sized pebbles of graphite encased in silicon carbide.HTR-PM, HTR-PM 600The first commercial version will be China's HTR-PM, built at Shidaowan in Shandong province.

It has been developed by Tsinghua University's INET, which is the R&D leader and China Nuclear Engineering & Construction Group (CNEC), with China Huaneng Group leading the demonstration plant project. This will have two reactor modules, each of 250 MWt/105 MWe (equivalent), with a single steam generator, and 8.5% enriched fuel (245,000 elements) giving 90 GWd/t discharge burn-up.

With an outlet temperature of 750ºC, the pair will produce steam at 566ºC to drive a single steam cycle turbine at about 40% thermal efficiency.

This 210 MWe, Shidaowan demonstration plant, paves the way for commercial 600 MWe reactor units using the twin reactor modules (3x210 MWe), also using the steam cycle. CNEC is promoting these. Plantlife is envisaged as 40 years with 85% load factor.

Fuller descriptions of HTRs is in the Small Nuclear Power Reactors paper.

FAST NEUTRON REACTORS

- Not moderated, cooled by liquid metal

Click here for a description of fast neutron reactors.

Several countries have research and development programs for improved fast breeder reactors (FBR), which are fast neutron reactors (FNR) configured with a conversion or breeding ratio of more than 1 (i.e. more fissile nuclei are produced than are fissioned). These use the uranium-238 in reactor fuel and the fissile U-235 isotope used in most reactors, and can readily use the world's 1.5 million tonnes of depleted uranium as fuel. They are now often designed to burn actinides as well.

About 20 liquid metal-cooled FBRs have already been operating, some since the 1950s, and some have supplied electricity commercially. About 400 reactor-years of operating experience have been accumulated. Today Russia and India have FNRs high profile in their nuclear programs, with Japan, China and France also significant.

India's 500 MWe prototype fast breeder reactor at Kalpakkam is expected to be operating in 2018, fuelled with uranium-plutonium oxide (the reactor-grade Pu being from its existing PHWRs) and with a thorium blanket to breed fissile U-233. This will take India's ambitious thorium program to stage 2, and set the scene for eventual full utilisation of its abundant thorium to fuel reactors.

The Russian BN-600 fast breeder reactor at Beloyarsk has been supplying electricity to the grid since 1981 and has the best operating and production record of all Russia's nuclear power units. It uses uranium oxide fuel, and the sodium coolant delivers 550°C at little more than atmospheric pressure. The core is 0.88 metres active height and 0.75 m diameter. The BN-350 FBR operated in Kazakhstan for 27 years, and about half of its output was used for water desalination. The BN-600 is configured to burn the plutonium from its military stockpiles.

BN-800

The first (and probably only Russian) BN-800, a new more powerful (789 MWe, 880 MWe gross, 2100 MWt) fast neutron reactor from OKBM with Atomenergoproekt at St Petersburg with improved features, was grid-connected at Beloyarsk in December 2015. It is designed to have considerable fuel flexibility – U+Pu nitride, MOX, or metal, and with a breeding ratio up to 1.3, though only 1.0 as configured at Beloyarsk.

The core is a similar size to that of the BN-600. Initially, it is being run with one-fifth MOX fuel, but will have a full MOX core from about 2020. It does not have a breeding blanket, though a version designed for Sanming in China has up to 198 DU fuel elements in a blanket. Its main purpose is to provide operational experience, and technological solutions, especially regarding fuels applied to the BN-1200. Further details in the information paper on Fast Neutron Reactors.BN-1200The BN-1200 is designed by OKBM for operation with MOX fuel initially and dense nitride U-Pu fuel subsequently, in the closed fuel cycle. It is significantly different from preceding BN models, and Rosatom plans to submit the BN-1200 to the Generation IV International Forum (GIF) as a Generation IV design. The BN-1200 has a capacity of 2900 MWt (1220 MWe gross), a 60-year design life, and burn-up of up to 120 GWd/t. The capital cost is expected to be much the same as that of the VVER-1200. Its breeding ratio is quoted as 1.2 to 1.4, using oxide or nitride fuel. OKBM envisages about 11 GWe of such plants by 2030, including South Urals nuclear plant. The detailed design was completed in May 2017, and the first unit is to be built at Beloyarsk, possibly from 2020. This is part of a federal Rosatom program, the Proryv (Breakthrough) Project for large fast neutron reactors.

