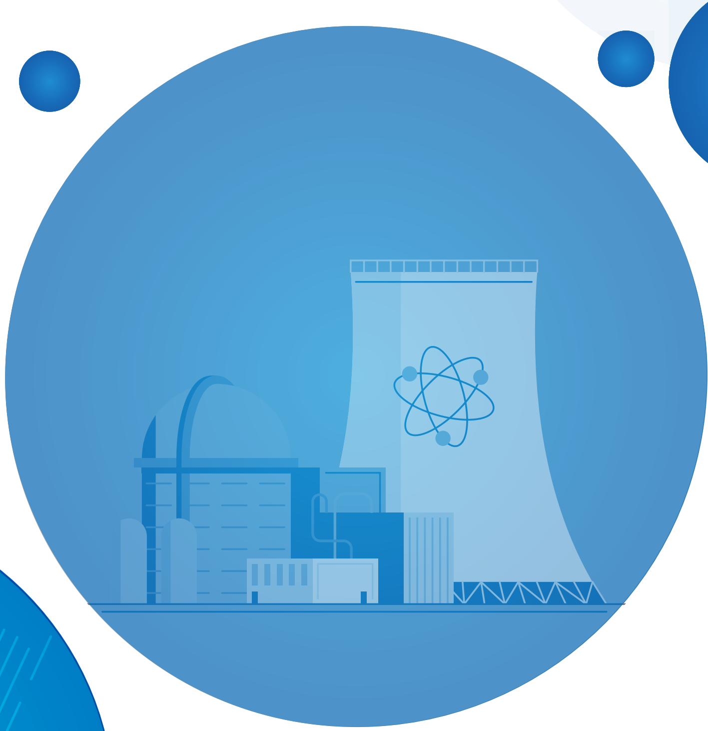
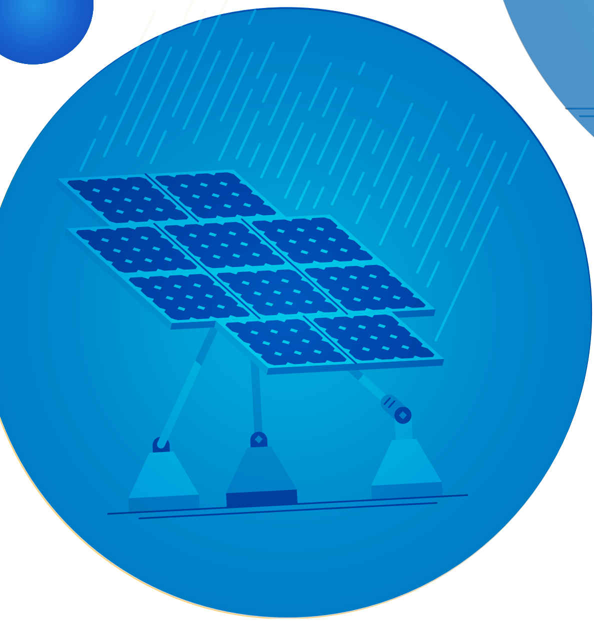




Pathways to net zero using nuclear innovation

International perspectives on the role of nuclear energy and innovation in reaching our climate targets

Published for the Clean Energy Ministerial 12,
31st May – 6th June 2021, Chile

FNC FLEXIBLE NUCLEAR CAMPAIGN
FOR NUCLEAR-RENEWABLES INTEGRATION
A CAMPAIGN OF THE CLEAN ENERGY MINISTERIAL

NICE Future
Nuclear Innovation: Clean Energy Future
An Initiative of the Clean Energy Ministerial

About this booklet

This document is a product of the Nuclear Innovation: Clean Energy Future (NICE Future) initiative under the Clean Energy Ministerial (CEM), coordinated by the UK's Department for Business, Energy and Industrial Strategy (BEIS) in its capacity as a co-lead country for the Flexible Nuclear Campaign.

Disclaimer on Report Contents

Introduction

The Nuclear Innovation: Clean Energy Future (NICE Future) initiative was launched at the 9th Clean Energy Ministerial hosted by Copenhagen in 2018. It leads the global conversation on the roles nuclear energy can play in the clean energy systems of the future.

The initiative explores the potential for nuclear energy uses, innovations, and greater systems integration to accelerate progress toward clean energy goals. The initiative recognises there is no one-size-fits-all solution to energy and fosters collaboration among clean energy supporters in exploring diverse solutions.

Further information and a range of published reports are available on the NICE Future Initiative website.

NICE Future Focus Areas

- Exploring innovative applications for advanced nuclear systems, both electric and non-electric.
- Pooling experience on economics, including valuation, market structure, and ability to finance.
- Engaging policy makers and stakeholders regarding energy choices for the future.
- Communicating nuclear energy's role in clean, integrated energy systems and developing the nuclear workforce of the future.

The Flexible Nuclear Campaign

NICE Future participants are exploring innovative technologies and diverse uses of nuclear energy, including nuclear-renewables integration, flexible electricity grids, rural electrification, industrial processes, water purification, clean transportation fuels, and alternative energy carriers such as hydrogen. Within NICE Future, the Flexible Nuclear Campaign for Nuclear-Renewables Integration is a joint effort between civil society and governments to enlist global experts in the valuation of flexible nuclear systems working in concert with renewables.

Pathways to net zero using nuclear innovation

This publication is intended to help policymakers and the Clean Energy Ministerial understand the paths that different participant countries are taking to reach their clean energy goals with the help of nuclear innovation. We have also included the perspectives of various international organisations that highlight where nuclear energy's contributions to emission reductions could grow further.

Contents

Part 1:

Country perspectives

1.1 Canada

Canada's Climate Goals – Pathways to Net-zero

The priority of the Government of Canada remains supporting people and businesses through this pandemic crisis, as long as it lasts, with whatever it takes. While COVID-19 is the biggest immediate threat to Canadians, the Government recognizes that Canada and the rest of the world cannot lose ground on addressing climate change.

In December 2020, the Government of Canada introduced A Healthy Environment and a Healthy Economy—Canada's strengthened climate plan (SCP), which builds on the 2016 PanCanadian Framework on Clean Growth and Climate Change. The SCP contains plans to enhance our price on carbon and advance the next wave of non-emitting technologies, such as electric vehicles, hydrogen, and small modular reactors (SMRs), that can enable a transition toward a net-zero future. During the 2021 Leaders' Climate Summit, the government also committed to increase the ambition of Canada's 2030 climate goals to 40-45% decreased emissions based on 2005 levels.

Canada's history of Nuclear excellence

Nuclear energy is already an important part of Canada's current energy mix with 19 operating Canadian Deuterium Uranium (CANDU) reactors with a combined capacity of over 14,000 megawatts, producing 15% of our electricity, and displacing nearly 50 million tonnes of greenhouse gas emissions every year.

As a Tier-1 nation, Canada is among a small and elite group of nations with a full spectrum of nuclear capabilities, which includes our own reactor technology, the world's largest deposits of high-grade uranium, expert operators, state-of-the-art laboratories, and a world-class regulator. In addition, Canada is a key player in the international supply chain of several medical isotopes, such as supplying over 50% of the world's cobalt-60.

Shawn Tupper

Associate Deputy Minister, Natural Resources Canada

CANDU Technology at Home and Abroad

Canada's successful nuclear program is based on our unique heavy water natural uranium reactor technology: the CANDU reactor. Developed in the 1950s by Atomic Energy of Canada Limited in cooperation with industry, CANDU remains one of the single largest research and development investments ever made by the Canadian government.

Canada has exported CANDU technology abroad to Argentina, China, India, Pakistan, Romania, and South Korea. Globally, there are 30 CANDU reactors in operation, representing a 7% market share (in terms of the absolute number of reactors). CANDU reactors will remain an important source of reliable, non-emitting energy around the world. Canada continues to work closely with its international partners on CANDU projects, from refurbishment and capacity building to new build projects.

Canada continues to invest in our CANDU technology. Utilities in Canada are currently investing $26 billion to extend the lifespan of 10 nuclear reactors by 30 years to enable them to play a key role in our net-zero carbon future. Despite the COVID-19 pandemic, the first refurbished unit returned to commercial operation in June 2020. This is one of the largest infrastructure projects in Canada and is expected to offset 40 million metric tonnes of carbon dioxide annually once completed.

