IAEA BULLETIN

INTERNATIONAL ATOMIC ENERGY AGENCY

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NET ZERO needs NUCLEAR

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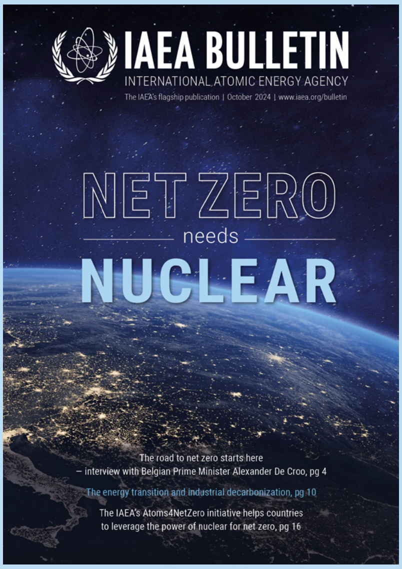

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The mission of the **International Atomic Energy Agency** (IAEA) is to help prevent the spread of nuclear weapons and to help all countries — especially in the developing world — benefit from the peaceful, safe and secure use of nuclear science and technology.

Established as an autonomous organization under the United Nations in 1957, the IAEA is the only organization within the UN system with expertise in nuclear technologies. The IAEA's unique specialist laboratories help transfer knowledge and expertise to IAEA Member States in areas such as human health, food, water, industry and the environment.

The IAEA also serves as the global platform for strengthening nuclear security. The IAEA has established the Nuclear Security Series of international consensus guidance publications on nuclear security. The IAEA's work also focuses on helping to minimize the risk of nuclear and other radioactive material falling into the hands of terrorists and criminals, or of nuclear facilities being subjected to malicious acts.

The IAEA safety standards provide the fundamental principles, requirements and recommendations to ensure nuclear safety and reflect an international consensus on what constitutes a high level of safety for protecting people and the environment from the harmful effects of ionizing radiation. The IAEA safety standards have been developed for all types of nuclear facilities and activities that serve peaceful purposes, as well as for protective actions to reduce existing radiation risks.

The IAEA also verifies through its inspection system that Member States comply with their commitments under the Nuclear Non-Proliferation Treaty and other non-proliferation agreements to use nuclear material and facilities only for peaceful purposes.

The IAEA's work is multi-faceted and engages a wide variety of partners at the national, regional and international levels. IAEA programmes and budgets are set through decisions of its policymaking bodies — the 35-member Board of Governors and the General Conference of all Member States.

The IAEA is headquartered at the Vienna International Centre, Vienna, Austria. Field and liaison offices are located in Geneva, New York, Tokyo and Toronto. The IAEA operates scientific laboratories in Monaco, Seibersdorf and Vienna. In addition, the IAEA supports and provides funding to the Abdus Salam International Centre for Theoretical Physics, in Trieste, Italy.

The time is now

Nuclear for a net zero future

By Rafael Mariano Grossi, IAEA Director General

The impact of climate change is becoming increasingly evident. Droughts, floods, and fires are telling us we need to act decisively and at scale.

In the global effort to decarbonize energy, industry and transport, progress is being made, especially in recognising the crucial role of nuclear energy.

Nuclear's inclusion in the Global Stocktake published during last year's UN Conference on Climate Change, COP28, in Dubai was nothing short of historic. For the first time since the inaugural climate summit was held in 1995, the 198 signatory countries to the UN Framework Convention on Climate Change (UNFCCC) officially called for hastening the deployment of nuclear. In addition, more than 20 countries pledged to work towards the goal of tripling global nuclear power capacity to help reach net zero by 2050.

In March 2024, the IAEA and the Government of Belgium organized the world's first Nuclear Energy Summit, with leaders from more than 30 countries and the European Union gathering in Brussels to highlight concrete steps towards accelerating nuclear power to achieve energy security, meet climate goals and foster sustainable development. This first-ever nuclear energy summit marked a turning point and laid out clearly what needed to happen, from setting the conditions necessary for investment to ensuring no country was left behind.

On the back of this momentum, the IAEA has raised its projections for nuclear electrical generation for a fourth year in a row. In the high-case scenario, there will be two and a half times more global nuclear capacity in 2050 than there is today, and a quarter of the growth will come from Small Modular Reactors (SMRs).

Around the world newcomer countries are looking to nuclear and countries with established programmes are extending the lives of nuclear power plants and building more. Technology companies needing to fuel energy-hungry data centres without increasing harmful emissions are making deals with actors in the nuclear sector, including established providers of nuclear-generated electricity and SMR start-ups.

This edition of the *IAEA Bulletin* surveys the current nuclear power landscape, illustrating recent successes and what still needs to be done so that nuclear power meets those projections. From growing the workforce, to streamlining processes and enabling faster reactor deployments, the path ahead of us is clearly illuminated. To accomplish our goals, we must act with intention and follow through on our stated global intentions. The world needs more nuclear energy, now it is time to deliver.

"In the global effort to decarbonize energy, industry and transport, progress is being made, especially in recognising the crucial role of nuclear energy."

– Rafael Mariano Grossi, Director General, IAEA

Photos: IAEA

IAEA UPDATES

The road to net zero starts here

Alexander De Croo, the Belgian Prime Minister, co-chaired the first ever Nuclear Energy Summit with IAEA Director General Rafael Mariano Grossi.

Nuclear energy is attracting growing interest from many countries because of its ability to cut the consumption of fossil fuels while meeting the rising demand for low-carbon dispatchable electricity, bringing us closer to achieving our global net zero targets. The Summit was the highest-level meeting to date exclusively focused on the topic of nuclear energy.

Prime Minister De Croo talked to us about the significance of the Summit and the role of nuclear energy in achieving net zero.

"The Nuclear Energy Summit was an opportunity for all participating leaders to share their views on the role that nuclear technology must play – and will play in the coming years – in meeting the decarbonization objectives that we have collectively set ourselves".

– Alexander De Croo, Belgian Prime Minister

Q: What were the key objectives of the Nuclear Energy Summit, and how did you anticipate it influencing global conversations and actions related to nuclear energy and developing technologies?

A: This wass the first time that a global Nuclear Energy Summit was organized with the participation of heads of State, and this underlined the importance of this meeting, held in Brussels on 21 March 2024. The Summit provided an opportunity for all participating leaders to share their views on the role that nuclear technology must play — and will play in the coming years — in meeting the decarbonization objectives that we have collectively set ourselves. This was a strong political signal, recognizing the essential role of nuclear power for many countries around the world on the road to net zero.

Talking about something is good. Implementing solutions is much better. That's why we decided to combine these discussions at a political level with a scientific symposium that brought together key industrial stakeholders to enable them to showcase their latest innovations and help them build the bridges and partnerships that will develop the projects of tomorrow.

Q: How do you see nuclear energy contributing to the global transition toward cleaner and more sustainable energy sources, especially in the context of transitioning to net zero?

A: As part of the solution. For one thing, the war in Ukraine has opened our eyes in Europe to the fact that we can no longer depend on others for our own energy needs. We need to take back control and diversify our energy sources as much as possible. Europe has rediscovered the geopolitical reality of energy policy. At the same time, we need to accelerate our energy transition if we are to meet the climate targets that we have set ourselves for 2050.

Q: Why now? Why do you think there was a need for a Summit?

A: Just look at how central nuclear energy was in the discussions at COP28 in Dubai. We now need to move from ideas and projects to implementation. That's the real challenge. We must seize this momentum to create the political and economic space that will enable us to move from PowerPoints to operating projects, whether we are talking about small modular reactors (SMRs) or other innovative solutions that will enable a stable base load for our industries around the world.

Q: Nuclear energy often meets with public scepticism. What strategies do you think are crucial for enhancing public understanding and acceptance of nuclear power to address climate change?

A: In a way, this shift has already happened. Public awareness of nuclear energy has not been this high in many decades. Even in countries like my own, where nuclear energy was set to be entirely phased out, you see a stark shift in public opinion favouring the contribution of nuclear power in the energy mix. You see this trend in other countries as well. We must seize this renewed support to establish the strongest possible transparency and trust of our public opinion. We cannot afford to downplay the contribution of nuclear power, but let's not oversell it either. We need to be realistic in our ambitions in terms of how nuclear energy fits in the overall energy mix of countries, and discuss the opportunities and challenges in a transparent way.

Prime Minister Alexander De Croo and IAEA Director General Rafael Mariano Grossi announce the world's first Nuclear Energy Summit at COP28 in Dubai.

(Photo: D. Calma/IAEA)

Q: What challenges and opportunities do you foresee in the widespread adoption of nuclear energy on a global scale, and how can these challenges be addressed?

A: It's important to me to talk about the opportunities, which are enormous. Climate change is the greatest challenge of the millennium. But we can turn it into a positive result, creating jobs, increasing the quality and resilience of our societies and offering a real future for innovation and our industry. The challenge is to consolidate our efforts by bringing together the expectations of citizens, politicians, our industries and all stakeholders to work together to implement this response, which involves nuclear energy. The goal was to make the Summit a truly global one, to involve partners from around the world. Climate change does not stop at national borders, and phasing out fossil fuels in only one part of the world will not be enough. We need a collective response at the global level that takes account of differences between continents and countries. Hosting the first Nuclear Energy Summit was a success and it will certainly not be the last.

Q: In your view, how can nuclear energy enhance energy security and foster economic development, both nationally and globally?

A: Look at what we were able to do in Belgium. We steered around 20 year-long policies and reviewed our position to phase out nuclear energy. We did this at a time when we had never invested so much in renewable energies. Belgium's ambition is to quadruple its production of offshore wind energy in the North Sea to 8 gigawatts (GW) by 2040 and connect our offshore infrastructure with other North Sea countries through the construction of the world's first energy island. By 2040, this will cover the consumption of 50% of all Belgian households. Not bad for a country with just over 60 kilometres of coastline! But this needs to be complemented by other low carbon energy sources, such as nuclear power. Besides the long-term operation of the Doel 4 and Tihange 3 reactors, we have decided to invest in nuclear innovation at the Belgian Nuclear Research Centre (SCK-CEN) in Mol. Belgium's ambition is to be part of innovative research into the dismantling of nuclear facilities, medical applications of radioisotopes and the development of fourth-generation SMRs.