BREST

Russia has experimented with several lead-cooled reactor designs and used lead-bismuth cooling for 40 years in reactors for its seven Alfa class submarines. Pb-208 (54% of naturally-occurring lead) is transparent to neutrons. A significant new Russian design from NIKIET is the BREST-300 fast neutron reactor, 300 MWe (700 MWt) with lead as the primary coolant, at 540ºC, and supercritical steam generators. It is inherently safe and uses a high-density U+Pu nitride fuel with no requirement for high enrichment levels. No weapons-grade plutonium can be produced (since there is no uranium blanket – all the breeding occurs in the core. Used fuel can be recycled indefinitely, with onsite reprocessing and associated facilities. A demonstration unit is planned at Seversk by 2022, and 1200 MWe (2800 MWt) units are proposed. Both designs have two cooling loops. BREST-300 has 17.6 tonnes of fuel, BREST-1200 about 60 tonnes. Click here for information on Nuclear Power in Russia.

PRISM

Today's PRISM is a GE Hitachi design for compact modular pool-type reactors with passive cooling for decay heat removal. After 30 years of development, it represents GEH's Generation IV solution to closing the fuel cycle. Each PRISM Power Block consists of two modules of 840 MWt, 311 MWe each, operating at high temperature – over 500°C. The pool-type modules below ground level contain the complete primary system with sodium coolant. PRISM is suited to operation with dry cooling towers due to high thermal efficiency and small size.

The Pu & DU fuel is metal and obtained from used light water reactor fuel. However, all transuranic elements are removed together in the electrometallurgical reprocessing so that fresh fuel has minor actinides with the plutonium. Fuel stays in the reactor for about six years, with one-third removed every two years. The breeding ratio depends on the purpose and configuration, so it ranges from 0.72 for used LWR recycle to 1.23 for the breeder. Used PRISM fuel is recycled after removal of fission products. The commercial-scale plant concept, part of an 'Advanced Recycling Center', uses three power blocks (six reactor modules) to provide 1866 MWe. See also Electrometallurgical' pyroprocessing' section in Processing Used Nuclear Fuel information paper.

A variant of this is proposed to utilise the UK's reactor-grade plutonium stockpile. A pair of PRISM units built at Sellafield would be operated initially to bring the material up to the highly-radioactive 'spent fuel standard' of self-protection and proliferation resistance. The whole stockpile could be irradiated in five years, with some by-product electricity. The plant will then re-use that stored fuel over perhaps 55 years solely for 600 MWe of electricity generation. GEH has launched a web portal in support of its proposal.

WESTINGHOUSE LFR

Westinghouse is developing a lead-cooled fast reactor (LFR) design with flexible output to complement intermittent renewable feed to the grid. Its high-temperature capabilities will allow industrial heat applications. Westinghouse expects it to be very competitive, having low capital and construction costs with enhanced safety. Further operational and security enhancements are achieved by adopting a fuel/cladding combination with high-temperature capability based on Westinghouse's under development in the Accident Tolerant Fuel program.

JAPAN

Japan plans to develop FBRs. Its Joyo experimental reactor which has been operating since 1977 is now boosted to 140 MWt. The 280 MWe Monju prototype commercial FBR was connected to the grid in 1995 but was shut down for 15 years due to a sodium leak. It restarted in 2010 before closing down again due to an ancillary mechanical problem and is now decommissioned. Mitsubishi Heavy Industries (MHI) is involved with a consortium to develop a Japan Standard Fast Reactor (JSFR) concept, though with a breeding ratio less than 1:1. This is a large unit which would burn actinides with uranium and plutonium in oxide fuel. It could be of any size from 500 to 1500 MWe.

GENERATION IV DESIGNS

See information on six Generation IV Reactors, also DOE paper.

SMALL REACTORS

See information on Small Nuclear Power Reactors for other advanced designs, mostly under 300 MWe. This paper includes some designs that have become significantly larger than 300 MWe since first being described, but outside the mainstream categories dealt with here.