Small Modular Reactors

SMRs are the next wave of nuclear innovation and have the potential to help Canada reach net-zero by 2050 by enabling deep decarbonization of the electricity sector, industry, mining, and could be an alternative to diesel for remote communities.

In December 2020, we launched Canada's SMR Action Plan with over 100 partners from across Canada to outline over 500 concrete actions that partners are taking to advance the development, demonstration and deployment of SMR technologies in Canada. This builds off the momentum of Canada's Small Modular Reactor Roadmap, released in 2018. The federal government has also recently announced funding of over $70 million to SMR technologies to support research and development in Canada.

While the federal government has important responsibilities relating to nuclear energy, decisions related to electric generation rest with the provinces. Each jurisdiction in Canada faces unique circumstances, demographics, geography, and economics. Four provinces, Alberta, Saskatchewan, Ontario, and New Brunswick have signed a memorandum of understanding to advance the demonstration and deployment of SMRs in Canada.

Regulatory and safety excellence

The Government of Canada's first priority when it comes to nuclear energy is protecting the health and safety of Canadians and the environment. Canada's liability regime is modern and adaptable, and we are currently reviewing the liability limit for power reactors to ensure the limit is appropriate. We have also launched a public engagement process to develop a modernized radioactive waste management policy that will cover Canada's existing radioactive waste, as well as waste from new technologies such as SMRs.
All radioactive waste in Canada is managed according to international standards at facilities that are licensed and monitored by our world-class regulator, the Canadian Nuclear Safety Commission (CNSC).

The CNSC has also put significant effort into refining and building its regulatory framework and expertise to effectively regulate SMRs, working with partners from around the world. There are currently 12 SMR designs undergoing the Pre-Licensing Vendor Design Review process by the CNSC and four technologies being examined by Canadian Nuclear Laboratories for siting at their Chalk River facility.

International Markets

With innovative technology and expertise in low-carbon and sustainable solutions, Canada is well positioned to take part in the demands of the growing global markets. Our robust supply chain is ready to support global emission reduction and energy security goals with both our CANDU reactors and advanced nuclear technologies, including SMRs.

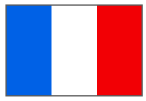
There is no doubt that Canadian nuclear expertise and technology will play a role not just in Canada's pathway to net-zero, but in helping the world on the pathway to net-zero as well.

Pathway Forward

The path to net-zero by 2050 is the challenge of this generation. In its 2019 report, Nuclear Power in a Clean Energy System, the International Energy Agency found that taking nuclear energy out of the equation would not only increase the risk of failure to meet climate targets, but it would also result in higher electricity prices for consumers. According to the report, it would cost an estimated US$1.6 trillion more to achieve global climate targets without investments in nuclear energy.

It is clear that Canada's pathway to net-zero includes nuclear energy, and that Canada's expertise in nuclear technologies can play a role in helping the world to achieve our collective climate goals.

1.2 France



France's aim is to achieve carbon neutrality by 2050. Achieving this goal will require profound changes in all sectors.

In the energy sector, it will be accomplished by reducing the use of fossil fuels and by developing low-carbon energy sources. France has defined a dedicated agenda for this transition by 2050: it relies on the use of electricity for transport, heating, etc., together with the development of hydrogen use. By 2050, despite strong efforts in energy consumption savings, there is expected to be an increase in the demand for electricity.

Currently, French electricity production is largely based on nuclear power (56 reactors accounting for 70 to 75% of the electricity production), with plans to increase the share of renewables to 40% by 2030 to achieve a more balanced zero-carbon mix with high resilience. This transition is manageable while remaining consistent with the French climate commitments, which is to say without introducing new fossil fuel capacities. The associated progressive closure of nuclear reactors will also enable France to avoid any cliff-edge effects related to the ageing of the French nuclear reactor fleet, which was built over a short period of time.

Moreover, the French government is conducting a work program to study the future energy mix beyond 2035. This program is carried out with the nuclear sector to examine questions related to the building of new nuclear capacities in France. This includes the economic, legal and technical aspects, with a view to making a decision in the coming years about the commissioning of the EPR nuclear reactor under construction in Flamanville.

As a mature, reliable, zero-carbon energy source, nuclear power can play a major role in the energy transition worldwide. In France it will remain one of the major assets of the low-carbon energy mix in the coming decades. Indeed, it will enable the growth of variable renewables, combined with the development of energy storage systems, including new hydrogen systems, and smart grid management that take advantage of emerging digital technologies.

Philippe Stohr

Energy Division Director, Alternative Energies and Atomic Energy Commission (CEA)

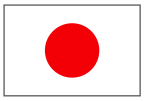
An increased contribution of nuclear to the development of a zero-carbon, reliable and affordable energy system will build upon innovation, in particular:

- The development of Enhanced Accident Tolerant Fuels (EATF) for even safer nuclear energy and flexible fuel, allowing for nuclear power to work best with variable renewable sources;
- The development of Small and Advanced Modular Reactors (SMR/AMR) with new approaches to nuclear design and safety features, including the development of a French-SMR technology: “Nuward”;
- The development of digital nuclear twins and the full use of digital technologies for plant design, operation and maintenance over their lifetime;
- Fast neutron reactors allowing for complete use of nuclear matters and circular economy of fuel (with the perspective of closing the fuel cycle in the long term);
- Energy convergence between nuclear energy and renewables, with even more flexible nuclear and hybrid designs allowing for new uses of nuclear energy, in particular for hydrogen and heat production as well as cogeneration.

The importance of nuclear innovation was emphasized with its inclusion in the 2020 French economic recovery plan, with around 500 M€ dedicated the nuclear sector, including Research and Development relating to the nuclear factory of the future, fuel cycle, radioactive waste management, and major experimental facilities.

It is now our duty to make this integrated vision of a low-carbon energy system a reality, through technological, organizational and social innovation, making the best sustainable use of all relevant energy sources.

1.3 Japan



Green Growth Strategy: Creating a virtuous cycle between the economy and environment

In October 2020, the Japanese government announced the ambition of Carbon Neutrality by 2050. To achieve this new target, we will take active measures to tackle climate change, transform industry and society, and realize strong growth. In December, we published the Green Growth Strategy, a set of industrial policies to create a virtuous cycle between the economy and environment. In pursuit of the 2050 Carbon Neutrality goal, putting in place effective measures in the field of energy is particularly important, as it accounts for more than 80% of greenhouse gas emissions. Through the Green Growth Strategy, the Japanese government sets high goals and will muster all possible and necessary policies to ensure that 14 focal industries thrive.

Nuclear power is one of these 14 industries. In addition to the further safety improvement of light-water reactors, it is necessary to continue with R&D for nuclear power through innovative technologies. In addition to supplying stable carbon-free electric power, with further innovation, nuclear power may respond to various needs such as complementary power production with renewable energy, carbon-free hydrogen production and heat utilization, while further improving safety, reliability and efficiency.

In the case of small modular reactors (SMRs), since the core size is small, it is possible to avoid an undesirable shutdown due to human error or the failure of safety-related equipment by incorporating natural principles such as natural circulation for reactor cooling, where the reliability of the safety system is enhanced by its simplification. By using such design methods, the probability of a loss of coolant accident due to a piping rupture is significantly reduced, with a resulting reduction of evacuation area. In addition, by reducing the initial investment cost through shortening the construction period with modular production, it is possible to mitigate some of the constraints in site selection and financing.

Shinichi Kihara
Deputy Commissioner for International Affairs, Agency for Natural Resources and Energy

Hereafter, the government will actively support the efforts of Japanese companies in cooperation with foreign demonstration SMR projects with the USA, UK, Canada and other countries, which aim for commercial operation at the end of 2020s. This work includes giving thoughts to safety, economy, supply chain construction, regulatory compliance and other enabling frameworks. While cooperating in R&D for innovative technologies, Japan will make contributions to bringing SMR technologies to market with Japanese companies' excellent design and production technologies.
In addition, Japan will continuously support SMR R&D by Japanese companies with their original designs that consider the diverse needs of deployment.