Q: Given the advancements in nuclear technology, including SMRs, large reactors and fusion technology, how do you see these innovations shaping the future of nuclear energy and contributing to a more sustainable energy landscape?

A: Innovation is key to any sector's future. Transitioning to a net zero future requires an overhaul of our energy systems. We will continue to need an important baseload in our societies, and nuclear energy will continue to play a critical role in many countries in this regard. But we will also need more agile and smarter energy systems if we are to succeed. Our future energy systems will need to be resilient, provide security of supply, be carbon neutral and come at the lowest possible operating cost. Much of the innovation in the nuclear sector is addressing these challenges. It shows that the sector is on the right path.

NET ZERO

COP29: Building on the momentum from Dubai to Baku

By Matt Fisher

After a year of significant progress for nuclear power, international momentum to help meet the world's most pressing climate and energy challenges with this clean and reliable technology has shifted from the 28th session of the Conference of the Parties to the United Nations Framework Convention on Climate Change (COP28) in Dubai to COP29 in Baku, where Azerbaijan will host the annual global climate summit.

COP28 was a landmark event for nuclear energy. After spending nearly three decades on the sidelines of the annual conference, nuclear energy was finally recognized last year in Dubai. The message at COP28 was clear: nuclear power expansion must be a central component of global efforts to reach net zero.

That momentum continued to build at the first ever Nuclear Energy Summit, which was organized by the IAEA and the Government of Belgium and held in Brussels in March 2024. Leaders from more than 30 countries and the European Union emphasized the importance of nuclear for energy security, climate goals and sustainable development.

COP29 offers nuclear energy another opportunity in the spotlight as countries chart pathways for fulfilling its potential. As leaders gather in Baku, this edition of the IAEA Bulletin highlights the increasingly prominent role nuclear power is playing in the clean energy transition.

> The message at COP28 was clear: nuclear power expansion must be a central component of global efforts to reach net zero.

Diversifying nuclear energy solutions

To triple nuclear capacity by 2050, the world will need to harness all available solutions. Nearly all of the 60 or so reactors under construction are large pressurized water

reactors. While these technologies will make up the majority of the build-out, there is also room for emerging technologies like small modular reactors (SMRs) and microreactors — including novel designs with innovative fuels and coolants — to play a significant role.

Nuclear energy is versatile: in addition to providing baseload power to electrical grids around the world, it can be used to decarbonize rapidly and abate the impact of industrial sectors, which account for almost 40 per cent of greenhouse gas emissions.

The power needs of data centres and artificial intelligence are set to skyrocket in the coming years and, as a result, companies like Google and Microsoft are actively eyeing advanced nuclear technologies as sources of clean, reliable and flexible power to meet their growing energy needs. That could result in a new and original pathway for the commercial deployment of advanced nuclear power in markets where it is struggling to emerge amid challenges related to the financing of first-of-a-kind technologies.

Major milestones within closer reach

As more and more countries look to add the atom to their energy mix, the IAEA Milestones Approach, recently updated to address SMR-specific considerations, provides a sound process for developing the necessary infrastructure for a safe, secure and sustainable nuclear power programme. Newcomer countries can benefit from the IAEA's guidance as demand for nuclear power in the developing world continues to grow.

Countries need support in charting their unique pathways to net zero. Energy scenario modelling is often the place to start: a comprehensive, data driven picture of the challenges and opportunities that lie ahead. The IAEA's Atoms4NetZero initiative provides policymakers with the data they need to make informed, science based decisions to harness the full potential of nuclear energy — including in non-electrical sectors — and decarbonize their national economies.

Channelling progress

Novel approaches to implementing new build projects on time and on budget are needed to optimize expansion plans. The IAEA's Nuclear Harmonization and Standardization Initiative is helping countries develop harmonized regulatory approaches and industrial standardization to facilitate the deployment of safe and secure SMRs and other advanced reactors.

A skilled and diverse workforce is needed now more than ever to meet the challenges of the moment and ensure the long term sustainability of nuclear energy. The IAEA supports countries in these areas through initiatives such as the Nuclear Energy Management School, the IAEA Marie Skłodowska-Curie Fellowship Programme, the Lise Meitner Programme and a range of other trainings, workshops and peer review services.

The IAEA is required to verify the peaceful use of nuclear material. The continued expansion of nuclear power will add to the steadily growing volumes of nuclear material and the number of facilities under IAEA safeguards. By utilizing advanced technologies and working cooperatively with States expanding their nuclear energy production, as well as with 'newcomers' looking to add nuclear energy to their energy mix, IAEA safeguards stand ready to meet the increased demands of the international community as the world looks to achieve net zero.

As COP28 made clear, the global appetite for clean and reliable nuclear energy continues to grow. At COP29, countries can work to ensure that nuclear energy reaches its full potential as a key element of the net zero future.

Large reactors poised to lead the nuclear power expansion as small modular reactors advance

By Joanne Liou

> In a high case scenario, the IAEA's projection is that nuclear energy capacity will more than double by 2050, **from 371 GW(e)** in 2022 **to 890 GW(e)** by 2050, with only around 10% of this increase expected to come from SMR deployments.

Scaling up nuclear power to the level needed to achieve net zero is a significant and multifaceted undertaking, and while many reactor types may play a role, large reactors are set to lead the way. Large water cooled reactors were central to the rise of the nuclear industry in the 20th century, and the advanced reactors planned or under construction today, many of which are in the 1–1.7 gigawatts (electrical) (GW(e)) range, are poised to provide the bulk of new nuclear capacity.

"For countries already operating nuclear power plants, large light water reactors, rather than small modular reactors (SMRs), will drive the increase in nuclear capacity," says Aline des Cloizeaux, Director of the IAEA's Division of Nuclear Power. "Large reactors are a proven technology that can economically provide a large and reliable baseload of energy. But we do expect countries and industries to tap into the potential of SMRs as well."

Nuclear power must be expanded to meet the world's net zero goals — that was the clarion call issued by IAEA Director General Rafael Mariano Grossi last December at the 28th session of the Conference of the Parties to the United Nations Framework Convention on Climate Change (COP28), in a statement supported by dozens of countries. This position was affirmed by the inclusion of nuclear power in the Global Stocktake for the first time in the Conference's almost 30-year history.

In a high case scenario, the IAEA's projection is that nuclear energy capacity will more than double by 2050, from 371 GW(e) in 2022 to 890 GW(e) by 2050, with only around 10% of this increase expected to come from SMR deployments. Hitting this mark means adding at least 20 GW(e) per year. "The high case projection is ambitious but technically feasible," says Henri Paillere, Head of the IAEA's Planning and Economic Studies Section.

Smaller reactors like SMRs and microreactors may be particularly suitable for providing power to industrial end users and remote communities with smaller electric grids, and for powering non-electric applications such as hydrogen production and seawater desalination. However, SMRs will need demonstration before their broader deployment; larger reactors will continue to dominate the nuclear power landscape in the years to come.

Almost all of the 58 nuclear reactors currently under construction are large reactors, and expansion plans in nuclear power operating countries and newcomer countries alike are mostly centred around reactors with 1 GW or more of capacity, although many of these countries are eyeing eventual SMR deployment as well. Poland, a newcomer aiming to add nuclear by the mid-2030s, plans to deploy 6–9 GW(e) of generating capacity with large nuclear power reactors. China, which currently operates 55 reactors, expects to expand its nuclear power capacity

eightfold to around 400 GW by 2060, mainly through the deployment of large reactors.

Challenges to nuclear expansion

According to Paillere, the biggest challenges in expanding nuclear energy capacity are those related to financial and human resources: “Mechanisms are needed to attract capital from investors and the private sector to fund new nuclear projects. There is enough money to fund investments for the clean energy transition. What is making investors cautious of nuclear power is the risk, like delays in construction”.

After a hiatus of decades in nuclear new builds, the construction of large, first-of-a-kind nuclear projects in Western countries has often been plagued by cost overruns and delays, as skills are relearned and processes revitalized. “There had not been construction in 20 years in some of those countries. Human resources needed to be trained and supply chains rebuilt,” says Paillere. “Increasing nuclear capacity means increasing construction and grid connections, which means finding more engineers, technicians, welders and more. The issue of human resources is not specific to nuclear, but it is a common challenge across clean energy technologies”. Lessons learned from previous projects, including in project management and stakeholder engagement, will be critical to the timely completion of new build endeavours.

In some countries, such as Belarus, China, the Republic of Korea, the Russian Federation and the United Arab Emirates, new build projects — most of which entail the construction of advanced water cooled reactors — have proceeded largely on time and on budget. “The standardized design of advanced reactors expedites licensing and reduces both capital costs and construction time,” says des Cloizeaux.

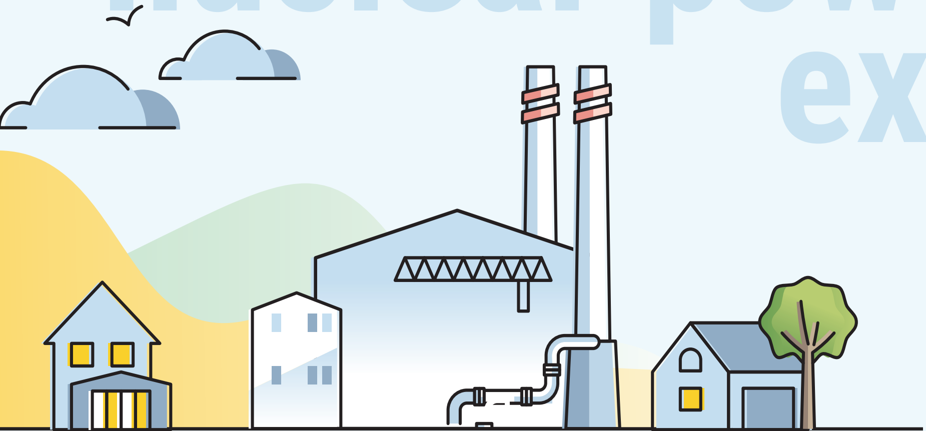
Past and future expansion

The 1970s saw a boom in nuclear power expansion, driven mainly by North America and Europe. In 1970, 15 countries operated 90 nuclear power reactors with a total capacity of 16.5 GW(e). Throughout the 1970s, construction started on 25–30 new nuclear units annually. By 1980, 22 countries operated 253 nuclear power reactors with 135 GW(e) of capacity. By the end of 1990, nuclear capacity had more than doubled to 326 GW(e) worldwide.