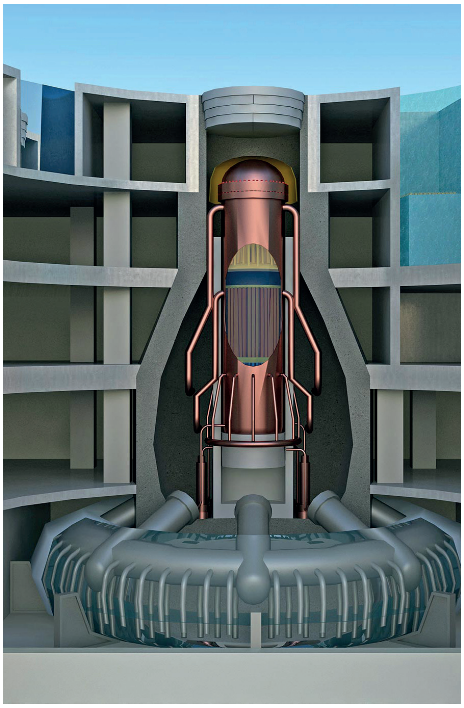
ACCELERATOR-DRIVEN SYSTEMS (ADS)

A related development has been merging accelerator and fission reactor technologies to generate electricity and transmute long-lived radioactive wastes.

A high-energy proton beam hitting a heavy metal target produces neutrons by spallation. The neutrons cause fission in the fuel, but unlike a conventional reactor, the fuel is subcritical, and fission ceases when the accelerator is turned off. The fuel may be uranium, plutonium or thorium, possibly mixed with long-lived wastes from conventional reactors.

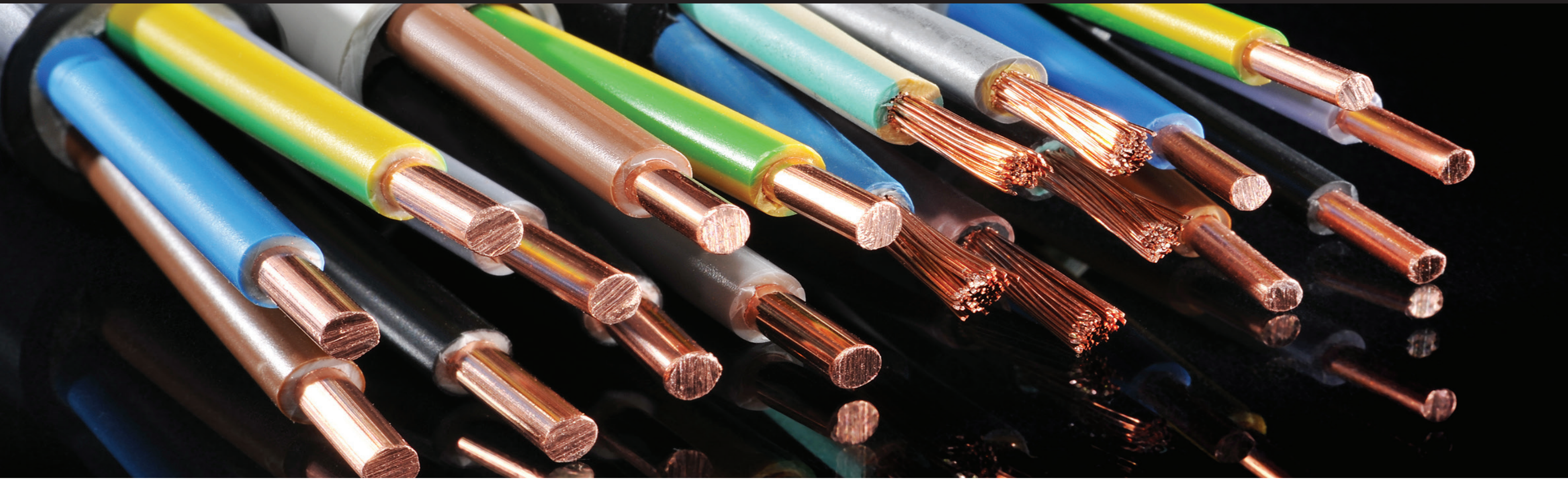
Many technical and engineering questions remain to be explored before the potential of this concept can be demonstrated.