Another technology that Japan is supporting is high-temperature gas-cooled reactors (HTGRs), which utilize carbon-free high temperature heat over 700°C by using chemically stable helium coolant, Tri-isotropic coated fuel particles (TRISO-CFPs) which do not melt even at high temperatures. In addition to electric power generation, HTGRs are worthy of attention for their effective heat utilization and massive and low-cost carbon-free hydrogen production.

As for hydrogen production, which is important for decarbonization in industrial fields including steelmaking and chemical production, there is a possibility that one HTGR could decarbonize one shaft furnace capable of complete hydrogen reduction steelmaking. Since the required footprint is 1/1600 compared to the case for electrolysis of water by solar power, local production for local consumption of hydrogen combined with heat supply needed for industrial process will become possible without incurring additional transportation cost of hydrogen. If a high level of safety is verified of the HTGR, combined use for electric power generation and heat supply may realize a cost comparable to natural gas (ca. 12 yen/Nm3) in 2050.

Hence, utilizing the High-Temperature Test Reactor (HTTR), a research reactor which recorded world's highest temperature, the government will support, in addition to international safety demonstration, necessary technology development for massive and low-cost carbon-free hydrogen production by 2030. Simultaneously, development of carbon-free hydrogen production method using ultra-high temperature heat including iodine-sulphur (IS) process and methane pyrolysis method will be supported.

Fusion reactors, which generate plasma of over 100 million °C, are a technology which can be used for heat utilization and hydrogen production in addition to electric power generation by heating coolant up to 1,000 °C. Its fuel is basically hydrogen and it generates no high-level radioactive waste requiring long-term management. Since plasma generation is a technology in which sustained reaction is difficult to maintain, fusion reactors have a high level of safety without risk of reactor excursion.

The ITER project aims for the commencement of operation in 2025 and commencement of fusion reaction with real fuel operation in 2035. Simultaneously, in order to complement the ITER project and realize a future fusion DEMO (Demonstration) reactor, Broader Approach (BA) activities are implemented in cooperation between Japan and Europe. In the BA activities, construction of a large Tokamak device (JT-60SA) for advanced plasma control technology and other associated research are being conducted.

To bring fusion reactors to life, technological verification of the major equipment and research into stabilizing energy output state for a long time will be established. Simultaneously, various design and technology development for the fusion DEMO reactor construction project in Japan will be implemented to have the prospect of the practical application of fusion energy by the mid-21st century.

1.4 Poland

As President of COP24, which was held in Poland in 2017, and the participant of the 9th Clean Energy Ministerial (CEM) in Copenhagen, where the NICE Future Initiative was launched, I am honoured to join the contributors to NICE Future's "Pathways to Net Zero" booklet together with many distinguished co-authors. Poland supports the activities of CEM and NICE Future, which contribute to the development of the global sustainable energy sector and highlight the indispensable role of nuclear in clean energy systems.

Poland is determined to start a historical transformation of its energy mix which is still based mostly on fossil fuels. This process will be difficult, lengthy and challenging because currently approximately 70% of electricity in Poland is still produced from coal. The coal mining sector provides employment to over 80.000 people, and, together with places directly and indirectly associated with coal, it provides over 200.000 jobs. This is why it is necessary to consider the social cost of the process of energy transformation. Apart from that there are many other factors behind the transformation which have to be mentioned, such as the global and European climate policy, the pace of energy innovations and the growing availability of new energy technologies. We must use all available technologies – nuclear, solar, wind and hydrogen – to achieve a clean energy system by the 2050.

This year the Polish Council of Ministers approved "Poland's Energy Policy until 2040" (PEP2040), which presents a vision of the reconstruction and transformation of the energy sector. The updated policy is based on three pillars:

i. just transformation,

ii. zero-emission energy system and

iii. good air quality.

PEP2040 takes into account changes in the energy mix, as well as the need to ensure energy security, fair transformation, recovery after the COVID pandemic, stable labor market, sustainable development of the economy and strengthening its competitiveness.

Poland wants to take advantage of a diversified portfolio of energy sources in the process of decarbonization. Nuclear power is a vital part of the future energy mix in Poland. We aim to have 6-9 GWe installed nuclear power capacity in Poland by 2043. The other pillar of the Polish energy transformation will be the deployment of renewable energy sources.

Michał Kurtyka

Minister of Climate and Environment

In 2030, we intend to have approximately 32% and in 2040 approximately 40% of electricity produced by renewables. In 2040 every third MWh of produced electricity and heat will come from renewable energy sources and more than half of the electricity will be generated by emission-free units. We see significant opportunities in off-shore wind development - the installed capacity in Poland's projects may reach 11 GW in 2040. Poland is also already the third producer of hydrogen in Europe and the fifth in the world. We intend to use this potential on our way towards climate neutrality.

When it comes to nuclear energy, the Polish Council of Ministers took an important decision last year and approved the update of the "Polish Nuclear Power Program" (PNPP). The objective is the construction and commissioning of nuclear power plants representing approximately 15% of the generation capacity in the national system. Nuclear power will play an important role in Poland's energy mix and in our policy towards climate change mitigation. It will be a pillar of energy security as a reliable source of electricity generation. Since nuclear power generates large amounts of electricity it will help Poland to replace old coal-fired power plants and will be an indispensable component in decarbonizing our economy. On the other hand, nuclear power, as a dispatchable and flexible baseload source, will allow renewable energy sources to be deployed on a mass scale in a stable manner, setting the direction of energy transition and helping to achieve the climate neutrality objective. There is the additional potential to provide the economy with heat for residential and industrial purposes, as well as clean hydrogen. The experiences of some countries show that without using zero-emission sources for baseload generation, huge investment in expansion of renewable energy sources does not lead to desired emission reduction effects.

Since Poland is a nuclear newcomer country, the development of nuclear power will contribute to the creation of a new innovative industry branch in Poland with a high degree of technological advancement, innovation and added value. Up to 70% of the project value of the construction of the Nuclear Power Plants (NPPs) can be carried out by Polish companies. It is estimated that by 2040, nuclear energy will generate around 25.000 to 38.000 new jobs, which will contribute to new specializations and technological development. It is, however, important to conduct the development of nuclear power in a fully transparent way, while maintaining a dialogue with all stakeholders and society as whole.

Having in mind the objectives of CEM initiative and the approaching Climate Summit in Glasgow, as the President of COP24, I am convinced that the Polish energy transformation, including both the ambitious renewable energy sources expansion plan and the Polish nuclear power project, will significantly reduce greenhouse gas emissions and effectively lead to decarbonization, helping Poland to achieve climate neutrality objective.

I also remain convinced that the global efforts will finally allow us to mitigate climate change and contribute to the well-being of all citizens of our planet.

1.5 Romania

Romania is strongly focused on accelerating the deployment of technologies that will support reducing the greenhouse gas footprint and meeting decarbonization targets.

It is both the prerogative and obligation of nation states to invest in energy capacities that are essentially large-scale decarbonization efforts. Romania's Energy Strategy Project and National Integrated Plan for Energy and Climate Change (PNIESC) place a high emphasis on the development of nuclear energy as a major contributor to decarbonization.

Romania's approach is two-fold: first, the further development of large-scale power reactors through the deployment of Cernavoda NPP's Unit 3 and 4 within an Euro-Atlantic partnership. This is to ensure new stable, clean sources of energy in early 2030s as conventional fuel will gradually be scaled down. Second, we will extend the lifetime of one of the Cernavoda Nuclear Power Plant units. It is currently in a full refurbishment process which will allow an additional 30 years of production, beginning in 2028. The new challenges facing countries in the transition to zero carbon emissions economies are securing energy supply while maintaining grid stability and resilience in the face of extreme weather challenges. Nuclear power answers to both these imperatives and is one of the most competitive sources in terms of levelized cost of energy (LCOE).

Romania is a strong advocate for the development of nuclear energy as an important contributor to the stable, clean energy mix, not only by nuclear new build or refurbishment, but by also extending innovation and research to develop Generation IV nuclear reactors: Lead-cooled fast reactors, such as the ALFRED project developed in Romania and small modular reactors (SMRs). This is the basis for Romania gladly joining the NICE Future initiative under the Clean Energy Ministerial. We salute this initiative as being a global effort to recognize and benefit from the flexible use of nuclear energy within the framework of the highest nuclear safety standards.