“The nuclear industry and supply chain were well established and able to build 30 GW per year,” Paillere says. “This is encouraging because, at that time, there were only a few countries leading the trend, such as France, Japan and the United States of America. Today, China and the Russian Federation have become major players and have the supply chain and industry to support the expansion of nuclear power”.

A revival and expansion of nuclear power to achieve global goals, whether through large reactors or SMRs, will require policy support and tight cost controls. “The momentum to realize the goals is there, but it will take more political action,” says des Cloizeaux.

nuclear power expansion



The energy transition and industrial decarbonization

By Eric Ingersoll and Chirayu Batra

Clean energy abundance for a high energy planet is the future we want. More than 30 terawatts (electrical) (TW(e)) of clean firm energy are needed to fully decarbonize the global energy system and enable every global citizen to receive modern energy services equivalent to the Organisation for Economic Co-operation and Development average. How can industries and economies keep growing, even as they pursue decarbonization? In 2022, the industrial sector accounted for 37 per cent of global energy use and was directly responsible for emitting 9 gigatonnes of carbon dioxide, or 25 per cent of global energy system carbon dioxide emissions (excluding indirect emissions from electricity use for industrial processes). Despite decarbonization commitments, process emissions from leading industrial nations have been steadily increasing.

In 2022, the industrial sector accounted for 37 per cent of global energy use and was directly responsible for emitting 9 gigatonnes of carbon dioxide, or 25 per cent of global energy system carbon dioxide emissions.

Navigating industrial heat and power needs in the energy transition

A major trend in the energy transition is the push towards full-scale electrification, even in industrial activities. However, this strategy of 'complete electrification' presents significant challenges, in particular when it comes to meeting industrial heat and power needs. These needs are different from those of grid-tied, electricity-only resources, as they follow the load profile of a behind-the-meter combined heat and power system. The first challenge is the simultaneous use of both heat and electricity, and the second is the requirement for robust reliability, availability and security in the process. Several other issues — such as the availability of new transmission lines and the efficiency and reliability of the new electrified process — are further barriers.

As analysed in a recent United States (US) Department of Energy report, the majority of emissions in the industrial sectors come from heat: nearly 60 per cent of emissions are the result of heat requirements and on-site power generation. When considering the carbon intensity of the power grid, industrial emissions could easily exceed 70 per cent of total emissions.

The inclusion at the 28th session of the Conference of the Parties to the United Nations Framework Convention on Climate Change (COP28) of nuclear as a clean energy source requiring accelerated development was unprecedented. More than 22 countries pledged to work towards tripling global nuclear capacity by 2050. However, this would produce around 9000 terawatt-hours (TW·h) of energy, equivalent to the total energy consumption of the iron and steel industry sector in 2022. Full decarbonization of energy intensive industries such as chemicals, petrochemicals, cement and paper/pulp would require a far greater increase in clean heat and electricity.

The use of intermittent sources of energy requires a massive expansion of the grid, affecting its stability and resulting in increased system and firming costs. These factors are not aligned with the energy requirements of industry and could severely limit industrial growth. However, a decentralized source of nuclear energy — such as a small modular reactor (SMR) or microreactor at an industrial site or industrial cluster — can provide enough heat and power to meet requirements. Companies like Dow Chemicals are already looking to test this model with plans to install high temperature gas cooled SMRs at one of its US production sites in order to replace natural gas with clean heat and power and decarbonize production.

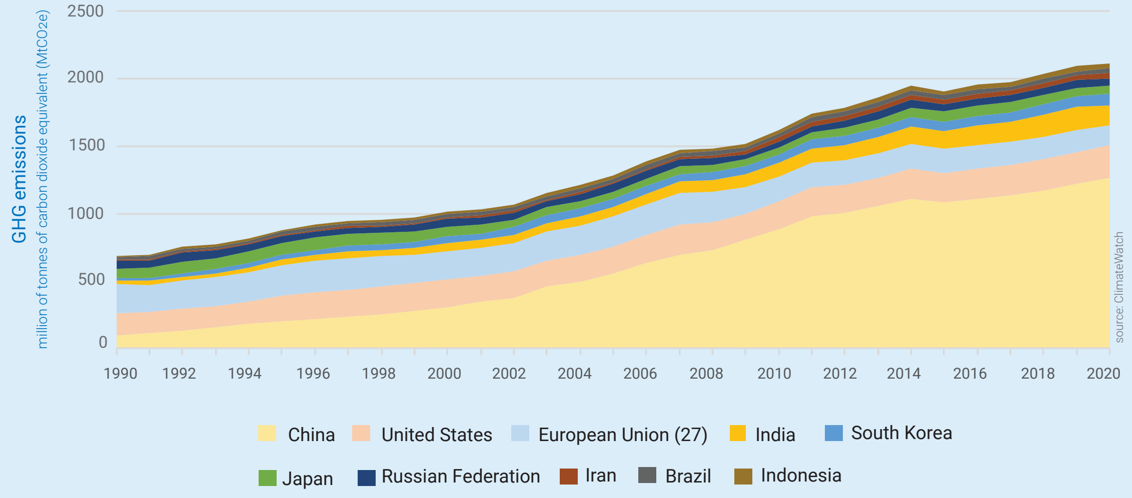
A sustainable energy future

The chemical sector is a critical provider of materials for a vast array of products such as plastics, fertilizers and pharmaceuticals. Its emissions predominantly derive from three heat generation sources (approximately 40 per cent), electricity consumption (approximately 29 per cent) and direct process emissions (approximately 24 per cent). Moreover, 80 per cent of operational emissions come from on-site point sources. The adoption of on-site nuclear can provide clean heat and power for these essential chemical processes.

Another growing industry is data centres, which are increasing global electricity demand The combined electricity use of

Decarbonisation

Greenhouse gas emissions from industrial processes
(top ten countries)



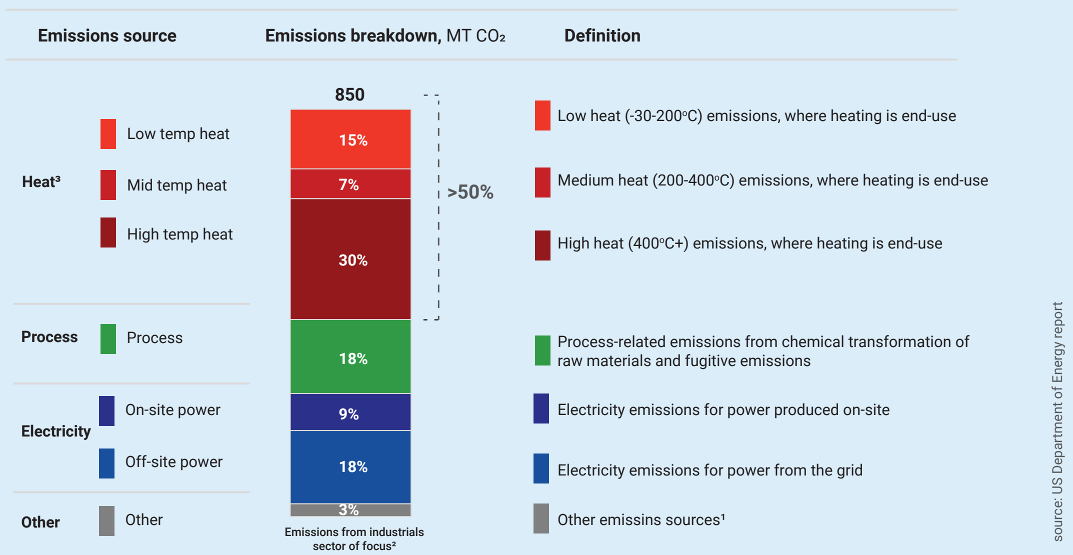
Amazon, Microsoft, Google and Meta more than doubled between 2017 and 2021. The electricity consumption of data centres is projected to exceed 1000 TW·h by 2026, and will increase further with the rise of artificial intelligence (AI). As a result, several major tech companies are looking at advanced nuclear power sources, such as SMRs, as a future clean energy option.

SMRs could help to meet the needs of industry through a deployment model based not on a large custom project but on factory built products using a pre-established design, supply chain and delivery process. This approach would reduce costs, improve efficiency and ensure a predictable construction schedule. It would provide a commercially low risk, cost effective, reproducible and scalable solution that aligns with industry goals and contributes to the achievement of global decarbonization targets.

Industrial decarbonization cannot be achieved with traditional nuclear power plants alone. New delivery models are needed that fit within the fast and predictable asset deployment process that companies use today.

Radically new approaches to designing, licensing and delivering clean energy technologies, together with the leveraging of new digital tools, will enable advanced nuclear to provide a solution for a sustainable, equitable and resilient energy future.

Breakdown of greenhouse gas emissions of major industries across the USA



Data centres, artificial intelligence and cryptocurrencies eye advanced nuclear to meet growing power needs

By Jeffrey Donovan

With the electricity consumption of data centres, artificial intelligence (AI) and cryptocurrencies set to grow in the coming years, major tech companies are actively looking to advanced nuclear technologies such as small modular reactors (SMRs) to provide clean, reliable and flexible power. This could result in a new pathway for the commercialization of SMRs and other advanced reactors in markets where they are yet to emerge.

Data centres (which house the servers and computing equipment needed to store digital information), AI and cryptocurrencies are driving an increase in electricity demand in several regions. Together, they accounted for 2% of global electricity consumption in 2022, a figure that may double by 2026, according to the International Energy Agency (IEA). The combined electricity consumption of four companies alone — Amazon, Microsoft, Google and Meta — more than doubled between 2017 and 2021 to about 72 terawatt-hours (TWh).