See also ADS briefing paper. wn



Copper Development Association Africa

Promoting the use of copper in Africa



Copper is found in all Energy Systems

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

Superior conductivity of copper and recyclability

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

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

Copper's contributions towards reducing greenhouse gas emissions

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

Renewable energy

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

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

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

The CDAA and ECI role in reducing energy consumption

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

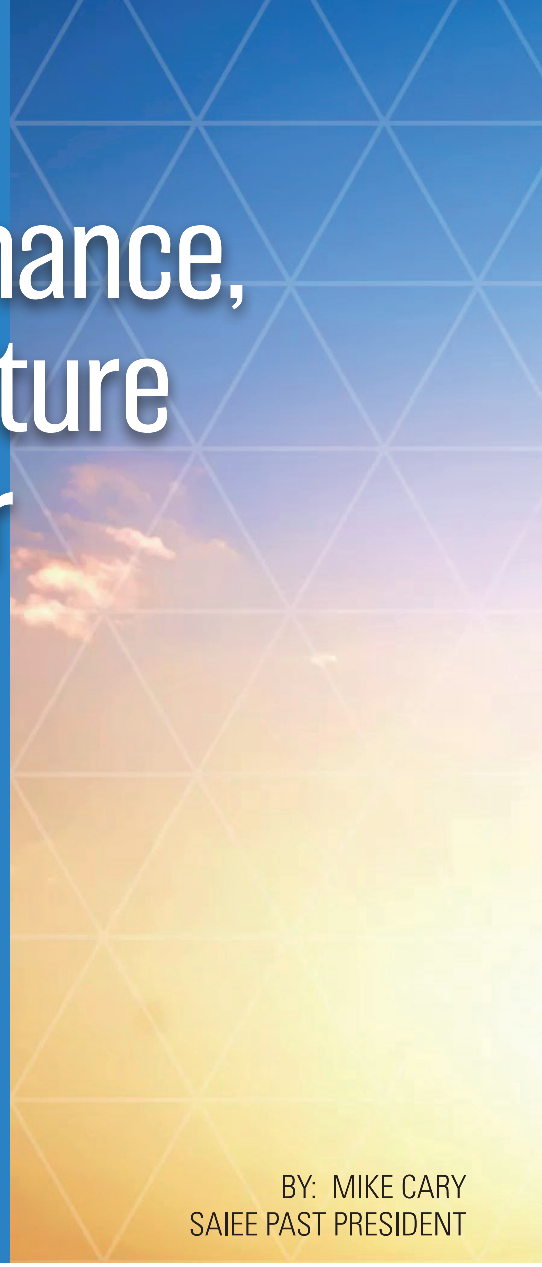
Electric motors account for a large amount of the electricity consumed by industry. Energy-efficient motor driven systems could save electricity consumption, resulting in reduced maintenance, improved operations and reduced environmental costs.

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

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

Power Station Maintenance, Refurbishment and Future of Synchronous Power Generation

There are various reasons to maintain equipment. The availability of equipment has become paramount in today's society because of the dependence on electricity for business and home life. Modern equipment manufacturers face much competition, which forces prices down. With the aid of powerful computers, new equipment is designed only to meet the specifications, often removing any safety factors that were previously inherent in the equipment.



BY: MIKE CARY
SAIEE PAST PRESIDENT

Fault levels have increased after installing additional equipment. Therefore, they are more likely to destroy the equipment.

The cost of replacing the equipment is too high. Maintenance and condition monitoring can often stop expensive repairs by eliminating the potential fault before a failure occurs.

DEVELOPMENT OF MAINTENANCE

The field of maintenance has evolved in its focus and application over the years.

This shift stems from the growing sophistication of technologies, equipment and techniques. The direction of maintenance has been modified from a Repair Approach to a Time-based Approach and finally to a Condition-based approach.