Virgil-Daniel Popescu

Minister of Energy

Through its nuclear operator, SN Nuclearelectrica SA, Romania signed a Memorandum of Understanding with NuScale regarding SMR technology development in 2019. Furthermore, this year the company was awarded a US$ 1,2 million grant by US Trade and Development Agency (USTDA) for the identification of potential SMR sites. SMRs are the way forward in low-carbon technologies, and Romania could deploy SMRs after 2035 either on a standalone basis or in hybrid systems with renewable sources. Modularity, flexibility, site effective size, fuel efficiency and associated benefits are the key reasons for the "nuclear renaissance".

In association with large-scale and small modular reactors, clean hydrogen production is another option being considered by Romania as part of the transition towards a clean, sustainable environment. This requires the deep decarbonization of carbon-dioxide-intensive sectors such as transportation and buildings. Nuclear energy can make a significant contribution to producing clean hydrogen through conventional electrolysis at low temperatures. By using affordable electricity from nuclear power plants, at base-load capacity, making nuclear hydrogen becomes more cost effective. We deem it necessary to stimulate demand and the production of hydrogen from low-carbon sources using the existing and planned installed capacities.

For most regions, the EU included, meeting the 2050 targets requires a mix of resources, with a large share of investment coming from the private sector; a fact which should be fully accounted for in decarbonization policies and in meeting targets. Policies that foreclose a role for nuclear energy negatively impact investments in nuclear energy and directly increase the cost of decarbonization.

The new focus should stem from aligning economic welfare with the long term interests of society, based on the principle of technology neutrality. Standalone economic policies have to make room for systemic approaches, systematically implemented. Measuring the performance has to go beyond gross domestic product (GDP) towards the 'Beyond GDP' goals. This approach includes different welfare indicators so that social and ecological components and citizen wellbeing are completely embedded in the economic approach.

The new energy policies should focus more on cooperation between the state and private sector in order to support R&D efforts in the field of advanced nuclear technologies.

The new policies should highly encourage fair competition, an industry level playing field, promote exports, support the development of integrated supply chains, and update regulatory frameworks.

Nuclear energy is essential to decarbonization and in addition to the current fleet of reactors and competitive cost refurbishments, innovation and advancements will certainly position nuclear as a sustainable solution.

1.6 Russia

Today the whole world is focused on the climate change agenda. Nuclear energy plays a significant role in the fight against climate change. The electricity produced by Nuclear Power Plants has zero direct CO_2 emissions and the minimal level of Green House Gas (GHG) emissions throughout the entire life cycle, which is almost equal to the emissions of wind farms.

Nuclear is the largest source of clean energy in Russia. In 2020, the share of nuclear energy generation stood at about 20% while in the European part of the country it reached up to 40%. On the global scale the share of nuclear generation is lower and amounts to 10%, but the total share of low-carbon sources reaches 34% with nuclear energy making a significant contribution. The savings in GHG emissions that are provided by NPPs currently operating around the world equal roughly 2 billion tons annually, which is comparable to the absorption capacity of all the forests on Earth. Besides the minimum level of GHG emissions, NPPs provide a stable base load on a grid for 24 hours a day, 7 days a week for at least 60 years.

Today, many countries are forming their long-term low-carbon strategies and climate policies. They are the key to the "green" healthy future of our planet. We see the tremendous work on green transformation in Europe within the framework of the Green Deal. Many countries are committed to achieving carbon neutrality by 2050 or even earlier. In order to come to fruition these legal innovations and strategic statements must be supported by effective instruments, and we believe that nuclear energy should be among these instruments.

Polina Lion

Chief Sustainability Officer of Rosatom State Corporation

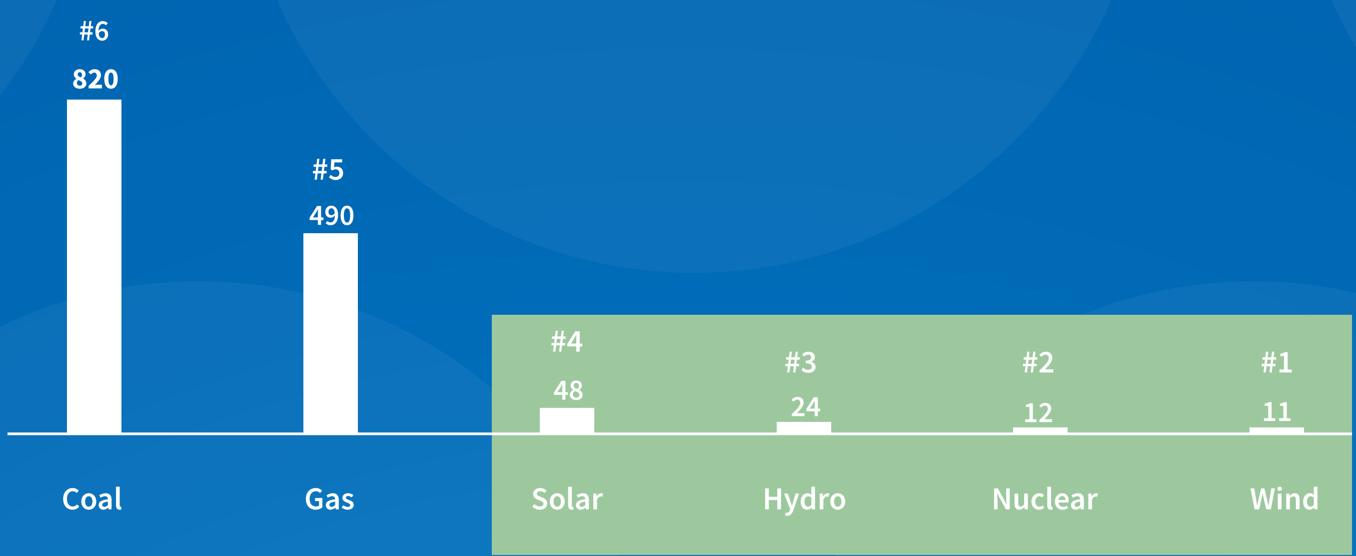
In September 2019, Russia joined the Paris Agreement. Currently, Russia is working on its climate-focused policy to stimulate low-carbon green activity in doing business. The low-carbon economic development strategy of Russian Federation until 2050 is being developed as a general framework. In 2021, the Russian government will approve a national Taxonomy of green projects to attract financing in "green" climate-positive initiatives in a move much aligned with the EU Taxonomy of sustainable financing. It is highly likely nuclear energy will be included in the list of "green" activities of the Russian Taxonomy. In order to stimulate low-carbon energy consumption, certificates of electricity origin used by Russian producers are being developed. It is of the utmost importance to ensure the mutual recognition of these certificates at the international level.

It is essential to include nuclear energy in the list of low-carbon "green" sources along with renewable energy in order to combat climate change.

Instruments and mechanisms for promoting low-carbon "green" activities should be synchronized at the international level, but can be adjusted with regard to the specifics of the national economy and the resource base. Thus, international regulation of low-carbon "green" activities should not be restrictive and technology discriminatory.

Supporting nuclear energy as climate-friendly, with low GHG emissions, goes together with strong safety and security requirements at international level as well as at a state level. This regulation fits the basic requirements of Do No Significant Harm (DNSH) criteria. Nuclear industry pays a lot of attention to further innovation aimed at improving its sustainability and positive climate effects. Such cutting-edge technologies include closed nuclear fuel cycle, SMR solutions and hydrogen technologies. All these efforts of nuclear industry are focused on making our planet "green" and more sustainable.

GHG Emissions*



*during entire life cycle (gC0$_2$eq/kwh)

Source: Intergovernmental Panel on Climate Change (IPCC)

1.7 United Kingdom

This year the UK is hosting the international Conference of Parties 26 (COP26). The UK is pleased to lead on putting together this booklet that sets out the different pathways countries are undertaking to reach net zero greenhouse gas emissions, including using nuclear innovation. It is a testament to the value of the Clean Energy Ministerial and the NICE Future initiative that so many countries and organisations have contributed to this booklet. The task is large, and to achieve a step-change in the reduction of greenhouse gas emissions we must think differently, and we must innovate.