As they seek to meet their rising power needs, major tech companies also want to decarbonize their operations, either because legislation requires them to do so or in order to meet their own sustainability goals. To achieve this, they are looking not only to variable renewable sources of electricity such as solar and wind but also to advanced nuclear technologies such as SMRs. A similar trend can be observed in other industries seeking clean 24/7 power and heat, such as petrochemicals.

"In some regions, the pathway to advanced nuclear power deployment may very well pass through major corporate end users in the tech industrial sectors," says Aline des Cloizeaux, Director of the IAEA's Division of Nuclear Power. "SMRs and other advanced nuclear reactors are well suited to play a key role for these companies, providing the flexible and reliable low carbon energy they need to run their operations".

In 2022, data centres consumed an estimated 460 TWh of electricity, according to the IEA.

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By 2026 that figure could rise to more than 1000 TWh — over one third of the total electricity generated by the world's nuclear power plants last year, and roughly equivalent to the electricity consumption of Japan.

By 2026 that figure could rise to more than 1000 TWh — over one third of the total electricity generated by the world's nuclear power plants last year, and roughly equivalent to the electricity consumption of Japan.

In China, electricity demand from data centres is expected to double to 400 TWh by 2030 compared to 2020. In the north-east of the United States of America (USA), it is expected that data centres will increasingly drive electricity demand. The data centre market in Europe is also developing rapidly. Electricity demand from data centres in Ireland, for example, was 5.3 TWh in 2022, equivalent to 17% of the country's total electricity consumption. The IEA has stated that "at this pace, Ireland's data centres may double their electricity consumption by 2026, and with AI applications penetrating the market at a fast rate, we forecast the sector to reach a share of 32% of the country's total electricity demand in 2026".

Searching for solutions to these emerging needs, both Google and Microsoft have recently released reports examining how advanced nuclear, along with other clean electricity sources, can support their business and sustainability goals. "We know that wind, solar and batteries will be critical in order to decarbonize our energy consumption. But we also need firm, dispatchable, carbon free electricity technologies to cost-effectively decarbonize our electricity consumption," says Devon Swezey, Senior Manager in Global Energy and Climate at Google.

As data centres, AI and cryptocurrency companies seek sources of clean and reliable baseload power to run their operations and achieve decarbonization targets, vendors of advanced nuclear technology are taking note. "Nuclear energy is obviously the best solution to both of these problems, so the question is how to deliver it most effectively," says Bret Kugelmass, Founder and Chief Executive Officer of Last Energy, a microreactor vendor based in the USA.

Electricity end users such as tech companies need the kind of clean and firm power that advanced nuclear can provide. At the same time, they can help to overcome the barriers to deployment that stand in the way of these technologies coming to market.

In its recent policy brief on the use of advanced nuclear fission and fusion as a decarbonization tool, Microsoft cited a number of areas in which the company and other stakeholders can advocate for addressing such barriers. These included accelerating research and development, enabling programmes for testing new technologies and modelling them for integration with other low carbon sources, advancing regulatory approaches for safe and cost-effective deployment, and leveraging the power of digital technologies, including AI, in the management of new energy technologies and the grid.

Google sees a similar role for itself: "Corporate buyers can help reduce barriers to the commercialization of these technologies, including advanced nuclear," says Swezey. "We hope to work with other clean energy buyers to scale these technologies in the coming decades and achieve 24/7 clean power, not just for Google but for everyone".

Financing new build nuclear projects remains a challenge in several markets worldwide, given their typically high capital costs and long construction times. By contrast, SMRs and microreactors, which are smaller and factory built, are expected to require lower upfront costs and shorter build times. Like companies in the tech sector, those in other industries, such as Dow Chemicals, are looking to deploy SMRs to power their operations not only with decarbonized electricity but with high temperature heat.

The result, according to Kugelmass, may be a new path for nuclear power deployment: "Packaging nuclear in a way that's smaller — micro scale, in fact — and modular is the key to making it affordable for private industry. Crucially, it is also the key to developing projects with purely private capital." If we can create a model for nuclear energy that relies solely on private funding, we will be able to develop projects more efficiently and realize the benefits of nuclear at scale".

advanced nuclear

Navigating nuclear development

The versatility of the IAEA's Milestones Approach

By Wolfgang Picot

The journey towards nuclear power is a complex undertaking, and the IAEA's Milestones Approach has emerged as a crucial framework for nations embarking on this intricate path. For many of them — from newcomers like Ghana and Estonia to established players seeking expansion or strategic planning — the structured nature of the Milestones Approach has proven to be versatile and indispensable.

The IAEA's Milestones Approach is a phased and comprehensive method designed to assist countries in developing their nuclear power programmes. The method is instrumental, providing a roadmap for nations from the early stages of considering nuclear power to the operational phase, a process which spans approximately 10–15 years.

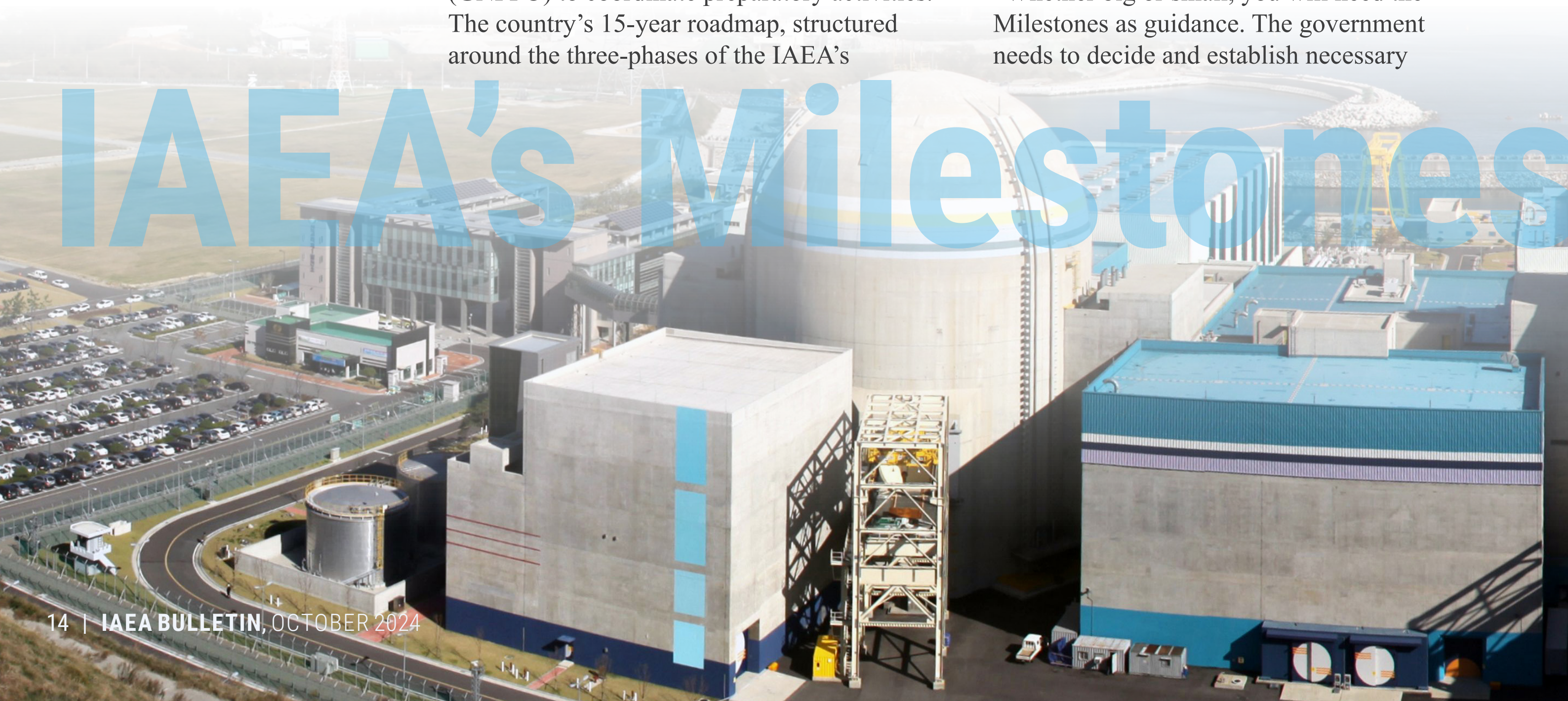
Seth Kofi Debrah from the Ghana Atomic Energy Commission (GAEC) provides insights into the significance of the Milestones Approach: "The Milestones Approach provides a very high-level roadmap and guidance on how to prepare. For a newcomer country, developing such a major infrastructure project is challenging. The Milestones Approach provides a comprehensive formal structure to develop it".

Ghana, one of the countries set to embrace nuclear power, has established the Ghana Nuclear Power Programme Organization (GNPPO) to coordinate preparatory activities. The country's 15-year roadmap, structured around the three-phases of the IAEA's Milestones Approach, envisages adding 700–1000 megawatt (electrical) (MW(e)) to the national grid by 2030.

Estonia, on the other hand, is also eyeing nuclear power as a reliable and low-carbon option. Reelika Runnel, Coordinator of the Estonian Nuclear Energy Working Group, emphasizes how the Milestones Approach gave them a starting point: "It provides an overview of how much work is needed to establish a nuclear programme and encompasses all topics related to nuclear power. It reassures decision-makers at the political level that they can make decisions based on the experiences of the IAEA, drawing on many Member States' experiences".

As the energy landscape evolves, traditional large-scale nuclear power projects are in part giving way to small modular reactors (SMRs). Estonia, recognizing this shift, is exploring SMRs given the limitations on accommodating large reactors in its relatively small electricity grid. "The Milestones Approach is also fully applicable to SMRs. Even though the concept of SMRs differs from conventional reactors, the same set of regulations are applicable," says Runnel.

Seth Kofi Debrah echoes this sentiment, emphasizing that the Milestones Approach remains a crucial tool regardless of size: "Whether big or small, you will need the Milestones as guidance. The government needs to decide and establish necessary



laws and regulations, and an operator to finance and run the reactor is needed, just like for larger reactors. It is all there, and the Milestones Approach remains a useful tool for embarking countries".