In short, each approach can be defined as follows:

- Repair Approach: Fix it when it breaks
- Time-based Approach: Maintain at fixed intervals
- Condition-based Approach: There is no "right" time to maintain
- Maintain as determined scientifically by monitoring the duties and condition of the equipment.

BUT WHY THE SHIFT TO CONDITION MONITORING?

The need for Condition Monitoring became apparent for the following reasons:

- To realise the inherent safety and reliability of equipment;
- To minimise the cost of actual and potential failures, e.g. the cost of injury or loss of life;
- Economic cost consequences (Lost production);
- Repair and maintenance cost - labour, materials, equipment such as cranes and travelling;
- To determine what action needs to be undertaken, e.g., restore equipment to the inherent safety arid reliability levels;
- To take action to rectify potential failures;

  - Rework - e.g. to re-install mechanisms correctly
  - Overhaul- e.g. to replace gaskets, dry - out of transformers
  - Discard - replace components, e.g. switchgear contacts

These areas can have both short-term and long-term implications on the condition of the plant. A case in point is the immediate short-term risks of failure linked to lightning faults. However, it may be that the plant does not fail in the short-term, but that the lightning causes structural damage, which only becomes evident in the longer term.

Condition Monitoring adopts an approach favouring low capital-intensive routine tests and monitoring the plant condition for effective plant care rather than expensive maintenance and repair operations.

Therefore, by implication, routine maintenance activities may not always be necessary, or the best alternative for the plant. The latter is particularly true considering the impact any such intervention on equipment has on its life expectancy.

Drawing on a host of testing methodologies (some as well-known as oil testing and other more novel methods such as infra-red scanning, X-rays or ultrasonic censoring), informed decisions could be made regarding corrective measures for your equipment. Thus, Condition Monitoring has rapidly forged itself as the "eliminator" of unnecessary activities, ensuring timeous execution only of the necessary.

To fully understand Condition Monitoring's value, it is necessary to comprehend equipment failures and its prevention.

Three areas impact on the condition of the power plant:

1. Inherent defects of the plant itself
   This may include specific vulnerabilities of the plant in terms of construction or design, such as poor design, incorrect application of materials and the unpredictable element of poor workmanship.

2. The power system to which the equipment is coupled
   This involves the entire environment; including aspects such as whether it is coupled in parallel, over-voltage conditions, transients and system fault levels. The lack of sufficient lightning protection also contributes to poor plant condition.

3. The operating conditions that the plant is subjected to
   How equipment is operated:
   > Transformers
      - Loading
      - Operating Temperature
      - Through Faults
   > Switchgear
      - Ambient Temperature
      - Switching Duty

Condition Monitoring and the host of other techniques available require highly specialised skills. While South Africa is the leading player in this sphere, we are currently facing the threat of a rapid decline in such skills. Trade professionals are among those choosing to emigrate, and the existing degree of technical skills amongst the present skills base is limited. Also, people increasingly seek to specialise in softer skill areas at universities. Due to the ever-diminishing training budgets and inadequate skills training and mentoring, organisations find it challenging to take advantage of optimum maintenance and condition monitoring programme benefits.

Looking to the future, many of the coal stations will come to the end of their lives, and it may be feasible to build a nuclear station on the coal station site and save dramatically on infrastructure costs. In this case, one would probably use dry-cooling technologies.

PLANNING FOR NUCLEAR BASELOAD SYNCHRONOUS GENERATION

In the 1980s, Eskom identified five sites suitable for building further Nuclear Power Stations after the current Koeberg units. These are all situated on the coast as water in most of the country is scarce, and seawater is then used for cooling purposes. Sites on the Kwa-Zulu coast were discounted because of the deep sands on the shore-line, resulting in high costs and low practicality of using this coast. In future, it may be possible to use inland water resources as KZN is a reasonably wet province.

The identified sites were:

- Duinefontein near Cape Town which already houses the Koeberg Power Station;
- Bantamsklip situated near Hermanus;
- Two sites were identified on the west coast: at Brazil and Skulpfontein near Kleinzee in the Namakwa district of the Northern Cape; and
- The final site was Thyspunt, about 100 kilometres west of Port Elizabeth.