In 2019, the UK became the first major economy to adopt a legally binding obligation to reach net zero greenhouse gas emissions by 2050. Between 1990 and 2018, economy-wide emissions fell by 43 per cent while GDP rose by 75 per cent, with the UK decarbonising faster than any other G20 country since 2000. We will build on 30 years of successfully reducing emissions while simultaneously growing our economy.[1]

Decarbonising the power sector has been pivotal to the UK's efforts to reduce greenhouse gas emissions. Over the same 28-year period, the percentage of the UK's emissions from electricity generation fell from 25 to 15 per cent. In 1990, fossil fuels provided nearly 80 per cent of electricity supply but today, the country gets over half of its power from low-carbon technologies.[2]

As we make these strides towards net zero, the demands on the electricity system are expected to increase. Electricity could provide more than half of final energy demand in 2050, up from 17 per cent in 2019. This would require a four-fold increase in clean electricity generation with the decarbonisation of electricity underpinning the delivery of our net zero target.

Anne-Marie Trevelyan

Minister for Business, Energy and Clean Growth

1 World Bank, UNFCCC National Inventory Submissions, ONS, BEIS Greenhouse Gas Inventory. Note: Data are provided for 1990-2018

2 Energy white paper: Powering our net zero future, December 2020

In our electricity system analysis, we have modelled almost 7,000 different electricity mixes in 2050, for two different levels of demand and flexibility, and 27 different technology cost combinations. This has produced a dataset comprising of over 700,000 unique scenarios, allowing us to identify common features of a low emissions, low-cost electricity system. All low-cost solutions include significant levels of renewables, but low-cost solutions at low emissions (at 5gCO_2/kWh or below) are likely to require a combination of new nuclear and gas carbon capture, utilization and storage (CCUS).[3]

A key driver for this is ensuring the system is reliable with variable renewables complemented by technologies which provide power, or reduce demand, when the wind is not blowing, or the sun does not shine. Today, nuclear is the only technology that is currently proven and can be deployed on a sufficiently large scale to provide continuous, reliable and low carbon electricity.

Nuclear power continues to be an important source of reliable clean electricity, supplying 17 per cent of the electricity generated in the UK in 2019. It is an energy-dense technology which provides large, reliable and continuous volumes of power from very little land area and can reduce system costs at low levels of emissions. But, with the existing nuclear fleet largely retiring over the next decade, we are taking steps to maintain the important place of nuclear in our energy mix. In addition to building Hinkley Point C, the first new nuclear power station in the UK in a generation, we aim to bring at least one large scale nuclear power plant to the point of final investment decision by the end of this Parliament, as well as investing in the next generation of nuclear technologies. In the Prime Minister's Ten Point Plan for a Green Industrial Revolution in November last year, the government announced up to £385 million in an Advanced Nuclear Fund to begin making advanced nuclear technologies a reality in the UK.[4]

Up to £215 million has been made available to support Small Modular Reactors (SMRs), in addition to £18m previously committed, to develop a domestic smaller-scale power plant design that could be built in factories and then assembled on site. Innovative manufacturing techniques and modular construction could mean that SMRs are faster to build than largescale nuclear plants and are potentially suitable for deployment in a wider number of sites across the country.

This investment is expected to unlock up to £300 million private sector match-funding. We hope that SMRs could provide cost-competitive nuclear power as early as the 2030s.

Furthermore, we will invest up to an additional £40 million in developing the regulatory frameworks and supporting the UK's supply chain to help bring advanced nuclear technologies to the market. Our first major step was to open the Generic Design Assessment to SMR technologies, the regulatory process through which developers can obtain approval for their proposed design approach, in May 2021.

3 Modelling 2050: Electricity system analysis, December 2020

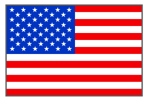
4 The Ten Point Plan for a Green Industrial Revolution, November 2020

In addition to SMRs, we are also committing up to £170 million for a research and development programme on Advanced Modular Reactors (AMRs). These reactors could operate at temperatures far higher than conventional reactors can and the high-grade heat could unlock efficient production of hydrogen and synthetic fuels, which would play a key role in decarbonising the entire energy system, not just electricity. Our aim is to build a demonstrator by the early 2030s at the latest to prove the potential of this technology to help decarbonise industry, heat and transport.

Looking beyond advanced fission, the government has also committed £400m towards fusion R&D programmes, to reinforce the UK's leadership in this highly promising technology. While fusion is not currently expected to play a significant role in energy generation before 2050, it is expected to play an important role in sustaining net zero over the longer-term.

In the coming year we look forward to hosting COP26 and to setting out further plans for reducing emissions across all the UK's major economic sectors. We aim to bring forward an overall Net Zero Strategy which will clearly set out our pathway to achieving net zero emissions by 2050. Through our Presidency of COP26, the UK is urging all countries to submit more ambitious Nationally Determined Contributions to enable further cuts in carbon emissions by 2030 and commit to reaching net zero as soon as possible. For those countries interested in nuclear energy, we believe nuclear innovation will play an important role in supporting the transition to net zero and we stand ready to collaborate with the global community in this important field.

1.8 United States of America



When President Joe Biden took office, he pledged to help the world overcome its greatest collective challenge: climate change. He has committed the United States to building a carbon-free power sector by 2035 and a net-zero economy by 2050—and he has tasked the Department of Energy with researching, developing, and deploying every viable clean energy technology that will move us to our goals.

Nuclear energy features prominently into our efforts.

Around the world, nuclear energy already generates about a third of zero-emissions electricity, 24 hours a day, seven days a week. In the U.S., nuclear energy provides more than half of our clean energy supply. Beyond providing clean heat and electricity, nuclear systems also support the production of life-saving medical isotopes, fresh water, hydrogen for a wide range of applications, and more.

Our program offices and National Laboratories are working to unlock innovations in nuclear technologies that can deliver even greater benefits. Smaller-scale systems such as small modular reactors and microreactors are now on the cusp of commercial deployment. These would enable nuclear energy to support flexible integration with renewable power and industrial processes, as well as provide reliable rural electrification, bringing clean energy to all corners of the world.

At the same time, we are improving the security and stability around nuclear systems through cutting-edge safety features, modern instrumentation and control systems, and advanced nuclear fuels—in many cases developed at DOE's National Laboratories. Many of these measures are already in use across the 94 nuclear reactors operating in the United States.

This pathway to clean energy can also lead to greater prosperity. Just one typical nuclear power plant creates $40 million in labor income each year. And our fleet already supports nearly 100,000 permanent, well-paid direct jobs for Americans across the country—more jobs per megawatt than other energy sources. As we continue to work on next-generation nuclear technologies, we will structure deployment strategies that help spread this economic activity to communities that have been left behind and gone unheard for too long.

Jennifer Granholm
Secretary of Energy

The climate crisis is urgent and the time for action is now. That's why the U.S. Department of Energy—the nation's powerhouse for science and innovation—will continue to drive zero-emitting nuclear power generation forward. I am so hopeful about the clean energy solutions we will deliver—not only to put our planet on the road to clean energy, but to bring global prosperity and promise to lift up our world. I applaud the focus of the Clean Energy Ministerial's Nuclear Innovation: Clean Energy Future—or "NICE Future"—initiative on this tremendous effort, and I look forward to continued collaboration with our partners around the world.

Part 2:

International organisation perspectives

2.1 Generation-IV International Forum (GIF)

The six most promising nuclear energy systems identified by GIF are:

Sodium-cooled Fast Reactor (SFR)

Very High Temperature Reactor (VHTR)

Gas-cooled Fast Reactor (GFR)

Molten Salt Reactor (MSR)

Lead-cooled Fast Reactor (LFR)

Super Critical Water-cooled Reactor (SCWR)

The Generation-IV International Forum (GIF) is a multinational co-operative endeavor organized to foster the research and development needed to accelerate the deployment of the next generation of nuclear reactor systems. Since its foundation in 2000, GIF has identified six nuclear energy systems being the most promising to meet its objectives, assuming a deployment horizon beyond 2030.

As well as the GIF Goals of sustainability, safety, Proliferation, Risk, and Physical Protection (PRPP) and, economics, the flexibility characteristics are becoming increasingly recognised as essential attributes for future energy sources. In the NICE Future initiative's "Flexible Nuclear Energy for Clean Energy Systems" report, GIF set out the flexibility characteristics of Gen IV reactors in Chapter 13.