SMRs are nuclear installations and in that regard the 19 infrastructure issues of the Milestones Approach generally apply. However, an upcoming revised version of *Milestones in the Development of a National Infrastructure for Nuclear Power* — the guidance publication for the Milestones Approach — addresses aspects of infrastructure that can be implemented or considered differently in the context of SMR deployment, where appropriate. The publication has a separate annex setting out the specific infrastructure considerations for SMRs.

SMRs also differ from their larger 'siblings' in that reactors were traditionally built and operated in one country. By contrast, the modular construction method of SMRs means that they can be constructed in one country and shipped, assembled and operated in another. This means that applicable requirements may need to become part of a more internationalized system in which there is agreement and mutual recognition of regulations among stakeholders. In this regard, the Milestones Approach works in synergy with the IAEA's Nuclear Harmonization and Standardization Initiative (NHSI).

Initially designed for countries embarking on nuclear programmes, the Milestones Approach is proving to be equally relevant to established players looking to optimize or strategically plan their nuclear capabilities. Aline des Cloizeaux, the Director of the Division of Nuclear Power at the IAEA, points out its role in evaluating nuclear infrastructure: "We observe that in Europe right now several countries intend to restart projects or expand existing projects. The Milestones Approach methodology can help with the evaluation of their current nuclear infrastructure".

Even for countries with nuclear operating experience, when building new reactors it is beneficial to reassess the maturity of their existing infrastructure issues for the end of Phase 2 to see if they have gaps compared to the level that the IAEA recommends before starting construction. Whenever gaps are identified, the IAEA can support expanding countries in areas such as supply chains, energy grids, human resources and other aspects of the broader infrastructure.

The adaptability and versatility of the Milestones Approach becomes even more relevant in light of the IAEA's annual nuclear power outlook, which projects a significant increase in installed nuclear capacity to 890 gigawatts (GW) by 2050, highlighting the sector's potential contribution to achieving net zero emissions. This trend is set to increase: leaders from 22 countries on four continents came together on 2 December 2023 to announce a declaration to advance a global aspirational goal of tripling global nuclear energy capacity by 2050. Around 30 countries will participate in the first ever Nuclear Energy Summit, to be held in Brussels in March 2024 and co-chaired by IAEA Director General Rafael Mariano Grossi and Belgian Prime Minister Alexander De Croo, emphasizing the renewed momentum in nuclear power.

The adaptability and versatility of the Milestones Approach mean that it will continue to be important in shaping the future of nuclear energy and its essential contribution to addressing global challenges such as reducing fossil fuel consumption and enhancing energy security.

"For a newcomer country, developing such a major infrastructure project is challenging. The Milestones Approach provides a comprehensive formal structure to develop it."

— Seth Kofi Debrah, Ghana Atomic Energy Commission

The IAEA's Atoms4NetZero initiative helps countries to leverage the power of nuclear for net zero

By Jeffrey Donovan

The road to net zero entails a series of complex choices. Policy makers must chart an energy course based on available resources, energy technologies (including those still under development) and costs. By leveraging advanced energy scenario modelling, the IAEA's **Atoms4NetZero** initiative helps countries to make science-based decisions about the full potential of nuclear energy — including for sectors beyond electricity generation — in order to prepare for the transition towards net zero greenhouse gas (GHG) emissions.

"The first step for a country seeking to meet its net zero targets is to assess its existing energy infrastructure, including power generation sources, transmission networks and consumption patterns," says Henri Paillere, Head of the IAEA's Planning and Economic Studies Section. "By analysing past and present data, and by modelling future energy demand, policy makers can identify areas for improvement and prioritize investments to build clean and resilient energy systems".

An increasing number of countries are interested in, or embarking on, the introduction or expansion of nuclear power. At COP28 in Dubai, more than 20 countries pledged to work towards tripling nuclear capacity to achieve net zero. Currently, around 60 nuclear power reactors with a total of around 60 gigawatts (electrical) (GW(e)) of capacity are under construction in 17 countries, and more than a third of them are in China, the world's leading reactor builder. The International Energy Agency says that global nuclear capacity must more than double by 2050 to achieve net zero, a level consistent with the high case scenario of the IAEA's annual projections for nuclear power to 2050.

However, achieving net zero requires more than clean electricity. Through low carbon heat and energy carriers such as hydrogen, it will require the decarbonization of hard-to-abate sectors such as petrochemicals, steel, cement making and transportation, which together are responsible for almost 60% of GHG emissions.

Atoms4NetZero assesses the potential of nuclear to develop credible scenarios for achieving that goal by using IAEA analytical tools such as the Model for Energy Supply

Strategy Alternatives and their General Environmental Impacts (MESSAGE), which combines technologies and fuels to construct ‘energy chains’, making it possible to map energy flows from supply (resource extraction) to demand (energy services). Other modelling tools used include the Model for Analysis of Energy Demand, which identifies structural changes needed to achieve net zero, and the Framework for the Modelling of Energy Systems, which assesses and quantifies the role and value of clean energy technologies, including nuclear, in the planning and operation of energy systems.

In its approach to energy scenario modelling, **Atoms4NetZero** marks a significant departure from current global practices. “Until now, nuclear energy has had a rather limited role in energy scenario studies used by governments and investors to chart the transition to net zero,” said Carolynn Scherer, Head of the IAEA’s International Project on Innovative Nuclear Reactors and Fuel Cycles Section. “This initiative aims to fill that gap by providing a fuller picture of the potential of nuclear energy, which has a proven track record in mitigating the causes of climate change while providing resilience to its consequences, and in enhancing energy security and sustainable development”.

Of course, variable renewable sources such as wind and solar are set to play a central role in the transition to clean energy systems. Here, too, **Atoms4NetZero** energy modelling can provide a key service, helping policy makers to optimize the integration of renewables into the energy mix through the assessment of resource availability and evaluation of the impact on grid stability. “By combining nuclear power with renewables, countries can achieve a more secure, resilient and sustainable energy system,” says Paillere.

“Energy modelling scenarios considered within the framework of **Atoms4NetZero** are important because, in Africa especially, we are facing a serious energy deficit situation, and our policy makers are looking at different options,” said Enobot Agboraw, Executive Secretary of the African Commission on Nuclear Energy. “They’re looking at nuclear power; they’re looking at renewables, and it is very important that they are properly informed in order to be able to make the best possible decisions. Energy modelling provides scientifically based evidence so that they can make decisions that are not based on hearsay or emotion, but solid decisions that would enable us to address this issue of climate change and energy deficit”.

Atoms4NetZero builds on the IAEA’s well established work with countries on technology neutral energy planning, an approach that impartially evaluates and selects energy sources based on their performance. Through its technical cooperation programme, the IAEA supports countries’ energy planning efforts using modelling tools such as MESSAGE and System Planning Test models. Since 2021, the IAEA has worked with the International Renewable Energy Agency to assist the African Union in developing an energy infrastructure development strategy known as the Continental Power System Masterplan. This will enable Africa to compare different energy scenarios and pool resources for investment in sustainable energy sources in order to solve the continent’s growing energy challenges.

Atoms4NetZero will also conduct techno-economic analyses and studies — such as a comparative analysis of low carbon energy sources for a country or region — possibly in collaboration with stakeholders such as countries, end users, research organizations, industry, financial institutions and other international organizations and agencies. The initiative encompasses other areas of activity to assist countries in their clean energy transition. These include an advisory service, workshops and training for capacity building, outreach and stakeholder engagement.

Atoms4NetZero is currently working with Estonian researchers to incorporate strict carbon constraints into the country’s MESSAGE model for net zero scenarios for electricity and heat production to 2050. Estonia, which obtains the bulk of its electricity generation from fossil fuels, is considering the introduction of nuclear power and of small modular reactors in particular.

IAEA
ATOMS 4 NET ZERO
helps countries to make science based decisions to harness the full potential of nuclear energy.

Scan to learn more

Standards for success

IAEA initiative works to boost SMR deployment

By Matt Fisher, Pekka Pyy and Brett Rini

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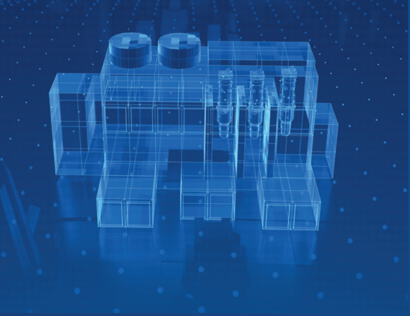
NUCLEAR
HARMONIZATION
STANDARDIZATION
INITIATIVE

aims to facilitate the deployment of safe and secure SMRs and other advanced reactors through harmonized regulatory approaches and industrial standardization.

Scan to learn more



As the global community works towards achieving the ambitious goals set out in the 2015 Paris Agreement, the consensus is increasingly clear: nuclear energy has a significant role to play in decarbonizing the energy and industrial sectors. However, in order to expand the deployment of nuclear power on a vast scale, including through the use of advanced technologies such as small modular reactors (SMRs), novel approaches are needed to implement new build projects sustainably and at cost and to ensure a high level of safety and security.

The IAEA's Nuclear Harmonization and Standardization Initiative (NHSI), launched in 2022, aims to facilitate the deployment of safe and secure SMRs and other advanced reactors through harmonized regulatory approaches and industrial standardization.

Focusing on standardized development, manufacturing and construction, members of the NHSI Industry Track are set to publish two white papers this year: one providing guidance on the challenges of harmonizing inspections of safety significant high integrity components, and the other highlighting the need to better harmonize non-nuclear codes and standards across jurisdictions. A third paper is planned regarding practical steps for early engagement in the use of high quality industrial grade components in safety systems. Members of the NHSI Regulatory Track, who are focused on the development of processes that enhance regulatory cooperation, are developing a comprehensive publication to support regulatory cooperation on design reviews and launching a multinational regulatory review process that will enable regulators to conduct joint reviews of SMR design.