In 2006 Eskom started an Environmental Impact Assessment (EIA) process to select a site for the next Eskom nuclear power station (called "Nuclear-1"). This process is now complete. In this long process, three sites have been removed from consideration for the next nuclear plant (they may be included in later EIAs). The two places in the Northern Cape were removed early in the process because they were too far away from any load centres. Transmission (and other infrastructure) costs will be high and efficiencies lower. Bantamsklip has also been put on hold because of the mountainous terrain, making it challenging to build transmission lines to and from the station.

In the draft assessment released by the EIA practitioners, it states that neither Duinefontein nor Thyspunt has fatal flaws and either could be selected. Thyspunt is recommended because that has more value in the national grid strengthening of the Eastern Cape.

Eskom owns the required land at Duinefontein and acquired most of the land required at Bantamsklip and Thyspunt in the 1980s and 1990s. In Bantamsklip the portion of the land needed not currently owned by Eskom is owned by other Government departments and is available to Eskom.

In the case of Thyspunt, Eskom has been recently buying more land to allow for site access roads and other infrastructure. Eskom currently owns some 4000 hectares of land on this site.

The current thinking seems to be installing four units at one power station (or transmission region). This would be about equivalent to the existing large coal stations Eskom operates (and Medupi). Two of the problems that come from Koeberg having two units is that it is not an efficient sharing of resources and the transmission planning has to plan to manage with no power from the Koeberg site. This is because if one unit is down for scheduled maintenance and the other unit trips, there is no site output.

With four units, there would always be three planned to be on load, and a single trip would not reduce the site output to zero.

The unit size for the nuclear programme that Eskom is looking at a range from 1000MW to 1650MW. The final decision will be a function of the vendor that the Department of Energy selects for the national programme.

CONCLUSION

South Africa's Eskom balance sheet hosts substantial assets consisting of an extensive and complex synchronous national power system, powered by a collection of significant synchronous generators; all operated at a fundamental frequency of 50 hertz and nominal national grid voltage of 400 kV. In the absence of adequate synchronous generation to support the national demand in real-time, the load is shed to balance and ensure the national grid's continued integrity.

All the existing power stations must be maintained and be available for dispatch by National Control. All plans for strengthening and expanding South Africa's synchronous generation must be pursued to support the National aspiration of economic prosperity for all in this global era of the 4th Industrialized Society.

CAUTIONARY NOTE :

1. Power electronic inverters connected to the national grid from renewable energy resources of imported hydro (Cahora Bassa and Future Inga), solar photovoltaic and concentrated utility-scale farms, wind farms and utility-scale battery storage will commutate in the absence of adequate national grid electrical strength. The electrical strength at the point of common coupling (PCC) is defined as the voltage and current product when all three synchronous phases are connected to yield the fault level, expressed as volt-ampere (MVA). Inadequate MVA of electrical fault level at the PCC will result in supply shedding of their complimentary energy contributions; the power electronics will automatically commutate and switch off.

2. The balance sheet of Eskom and that of Sovereign is presently heavily leveraged. The debt burden is full. The only opportunity to relieve the heavy debt is to grow and strengthen the cash inflows into Eskom; its revenues. This can be done either by growth in price or growth in volume.

   Eskom has substantial installed generation capacity as in physically installed synchronous generators. All these generators must be maintained, refurbished and be available for National Control dispatch. Volume growth, driven by lower prices, is the recommended path for increased national economic activity and national prosperity for all. The price change will throttle the economy.

3. The credit ratings of Eskom and the Sovereign has declined. S&P and others place the debt of both Eskom and the Sovereign in the category of junk. This implies that both cannot enter into Power Purchase Agreements (PPA's). PPA's will be required for new long term utility-scale generation investments.

   Without bankable Power Purchase Agreements, no project will find closure, and we will all be locked in futile conversations of blame and counter blame. A way forward is that of a competitive market model that works on the "invisible hand" principle that manages trade.

   The proposed globally accepted Independent Transmission System Market and System Operator Model. (ITSMSO) has relevance and must be accelerated. wn

ABOUT THE AUTHOR:

Mike Cary is a Past President of the SAIEE. For fifteen years before he retired from formal employment in 2010, he was employed by Rotek Engineering – 9 years as Managing Director. Rotek is a 100% owned Eskom subsidiary which maintains Turbines, Generators, Transformers, Switchgear, and Auxiliary plant.