Sustainability is a key issue of Generation-IV reactor systems, as these technologies enable stable and long term utilization of nuclear across a broader clean energy system. These new designs aim to efficiently use uranium resources and further minimize waste and environmental load. The minimization of environmental load means not only being CO_2-free but also reducing the amount of high level radioactive waste by means of burning of long term radioactive nuclides of Minor Actinides in the spent fuel.

One particular benefit of the Generation-IV reactor systems is higher outlet temperatures ranging 700 to 950°C (i.e., VHTR, GFR, LFR, and MSR), and ~550°C (SFR). This high temperature brings flexibility of energy use. This includes non-electrical applications of their nuclear heat, such as hydrogen production, industrial process heat to chemical processing facilities, and efficient heat storage.

Hideki Kamide

Chair of GIF

The flexibility characteristics we pursue are categorized into three genres. Firstly, we look for Operational Flexibility such as Maneuverability, ramp rates, minimum power level, frequency control, island mode, and the flexibility of fuel. Secondly, we look for Deployment Flexibility such as Scalability, siting requirements, and modularity. Finally, we look at Product Flexibility including, cogeneration of hydrogen, heat applications, and isotopes. All Generation-IV reactor systems, from large electric-output type reactors to small modular reactors (SMRs), regardless of coolant, have such flexibility characteristics.

The operational flexibility of Generation-IV reactors including the heat storage can contribute to wider utilization of the variable clean energy such as solar and wind, by increasing the stability and reliability of the electricity grid. Operationally flexible electricity has a higher value in the market and contributes to the economy.

These flexibility characteristics depend on development histories of the reactors and market needs for different outputs. Recognizing the wide range of requirements for different markets, GIF started the Non-Electrical Application of Nuclear Heat (NEANH) Group, and began to make visual maps to show the relationships between influencing factors. This group mapped the six reactor systems (SFR, VHTR, GFR, MSR, LFR, SCWR), the three Power levels (large-scale reactor, small modular reactor, micro reactor), and the six products (Hydrogen-production, Heat production, Dispatchable electricity, Cold generation, Chemical products, Seawater desalination). Based on these discussions and activities, GIF has a plan to initiate a new Task Force for NEANH. The objective of this Task Force is to adapt flexible technologies to fit the present market, so this Task Force will connect other flexible activities outside GIF.

We hope that organizations and players involved with flexible energy technologies can make bridges to demonstrate the strong characteristics of these technologies, and GIF NEANH-TF can become one key part of the bridges.

When Gen-IV reactor systems are deployed, regulation is of key importance. GIF has developed SFR safety design criteria (SDC) and safety design guidelines (SDG) with the help of contributions and reviews by the IAEA and regulatory bodies of several SFR developing countries. Such activities have been expanded to other reactor systems like the LFR, GFR, and VHTR. Recently, GIF specialists have participated in several IAEA meetings of SMR safety regulation developments including the Generation-IV reactor concepts based on accumulated knowledge of the SDC and SDG. We believe that these activities contribute to regulations considering various safety characteristics of Generation-IV reactors.

Lastly, I truly appreciate the Clean Energy Ministerial's NICE Future initiative and Flexible Nuclear Energy for Clean Energy Systems report. The seven conclusions reached in Chapter 18 accurately summarize the present nuclear position and situation. I dare not to repeat these seven conclusions here, but I hope these messages will be shared by people in different positions and will be able to become the flexibility bridge that brings the next generation of nuclear reactors to life.

2.2 International Energy Agency (IEA)

Covid-19 delivered an unprecedented shock to the world economy. But it also underscored the scale of the climate challenge: Even with the deep recession caused by the pandemic, global carbon emissions remain at unsustainable levels. Emissions in 2021 are expected to rise by 1.5 billion tonnes, the second highest increase in history.

Fortunately, the impetus to take action on climate change is stronger than ever. Countries, companies and financial institutions are increasingly aiming for a future with net-zero greenhouse gas emissions – where any remaining fossil fuel use is entirely offset by the removal of corresponding amounts of carbon dioxide from the atmosphere. As of late April 2021, 44 national governments – including in recent months those of the United States, Japan and China – had stated ambitions of reaching net zero by mid-century or soon after.

But commitments are relatively easy to make. What changes are required in our energy systems to make net zero a reality?

For the first time, the IEA through its latest Energy Technology Perspectives report, took a systematic look at what technologies would be required to put the global energy system on a path to net zero.

It found that decarbonising electricity generation is essential, as it is the largest contributor to global carbon emissions. However, decarbonising the power sector is not enough: alone, it will take us only about one-third of the way to net zero emissions.

The story is similar with electric cars. There is no pathway to net zero without building on their recent success and scaling them up further – and at a faster rate. But electrifying passenger cars alone will provide just a moderate additional cut in emissions.

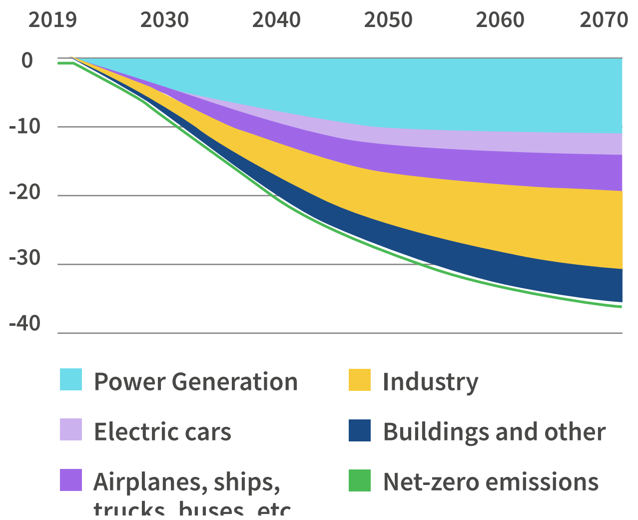
Emissions come from many other sources where much less progress is currently being made. Long-distance transport and heavy industry are two important sectors where clean energy technology solutions are much less available than for power generation or cars. Industry, transport and buildings sectors together make up 55% of today's energy and industry-related CO_2 emissions. The pace of their transitions is at the heart of the challenge.

Fatih Birol

Executive Director, IEA

Focusing on the power sector is not enough on a path to net zero.

Global CO2 emissions reductions in the Sustainable Development Scenario (SDS), relative to baseline trends



Source: IEA, Energy Technology Perspectives, 2020

This means of course that we will need to tap into a wide variety of technologies to reach net zero. Energy efficiency and power generation from renewables are critical to bend the emissions curve and place emissions in a rapid decline in the coming years. But to achieve net zero, we will also need to electrify end-uses, integrate hydrogen into hard-to-decarbonise sectors, deploy carbon capture and storage on a much greater scale, and use sustainable bioenergy for transport, power and heat.

Around half the emissions reductions to get to net zero will need to come from technologies that are not yet on the market.

As part of this, nuclear power, as a dispatchable low-carbon generation technology, needs to grow. Nuclear power in a net zero scenario would be roughly double its current level, IEA analysis shows. But based on today's policy settings, the world is not nearly on track to double nuclear power by 2050. In many advanced economies, nuclear power is declining rather than growing. IEA analysis has shown that clean energy transitions in advanced economies with less nuclear, particularly fewer lifetime extensions, would require 15% more investment and raise costs to consumers (IEA, 2019).

The situation calls for policy support and more innovative technologies. Accelerating the build-out of large-scale modern designs in established markets is an essential step. Fostering the commercialisation of new designs that open non-electric markets, including heat and hydrogen production, will also be important. Small modular reactors could also be attractive for electricity, as they offer operational and safety advantages, require less upfront investment, and will be easier to integrate into electricity systems than the nuclear technologies in use today. The private sector is interested in these emerging technologies, but government policies are crucial for their development.

Nuclear power is one of the clean energy technologies – along with efficiency, renewables, carbon capture and storage, and hydrogen – that are needed to get the global energy system to net zero emissions. Nuclear power is already helping to reduce global carbon emissions and, as a dispatchable low-carbon source of energy, has a clear role in enabling the global energy system to reach net zero securely. Given the scale and urgency of the climate challenge, we do not have the luxury of excluding nuclear power from the tools at our disposal.