On track to improve efficiency

SMRs are designed to be factory built and installed on site, thereby reducing costs and shortening construction times, and their relatively small size of typically up to around 300 megawatts (electrical) (MW(e)) per unit may allow for their deployment in areas unsuitable for large reactors. However, the bespoke nature of many nuclear components can lead to bottlenecks in the supply chain, as the manufacture of tailor-made items, together with current inspection procedures, may significantly lengthen the production process.

Moving towards a model of reactor design based on serially produced items and harmonizing requirements among regulators and end users in different jurisdictions could greatly reduce the time and effort required to get SMRs and other advanced reactors up and running.

"Obtaining approval to use custom-built technologies is a difficult and often lengthy process, as nuclear regulators do not currently allow non-nuclear standard industry components for safety applications in nuclear facilities," says Matheus Abbt, senior advisor for nuclear technology at Swedish power company Vattenfall. "Aligning nuclear safety requirements with relevant industry standards could help overcome supply chain challenges and facilitate quicker deployment of SMRs".

Streamlining the process

Differing inspection protocols for long lead items, or items with production times lengthy enough to impact the final project delivery date, are a further concern. Pressure vessels, for instance, must generally be inspected by the end customer with the involvement of regulators or their notified organizations, beginning with material selection and continuing throughout each fabrication phase. This entails a significant time burden and results in potentially redundant inspections. By contrast, the completion of a streamlined process long before the submission of a construction license application would enable SMR projects to be implemented on shorter timelines.

"By mutually recognizing some long lead item inspection activities, there is the potential to dramatically reduce project life spans and manufacturing risks," says Aline des Cloizeaux, Director of the IAEA Division of Nuclear Power. “This could be especially beneficial when production ramps up and SMR long lead items bound for disparate jurisdictions are being manufactured simultaneously. There is an excellent opportunity to optimize resources here”.

Nuclear power plants (NPPs) are subject to a wide range of regulations, many of which fall outside the scope of nuclear regulatory bodies. At a technical meeting held in late 2023, a working group within the NHSI Industry Track reviewed potential solutions to challenges presented by non-nuclear codes and standards. Suggestions included encouraging project owners and operators to engage early with relevant government agencies, and working together with suppliers early on to strengthen the supply chain by lowering commercial, project and quality management risks that might be present in the proposed deployment areas. Furthermore, it is essential to understand procurement dynamics and ensure compliance with local and national regulations in order to ensure that projects are completed on time and on budget.

A global framework for regulatory review

The long-term aspiration of the NHSI Regulatory Track is to advance towards the development of a global framework for the regulatory review of advanced nuclear reactor designs, in particular SMRs. This global framework could be presented as a set of documents and procedures outlining common regulatory requirements and an understanding of how to meet them, which would enable joint regulatory reviews of advanced reactors to be undertaken. The global framework would also facilitate the sharing of reviews and resources and the achievement of a shared review outcome.

“The first step for the development of such a framework is for regulators to cooperate with each other during regulatory reviews of advanced reactor designs. The NHSI Regulatory Track has developed approaches for collaboration on regulatory reviews. Regulatory body experts developed these approaches, which take account of feedback from the industry,” says Anna Bradford, Director of the IAEA Division of Nuclear Installation Safety.

The NHSI Regulatory Track has investigated solutions that would enable information sharing among regulatory bodies during their reviews and it is planning to draft a memorandum of cooperation — an overarching, non-binding agreement that would demonstrate the aspiration of signatory regulatory bodies to work together and share information. Moreover, the Regulatory Track is developing a multinational pre-licensing regulatory design review that would enable regulators to jointly evaluate specific technical areas of a proposed reactor design and identify technical issues that might present difficulties or raise questions during the subsequent national regulatory assessment. The process would allow participants to identify areas in which there are important regulatory differences between countries, as well as areas in which additional efforts would be required to help standardize design.

Furthermore, NHSI is developing processes that would enable regulators to collaborate during ongoing national reviews and leverage other regulators’ reviews, potentially resulting in resource savings for the regulator and industry.

As the NHSI moves towards the goal of maximizing its contribution to achieving net zero by 2050, its work is progressing according to plan, and the findings of both the Industry Track and the Regulatory Track will be presented at the NHSI plenary in June and at the IAEA International Conference on Small Modular Reactors and their Applications, to be held in Vienna in October 2024.

NHSI

Nuclear human resource development for a net zero future

By Matt Fisher

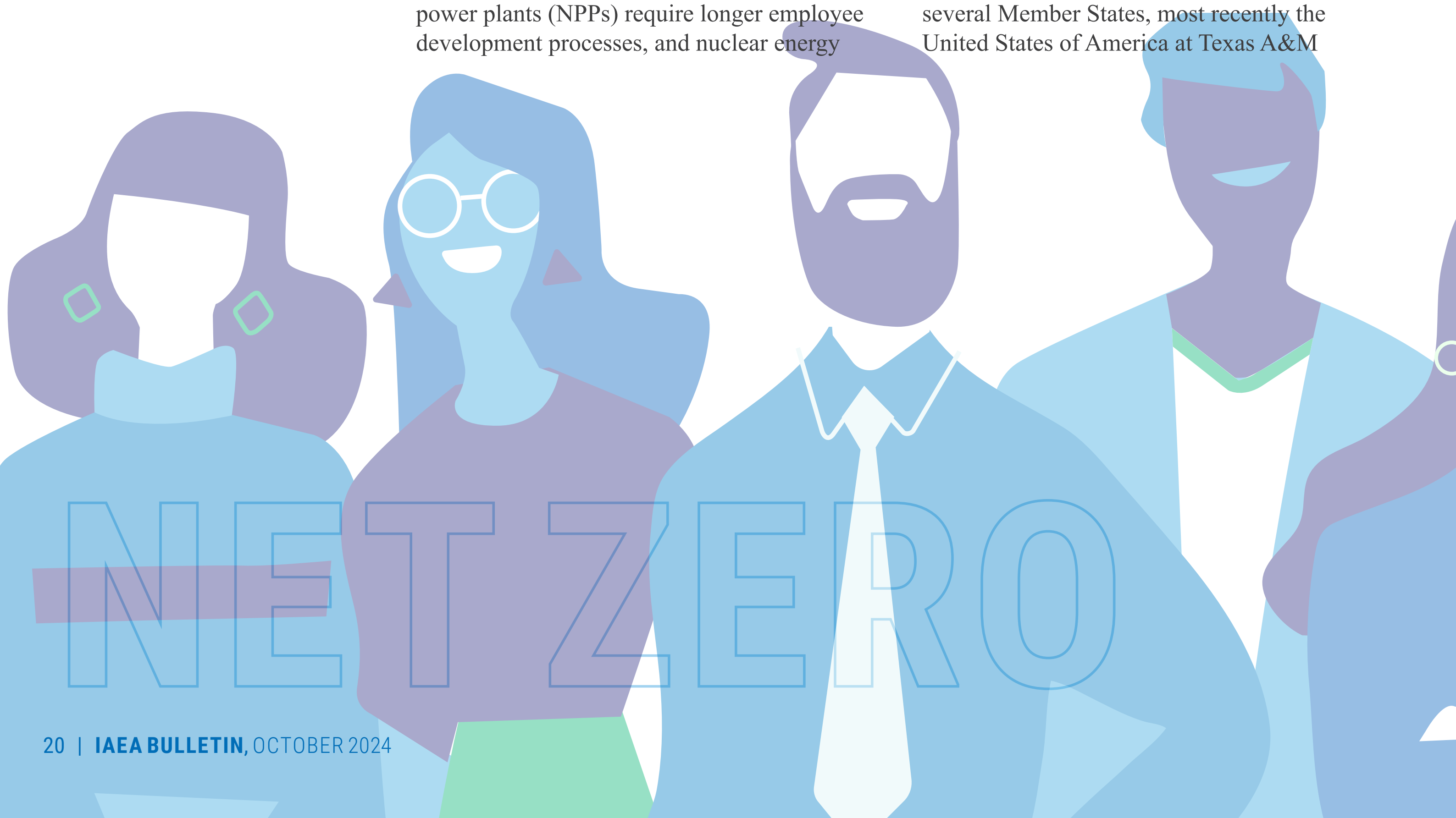
Human resource development is fundamental to the long term sustainability and expansion of nuclear power. However, it stands out as one of the most significant challenges facing the industry due to the rigorous demands it places on the workforce.

To help build and maintain the workforce needed to expand nuclear power at the scale envisioned, the IAEA offers capacity building initiatives such as Nuclear Knowledge Management (NKM) Schools, strategic planning training programmes, assist visits and fellowship opportunities. These initiatives are designed to prepare the next generation of professionals and bolster the skills of the current workforce to ensure that nuclear power continues to expand globally as we strive to meet our net zero goals.

As the nuclear power landscape continues to evolve, so too do industry challenges. According to an IAEA report published in 2023, nuclear facility workforces are typically older than those of other major industrial facilities, highlighting the need to emphasize knowledge retention as more and more long-term employees approach retirement. The complex technologies associated with nuclear power plants (NPPs) require longer employee development processes, and nuclear energy activities require exceptionally high levels of oversight. Strong human resource development processes are vital to addressing these and other issues.

“Capacity building as an ongoing and ever-improving process is vital for nuclear power expansion,” says Mikhail Chudakov, IAEA Deputy Director General and Head of the Department of Nuclear Energy. “With considerable expertise cultivated over nearly seven decades, the IAEA is well equipped to assist our Member States in developing the human resources needed to meet their ambitious goals for nuclear power”.

Effective knowledge management is essential for retaining years of acquired information in areas such as design, licensing and operation, which is needed to maintain and build competencies. The NKM School is a one-week course providing specialized education and training in the implementation of NKM programmes in nuclear science and technology organizations. Covering areas such as the fundamentals of knowledge management and practical guidance and best practices, the School is designed for young professionals working in knowledge management roles and has been hosted by several Member States, most recently the United States of America at Texas A&M



University in 2023. 2024 marks the 20th anniversary of a joint IAEA-Abdus Salam International Centre for Theoretical Physics NKM School. To date, 1139 professionals have been trained through the NKM School.

The Knowledge Management Assist Visit service provides an expert review to Member States looking to implement or improve their knowledge management programme. The visits are tailored to the knowledge management programme's level of maturity and can provide strategic advice, specialized training and other relevant support.