Mid-sized companies defenceless in the face of cyberattacks

Medium-sized companies in South Africa are in a precarious position in terms of cybersecurity. While they find themselves firmly in the crosshairs of cybercriminals, they also have limited options to successfully defend themselves against cyberattacks, as the challenges faced by this market segment are multifaceted.

BY LUKAS VAN DER MERWE, SPECIALIST SALES EXECUTIVE: SECURITY, T-SYSTEMS SOUTH AFRICA

South Africa has been near the top of the list for cyberattacks for some time now and has one of the world's highest-risk ratings. Unfortunately, it is becoming increasingly difficult to reduce this, as attacks continue to evolve more sophisticated.

Consequently, companies in the mid-market sector face numerous hurdles regarding cybersecurity, with affordability topping the list. In most cases, smaller and lower-margin organisations cannot afford next-generation technology to improve their cybersecurity posture. At the same time, many still believe that smaller entities are less likely to be targeted than large enterprises.

The affordability aspect is also related to the fact that it requires expert skills to implement and maintain not only next-generation security solutions but simply what is currently accepted as good practice. Given that the cybersecurity landscape changes daily, no static implementation would be relevant or offer the kind of protection required. So, if an organisation does not have an extended security team, it isn't easy to maintain currency.

BIGGER ATTACK SURFACE

The situation is further exacerbated by the current pandemic, as many organisations are adopting remote work practices, cloud and software-as-a-service solutions. While this offers more sustainability under the circumstances, it frequently expands an organisation's attack surface in terms of cyberattacks.

As a result, the cybersecurity question becomes so overwhelming for many mid-market enterprises that they stick to what they know, which is the traditional "castle and moat" approach. This entails putting some perimeter defence and endpoint protection, keeping it current and hoping for the

best. Yet, this is becoming increasingly inadequate.

It isn't easy to quantify a cyberattack in terms of mid-sized companies' costs, as reporting is not mandated in South Africa. However, IBM's 2019 Cost of a Data Breach Report found that a data breach now costs $3.92 million on average. The report warns that a violation can be particularly acute for small and midsize businesses, with companies with less than 500 employees suffering losses of more than $2.5 million on average.

South African mid-sized businesses come close to the average number quoted in the report, so a cyberattack could potentially be financially devastating. What's more, enterprises could suffer reputational damage and a resultant loss of business if sensitive customer data is exposed. Depending on the industry, the company and its dependence on IT, a breach could bring operations to a halt, leading to further financial implications.

THE BARE MINIMUM

As an absolute minimum, all mid-sized enterprises should have perimeter and endpoint protection in place. A myriad of solutions offers multiple security layers, depending on the type of information an organisation processes and its specific risk profiling.

From an access protection point of view, companies need to consider network access control beyond essential perimeter protection to ensure that only authorised users can access its network.

With a significant amount of remote workers, companies now need to ensure that they securely connect its network so that VPN technology would be critical. The list is almost endless in terms of what solutions can be added on top.

Most midsize companies can do little of this successfully, and this is where managed security service providers can offer significant value. They can leverage shared solutions in place for a larger number of customers, whilst maintained by a group of experts with considerable experience. This can be implemented at a unit cost, far below what a dedicated investment would be.

They should consider looking at managed security service providers that deliver an end-to-end service, instead of investing in their technology, which could be prohibitively expensive and difficult to manage and maintain.

Enterprises must perform a holistic risk assessment and define the defence cost relevant to their organisation, before dismissing any cybersecurity investment as too expensive. The impact of a breach would be far worse. wn

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SAIEE South African Institute of Electrical Engineers

110 YEARS 1909-2019 SAIEE

MEMBERSHIP FEES EFFECTIVE 1 DECEMBER 2020

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

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

MEMBERSHIP FEES CAN BE PAID IN MONTHLY RECURRING PAYMENTS

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

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

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

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

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

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

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

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

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

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

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

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

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