2.3 International Atomic Energy Agency (IAEA)

Climate change has presented the world with a stark challenge: to reduce greenhouse gas emissions to net zero by 2050—or face potentially catastrophic effects from an inexorably warming planet. To meet this challenge, we need an unprecedented mobilization. Fortunately, proven solutions are at hand. In many countries, nuclear energy is the low carbon backbone of the power system and figures to remain so into the future, enabling clean energy transitions by complementing variable renewables such as solar and wind.

Despite a variety of challenges, the use of nuclear power continues to grow, providing some 10% of electricity production worldwide. Last year, the number of IAEA Member States that operate nuclear power plants increased to 32 after Belarus and the United Arab Emirates connected their first reactors to the grid. Of these operating countries, 19 have projects in place to expand their nuclear power capacity. Around 30 other so-called newcomer countries are embarking on or considering nuclear power. Bangladesh and Turkey, for example, are already well advanced in the construction of their first nuclear power plants.

Why are countries looking at nuclear? To put it simply, nuclear power is clean, reliable and sustainable. Globally, it produces around one-third of all low-carbon electricity. Over the last five decades, nuclear power has cumulatively avoided the emissions of about 70 Gt of CO_2 and continues to avoid about 1.7 Gt of CO_2 annually—roughly the equivalent of removing 400 million cars from the road. In addition, nuclear power is a dispatchable, flexible and reliable source of electricity.

At a time when the use of variable renewables is growing worldwide, nuclear power makes a key contribution to energy supply security and grid stability, as was demonstrated during the global pandemic lockdowns. And as a critical part of decarbonized energy systems, nuclear power is an “indispensable tool” for achieving the Sustainable Development Goals (SDGs), according to a report issued in March 2021 by the United Nations Economic Commission for Europe.

Rafael Mariano Grossi

Director-General, IAEA

The Intergovernmental Panel on Climate Change (IPCC) has recognized the role of nuclear power in helping to limit global warming to under the vital 1.5°C threshold, with its four illustrative model pathways including significant nuclear capacity build up. These are not predictions but highlight the importance of nuclear power's contribution to meeting the net zero objectives of the Paris Agreement. The IAEA's projections see a more modest build-up by 2050 than the IPCC scenarios, with a near doubling of present capacity relying on both long-term operation of existing plants and about 500 GW of new build. This would represent a doubling of the grid-connection rates observed in the last decade, to over 16 GW per year, still below what was observed in the 1980s when much of the current fleet was constructed.

Unfortunately, the world is not currently on track to meeting the Paris Agreement goals. As was recalled in the IEA-COP26 Net Zero Summit in March, an increasing number of countries has committed to net zero objectives by 2050 or a little later. Massive electrification using all available low-carbon technologies, including a key contribution from nuclear power, will be needed to achieve these goals.

But decarbonizing electricity will not suffice. While the power sector is responsible for 40% of the global CO_2 emissions produced by the energy sector, the other 60% is generated by the heating and cooling of buildings as well as transportation and industry. Electrifying these sectors with low-carbon sources will reduce emissions. But there are hard-to-abate areas which require other solutions, such as the use of low-carbon fuels (hydrogen or ammonia) to substitute fossil fuels, and the use of low-carbon heat to replace heat produced by burning fossil fuels. This opens up real opportunities for furthering the role of nuclear power. Of all low-carbon energy sources, nuclear power is the only one that can generate electricity, heat and hydrogen without emitting greenhouse gases.

Nuclear power has long provided low-carbon district heating in a handful of countries such as Hungary, the Russian Federation and Switzerland. But there is now growing interest in expanding the use of this application in several countries with large reactors, small modular reactors (SMRs) or dedicated "heating" reactors under development. This trend is due partly to the need to meet climate goals and partly to address the sometimes more pressing issue of local air pollution caused by coal-fired district heating systems. Countries that are heavily dependent on coal for electricity and heat, such as China and Poland, are looking at nuclear power to help move away from coal.

In the medium term, for higher temperature low-carbon heat, advanced reactors such as high temperature reactors will be able to deliver the process steam that industry requires.

So-called green hydrogen will also be an important enabler of the transition towards net zero energy systems to substitute gasoline, natural gas or other fossil feedstocks. Used extensively in various industrial sectors, hydrogen today is almost entirely produced from fossil fuels. But low-carbon hydrogen can be produced by using electricity from renewables or nuclear to split water. More cost-efficient processes than low-temperature electrolysis can be developed using advanced nuclear reactors to provide the heat and electricity needed for high-temperature steam electrolysis or thermo-chemical splitting of water.

According to the IEA, almost half the emissions reductions for reaching net zero will need to come from low-carbon technologies not yet on the market. Governments, industries and international organizations have an important role to play in supporting innovation and the early deployment of these clean energy technologies including advanced nuclear reactors. As we head toward this year's vital United Nations Climate Change Conference in November (COP26), the IAEA will be highlighting the message that nuclear power is part of the solution and has a place at the table when the world decides the energy polices to save our planet.

2.4 International Framework for Nuclear Energy Cooperation (IFNEC)

As Chair of the International Framework for Nuclear Energy Cooperation (IFNEC), I am honored to join the contributors to the NICE Future Initiative's Pathways booklet marking the occasion of the 12th Clean Energy Ministerial. The launch of NICE Future three years ago at CEM 9 highlighted the importance of nuclear in clean energy systems. Since its inception, NICE Future and IFNEC have coordinated on a variety of efforts aimed at partnering with countries to meet their carbon reduction goals while recognizing the complementary role that nuclear innovation can play in clean energy systems.

IFNEC is comprised of sixty-five diverse member countries and four international organizations that share the common goal of ensuring that nuclear energy is used for peaceful purposes in a manner that is efficient and meets the highest standards of safety, security and non-proliferation. Since its inception in 2010, the scope of work and priorities of IFNEC have expanded and evolved consistent with the challenges and opportunities facing nuclear energy. As the global pandemic continues into its second year, IFNEC has been forced to become more creative in the way we engage policy makers and stakeholders; pool our experience and resources; refine our communication and messaging around applications for nuclear energy in an integrated system; and explore advanced technologies and innovation in the nuclear sector.

We find ourselves in challenging, yet exciting times. On the one hand, our global partners are working diligently to develop and deploy advanced reactor technologies to expand the use of both electric and non-electric applications. We are excited about ever expanding medical applications, water purification, hydrogen generation, and high-quality process heat for industrial applications. On the other hand, we face challenges with financing; the recognition of nuclear as a clean and sustainable energy source; harmonization of licensing frameworks; public perception about the fuel cycle, and pursing innovative waste management options, including consideration of a nuclear circular economy . Oftentimes, we see scenarios where policies have not caught up to the innovation, and therefore, we are moving more slowly than we should be.

Aleshia Duncan

Chair of IFNEC

The one thing we have grown to embrace in our diverse IFNEC community is the power of our connection and commonalities. As we have grown to appreciate the century-long relationship that a nuclear project establishes, along with the jobs created, reliable electricity generated for a growing economy, and power to homes, we recognize, as human beings, that no matter which country we call home, we share the desire to improve our quality of life. Around the world, nuclear technology can enable medical advances, clean water, safer food, and heat to industries.

Thus, our work together continues, in partnership with emerging and advanced countries, as well as those who have chosen not to pursue nuclear energy at this time, as we aspire to the carbon reduction goals of the Paris agreement to substantially reduce the risks and impacts of climate change.

The IFNEC community has partnered with NICE Future, the Nuclear Energy Agency, the International Energy Agency, the International Atomic Energy Agency, the World Nuclear Association, and other international, industrial, and non-governmental organizations to pool our experience and resources to address the challenges facing nuclear energy for the betterment of the broader global community and to offer solutions to policy makers. We have examined the benefit of using a regional approach to leverage resources and synergies to tackle shared issues as well as develop mutually beneficial opportunities. We have been challenged to continue this momentum despite the inability to meet in person due to current travel restrictions. As we heard from many speakers during IFNEC's last in-person Ministerial Conference held in Washington D.C., in 2019, "The Time is Now!"