Successful teams are always guided by forward-looking, driven leaders. The Nuclear Energy Management (NEM) School programme, supported by the IAEA's Technical Cooperation (TC) programme, helps current and future leaders in nuclear energy capitalize on their talents and get the most out of their teams. With two-week courses designed for young professionals who display leadership potential, the programme includes lectures, technical visits and case studies to help strengthen managerial and technical competencies and share Agency knowledge in areas across the nuclear energy lifecycle. South Africa's Department of Mineral Resources hosted the NEM School in November 2023, its 52nd iteration since the programme's inception in 2010. For 13 years, more than 2000 people from a variety of disciplines have developed their professional skills through the programme, and nearly half of the participants in the NEM Schools held in 2023 were women.

"I've had the opportunity to learn about all the different technologies which contribute to net zero, including nuclear power, and it has been very enlightening to learn about how safety culture and leadership are built into an organization," said Zeridah Kimanywenda, a civil engineer at the Ugandan Ministry of Energy and Mineral Development who attended the NEM School held in South Africa last November. "The content is very well-curated and relevant to my role."

Although women have achieved some of history's most revolutionary scientific breakthroughs, they continue to be underrepresented in most if not all technical fields, including nuclear. To address this issue, the IAEA launched the Marie Skłodowska-Curie Fellowship Programme (MSCFP) in 2020 and the Lise Meitner Programme (LMP) in 2023. The MSCFP encourages young women to enter the nuclear field by providing successful applicants with scholarships for master's degree programmes and the opportunity to undertake an internship at the IAEA or a partner organization. In 2023, 200 scholarships were awarded — the highest number of any application cycle to date. The LMP offers early- and mid-career women professionals opportunities to advance their skills through a multi-week visiting professional programme. The visits are generally between two and four weeks' duration and may include project development and implementation, as well as technical assignments and discussions.

In addition to these programmes, the IAEA supports over 1000 TC fellows and scientific visitors each year through the TC programme. As the IAEA's main mechanism for delivering development support to Member States, the TC programme — which is results-based and tailored to the specific challenges faced by countries and regions — aims to facilitate cooperation among countries to build capacity sustainably, including through South-South cooperation.

Developing the nuclear energy workforce of tomorrow requires specific education programmes. Established in 2013, the International Nuclear Management Academy (INMA) scheme supports universities in establishing and delivering master's degree programmes in nuclear technology management for the nuclear sector, including nuclear power programmes, nuclear applications and radiological technologies. The programmes combine advanced aspects of management and leadership with nuclear technologies, providing high level education and support for future leaders in the nuclear sector. Successful IAEA peer review missions to candidate universities lead to INMA endorsement of the degree programme. As of 2024, there are ten member universities in eight countries.

The IAEA maintains the Cyber Learning Platform for Network Education and Training (CLP4NET), a trove of online learning resources available to the public. The platform includes over 1400 training courses and nearly 200 webinars covering a wide range of topics in nuclear energy, and users can choose between self-directed and instructor-led options.

To help build and maintain the workforce needed to expand nuclear power at the scale envisioned, the IAEA offers capacity building initiatives such as Nuclear Knowledge Management (NKM) Schools, strategic planning training programmes, assist visits and fellowship opportunities.

What the nuclear declaration at COP28 means for IAEA verification

By Eva Morela Lam Redondo

The 'Declaration to Triple Nuclear Energy' reflects a collective commitment to advancing nuclear energy as part of a sustainable and low-carbon future. This aspirational goal will also entail an increase in the nuclear material and facilities subject to IAEA safeguards.

On 2 December 2023, during the 28th annual Conference of the Parties to the United Nations Framework Convention on Climate Change (COP28), representatives from more than 20 countries came together to sign the 'Declaration to Triple Nuclear Energy' aiming to reach that target by 2050. As the world is eager to harness the benefits of nuclear energy, tripling nuclear capacity globally will also contribute to another global trend: the steadily growing volumes of nuclear material and numbers of facilities subject to IAEA nuclear verification.

The IAEA fulfils its nuclear verification mission through the application of technical measures commonly referred to as nuclear 'safeguards'. These measures allow the IAEA to independently verify that States comply with their international obligations to use nuclear material solely for peaceful purposes.

"Between 2010 and 2022, we saw a 34 percent increase in the amount of nuclear material, and a 15 percent increase in the number of nuclear facilities and locations outside of facilities, under IAEA safeguards", said Massimo Aparo, IAEA Deputy Director General and Head of the Department of Safeguards. "The Declaration to Triple Nuclear Energy will further accelerate these trends. While the IAEA is ready to meet this challenge and continue to draw conclusions on the peaceful use of nuclear material, this will require sustained interaction and cooperation with all stakeholders and the adoption of innovative verification technologies."

To meet the increase in demand for its services, the IAEA's Department of Safeguards continually seeks to increase the effectiveness and efficiency of IAEA safeguards. Furthermore, the IAEA is legally obliged under comprehensive safeguards agreements to take full account of technological developments in the field of safeguards. Such examples of recent technological advancements include exploring and leveraging artificial intelligence and robotics in nuclear verification processes.

To keep abreast of new technologies with promising potential applications for safeguards, the IAEA works with its Member State Support Programmes (MSSPs). MSSPs extend support to the IAEA in various forms, including via R&D, knowledge exchange, technology transfer, expert collaboration and financial support.

The Next Generation Cherenkov Viewing Device (XCVD) represents a notable, tangible outcome of the IAEA's development of safeguards instrumentation combined with MSSP facilitation and support of in-field testing. The XCVD substantially improves the verification efficiency and data quality of images taken by IAEA safeguards inspectors to verify the presence and integrity of nuclear material in spent fuel ponds. In 2023, the XCVD was used for the largest spent fuel verification campaign in the history of IAEA. It demonstrated an eight-fold increase in efficiency in the successful verification of spent nuclear fuel compared to previous methods.

Safeguards implementation is a collaborative effort between the IAEA and States. To this end, the IAEA also supports States in building the knowledge and capacity of their national authority responsible for safeguards implementation (SRA) and of their respective system of accounting for and control of nuclear material (SSAC). The IAEA does this through a variety of assistance mechanisms, including advisory service missions, training courses, e-learning and webinars, legal and regulatory assistance and the safeguards traineeship programme. One significant development in the field of safeguards assistance for States is the integration of COMPASS, the IAEA's Comprehensive Capacity-Building Initiative for SSACs and SRAs, into the suite of IAEA safeguards assistance for States. Launched in 2020, and supported both financially and in-kind by IAEA Member States, COMPASS partners with States to help them strengthen the effectiveness of their SRA and SSAC. By offering State-specific support in the areas of stakeholder outreach, national training, software, legal and regulation and human resources, COMPASS represents a multi-year effort to sustainably build and enhance State capacity.

"The COMPASS initiative has been a game changer for Malaysia. It really helped us to identify the gaps in safeguards implementation", said Nurul Hafiza binti Mohamed Aliasrudin, Assistant Director, Nuclear Installation Division, Department of Atomic Energy, Malaysia. "In two years, COMPASS helped us review safeguards regulations, develop technical guidelines and license conditions, and also enhance the training within the national safeguards authority."

The IAEA is also looking to the future and, through Safeguards by Design (SBD), provides guidance to State authorities, designers, equipment providers and prospective purchasers on the importance of taking international safeguards into account when designing a nuclear facility or process. A voluntary best practice, SBD allows for informed design choices that optimize economic, operational, safety and security factors, while taking into account international safeguards. It is applicable to all aspects of the nuclear fuel cycle, from initial planning and design through construction, operation, waste management and decommissioning. For new nuclear facilities, especially novel designs or processes, the earlier the discussions of safeguards occur the better. SBD allows for safeguards to be 'built into' the design rather than around it.

The 'Declaration to Triple Nuclear Energy' reflects a collective commitment to advancing nuclear energy as part of a sustainable and low-carbon future. This aspirational goal will also entail an increase in the nuclear material and facilities subject to IAEA safeguards. By utilizing advanced technologies and working cooperatively both with those States looking to expand their nuclear energy production and those just starting out, IAEA safeguards stand ready to meet the increased demands of the international community as the world looks to achieve net zero.

IAEA launches Antarctica microplastics research project

Scientists from the IAEA travelled across Antarctica in January 2024 to measure the scale of microplastic pollution on the continent.

They collected samples of penguin droppings, water, mud and limpets to be shipped to the IAEA Marine Environment Laboratories in Monaco for analysis.

There, IAEA researchers will apply nuclear science to measure the presence of microplastics — plastic particles below five millimetres in diameter — and hope to discover the main source of this type of pollution.

Although the first evidence of microplastics on the continent was found in 2009 in East Antarctica, there is almost no information about the scale of the problem and whether the pollution comes from clothes, tyres, bottles, industrial processes or other sources.

Moreover, there are very few data on how much plastic pollution is taken up by Antarctic organisms and how microplastics reach Antarctica, whether through ocean currents, atmospheric deposition or the presence of humans on the continent.

The IAEA's first scientific research expedition to Antarctica — the world's southernmost continent —forms part of efforts to combat this growing environmental problem, even in the planet's most remote areas.

The mission is being carried out through the IAEA's NUTEC Plastics initiative.Through a network of NUTEC Plastic monitoring laboratories, nuclear and isotopic techniques are being used to produce data on the distribution of marine microplastics by sampling and analysing the prevalence of microplastics in the environment. This provides valuable information for the development of systems to limit plastic pollution.

The President of Argentina, Javier Milei, and IAEA Director General Rafael Mariano Grossi joined the IAEA scientific team to mark the start of their mission at the Argentine Marambio Antarctic Base.

Director General Grossi has said that the discovery of microplastics in the once untouched Antarctic environment is testament to the impact of this widespread and detrimental pollutant: "Microplastics are a global problem, but the international community still lacks the scientific data needed to make informed decisions. This is the goal of NUTEC Plastics: by understanding the plastic origin, movement and impact, we can make informed decisions on how to address the problem".