I look forward to continuing these efforts with the IFNEC member countries in partnership with NICE Future and our partners in the global clean energy community.

2.5 Nuclear Energy Agency (NEA)

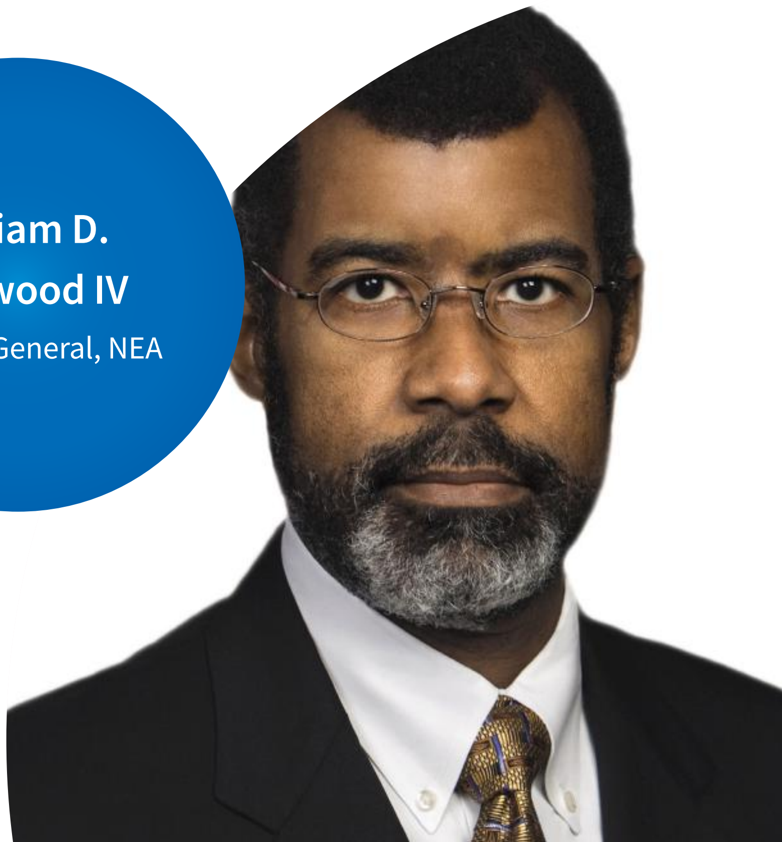
Throughout the experience of the COVID-19 pandemic, the world has been reminded of the critical importance of access to reliable electricity to ensure the resilient operation of critical services indispensable to modern societies. As nations come together to address the pandemic and its economic consequences, the COP-26 offers a historic opportunity to support efforts to build back better and put us on track to meet the climate objectives set in the Paris Agreement.

Reaching net-zero targets by 2050 while supporting economic development and growth will require the mobilisation of all low-carbon technologies. All credible models show that this includes a substantial role for nuclear power. Today, approximately 10% of the world's electricity supply is generated from nuclear power, making nuclear energy the second largest source of clean electricity after hydropower. In OECD economies the share is even higher: nuclear power is the largest source of low-carbon electricity, supplying approximately 18% of the electricity mix.

To keep emission reductions targets within reach, countries will need to extend the operation of existing nuclear energy fleets. New nuclear energy capacity will also be needed to decarbonise current fossil electricity systems and other hard-to-abate parts of the economy, such as heavy industry.

As of 2020, the global nuclear fleet is on average 30 years old. Many existing reactors had initial operating licenses of 30-40 years. Decisions about the extended operation of these facilities will be key in the next decade to meeting climate goals. The analysis is clear: long-term operation of the existing nuclear fleet remains the most competitive option to provide dispatchable low-carbon electricity generation in the next few decades. Extending the operation of these plants will allow countries to reconcile decarbonisation, affordability and security of the electricity provision in the next decade and beyond.

William D. Magwood IV
Director-General, NEA



Nuclear new build can also be part of the solution. More than 50 projects are currently under construction and a growing number of countries are considering new nuclear energy projects to meet their climate goals. With various “Generation III” designs recently commissioned, there is a clear window of opportunity to significantly improve the competitiveness of these reactors by building on lessons learned from first-of-a-kind projects. Several cost reduction opportunities – such as digital transformation and innovations in advanced construction – also offer promising prospects for near-term cost reductions. The lessons learned can then be applied to the development and deployment of new and innovative reactor concepts such as Generation IV and Small Modular Reactors (SMRs).

SMRs and next generation reactor concepts are gaining momentum and capturing the attention of clean energy policy makers around the world. These technologies have the potential to significantly increase the contribution of nuclear power to climate change mitigation. Approximately half of the new reactor designs under development are based on Generation IV concepts, using advanced coolants such as liquid metals, molten salts, or gas. Many of these advanced concepts also generate higher temperatures, with potential applications to industry and other hard-to-abate parts of the economy.

Near-term innovation in SMRs and next generation nuclear technologies represents a different value proposition. The size of many SMRs would be suitable to replace ageing coal power plants. High temperature technologies have non-electrical applications such as production of hydrogen and synthetic fuels, desalination, and district heating.

The higher temperatures can also be used to decarbonise process heat for the chemical, cement and steel making-industries. SMRs are under development to offer more operational, deployment and product flexibility by design, to enhance the overall resilience of low-carbon and integrated electricity systems, especially with high shares of variable renewables.

Energy policymakers have an important role to play in supporting the development and deployment of nuclear innovation, in four key areas:

1. Electricity market reforms: Existing electricity markets often fail to properly remunerate the climate and reliability attributes in electricity systems and to steer the necessary investments toward an affordable, reliable long-term decarbonisation.

2. Robust and predictable financing frameworks: Securing capital-intensive low-carbon infrastructures needs direct or indirect support from government as well as international financial institutions. This includes the need to follow a science-led approach when assessing future clean energy finance taxonomies.

3. International licensing frameworks: Innovative nuclear designs such as SMRs offer an opportunity for early development via international collaboration. Having access to a global market supported by a higher degree of regulatory and industrial harmonisation will also be key to foster the commercial viability of SMRs.

4. Innovation and investment in nuclear research: The development of advanced nuclear technologies is guided by policies that offer support through access to national research and development capabilities and dedicated cost-sharing financial mechanisms for the development and construction of demonstration units as well as advanced fuels. Ensuring the preservation of knowledge and nuclear expertise is also essential.

For more than 60 years, the Nuclear Energy Agency (NEA) has provided authoritative assessments and forged common understandings of key issues. At a time when rapid and profound transformations are required, international collaboration and sharing of best practices is essential. The experience and knowledge gained over six decades by the NEA are important assets as the world seeks to meet its climate change mitigation targets.

The NEA will play an important role supporting the International Programme for Action on Climate (IPAC), an initiative of the Organisation for Economic Co-operation and Development (OECD), announced in April 2021. It offers participating countries a new steering instrument, complementary to and consistent with the United Nations Framework Convention on Climate Change (UNFCCC) and the Paris Agreement, to pursue progress towards the transition to the goals of net-zero greenhouse gas emissions and a more resilient economy by mid-century.

I am honoured to lead the NEA as we work with partners around the world to build back better.

Acknowledgements

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Department for Business, Energy and Industrial Strategy (BEIS), UK

Department of Energy (DOE), USA

Directorate General of Energy and Climate (DGEC), France

Idaho National Laboratory (INL), USA

International Atomic Energy Agency (IAEA)

International Energy Agency (IEA)

International Framework for Nuclear Energy Cooperation (IFNEC)

Japan Atomic Energy Agency (JAEA)

Ministry of Climate and Environment, Poland

Ministry of Economy, Trade and Industry (METI), Japan

National Renewable Energy Lab (NREL), USA

Natural Resources Canada (NRCan)

Nuclear Energy Agency (NEA)

Rosatom

SN Nuclearelectrica SA, Romania

FNC FLEXIBLE NUCLEAR CAMPAIGN FOR NUCLEAR-RENEWABLES INTEGRATION

A CAMPAIGN OF THE CLEAN ENERGY MINISTERIAL

NICE Future

Nuclear Innovation: Clean Energy Future

An Initiative of the Clean Energy Ministerial