Since their establishment in 1961, the IAEA Marine Environment Laboratories in Monaco have provided countries with the tools and knowledge necessary to understand and tackle pressing marine environmental challenges. The IAEA hosts the only marine environment laboratory of the United Nations system.

NUTEC Plastics provides science-based evidence to assess marine microplastic pollution while demonstrating the role of ionizing radiation in plastic recycling and the transformation of plastic waste into reusable resources.

The IAEA's work to address and monitor the presence of microplastics in Antarctica is carried out in cooperation with Argentina.

— By Katy Laffan

This **NUTEC Plastics** project is being conducted together with Argentina and was launched by Argentinian President Javier Milei and IAEA Director General Rafael Mariano Grossi at a joint event at Base Marambio in January 2024.

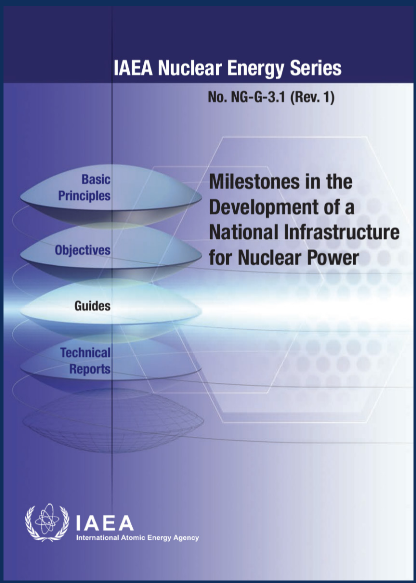
(Photo: K. Laffan/IAEA)

The icy continent of Antarctica is considered to be one of the last pristine areas on Earth. However, research has already shown that microplastic pollution is reaching the continent — IAEA scientists are trying to find out how much, and where its coming from.

IAEA scientists collected samples of pengiun droppings as part of their research into the impact of microplastics on animals living in Antarctica.

(Photo: M. Klingenboeck/IAEA)

IAEA Milestones guidance updated to include considerations for small modular reactors



A new version of the IAEA publication *Milestones in the Development of a National Infrastructure for Nuclear Power*, revised to address issues related to small modular reactors (SMRs), has now been published.

The updated version, which set out the IAEA's foundational guidance on how to prepare for the introduction of a nuclear power programme or expand an existing one, includes an annex outlining aspects specific to the deployment of SMRs and highlights the recent experience of several countries that have completed or made significant progress in all three phases with reactor types other than those defined in the IAEA's Milestones Approach.

This new edition of the publication, originally issued in 2007 and revised in 2015, is provided within the context of other IAEA guidance and materials relevant to nuclear power development in areas including nuclear safety, security and safeguards. The publication incorporates lessons learned from Integrated Nuclear Infrastructure Review (INIR) missions recently conducted in countries introducing or expanding nuclear power programmes.

Although most new capacity is still expected to come in the form of large water cooled reactors in the coming years, the opportunities for SMRs to play an important role in reducing emissions and supporting sustainable prosperity are increasing. Designed to produce typically no more 300 megawatts (electrical) (MW(e)), SMRs could be ideal for deployment in remote areas and regions with smaller electric grids. SMRs will feature modular designs, thereby enabling systems and components to be factory assembled and transported as a unit for installation at a given location. This could help to reduce the time required for construction. Moreover, new end users such as data centres are considering nuclear power to meet their growing electricity needs and many industrial applications require decarbonization, so there is no shortage of potential applications. SMRs could be deployed faster and play a larger role, depending on how quickly they are licensed and achieve commercial readiness.

"As the nuclear power landscape continues to evolve, so too must the assistance we provide. This latest update of the IAEA Milestones guidance comes at a pivotal moment when an increasing number of countries is considering nuclear power for their energy mix to achieve their net zero pledges," said Aline des Cloizeaux, Director of the IAEA's Division of Nuclear Power. "It is clear that SMRs will be a vital component of the clean energy transition, and we must ensure that countries interested in this technology have a solid understanding of what is needed to successfully implement SMR projects."

In many ways, SMRs are very similar to their larger counterparts. They comprise many of the same systems and operate according to the same principles that have driven nuclear power reactors for decades. The needs for SMRs are mostly the same as for traditional reactors, such as strong legal and regulatory frameworks, proactive stakeholder engagement, and environmental protection considerations. However, on account of their unique features — including lower power output and simplified designs — some specific infrastructure requirements may vary.

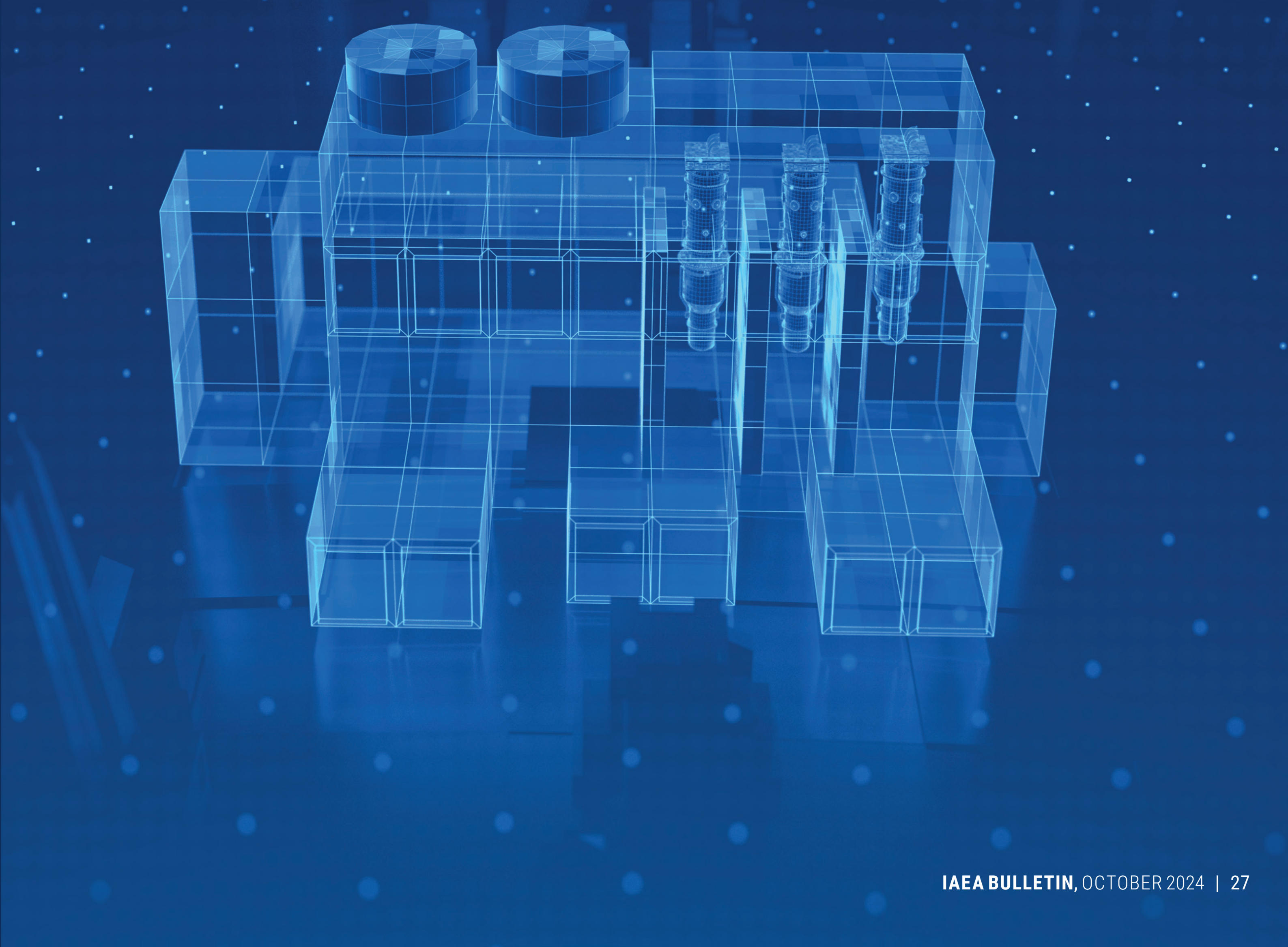
Some SMRs, particularly those using coolants other than water, may generate new forms of radioactive waste, so countries planning to deploy SMRs must plan to manage these new waste types. If new fuel types are used, it will be important to establish a supply chain to secure the consistent availability of fuel. New safeguards approaches may need to be developed to address some of the novel design features of SMRs so as to ensure that the application of robust nuclear material accountancy and control measures is not hindered.

Around 30 newcomer countries are currently either considering nuclear power or moving forward with plans to construct their first nuclear power plant. Bangladesh, Egypt and Türkiye are constructing their first nuclear power plants, and several other countries are expected to build their first plants over the next decade or so.

Argentina, China and the Russian Federation have SMRs under construction, with the latter two having deployed their first SMRs in 2019 and 2021 respectively. Several newcomer countries, including Estonia, Jordan and Poland, have identified SMRs as part of their future clean energy systems. An INIR mission focused on SMRs was conducted in Estonia last October, and Jordan is examining how SMRs could be used to address its seawater desalination needs, following a meeting with IAEA experts last August.

— By Matt Fisher

SMRs could be ideal for deployment in remote areas and regions with smaller electric grids.



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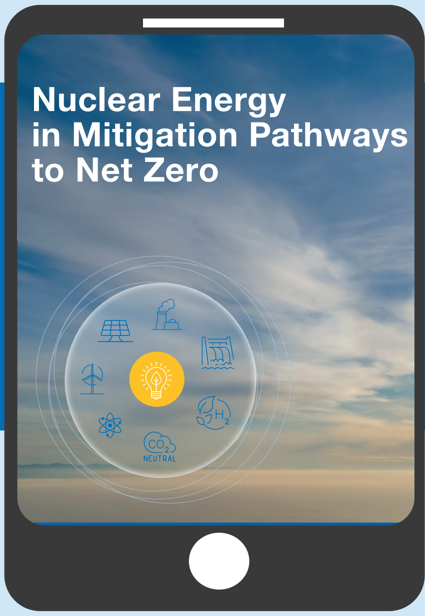

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