IAEA
International Atomic Energy Agency
Atoms for Peace and Development

First Global Stocktake

International Atomic Energy Agency (IAEA) Submission

March 2023

The International Atomic Energy Agency (IAEA) appreciates the invitation from the SBI and SBSTA Chairs to submit inputs for the first Global Stocktake. The IAEA is pleased to submit this contribution related to the energy sector addressing the Chairs' guiding questions for the technical assessment component of the Stocktake.

Mitigation guiding questions

1. ***What is the collective progress in terms of the current implementation of, and ambition in, mitigation actions towards achieving the goals defined in Articles 2.1(a)[1] and 4.1[2] of the Paris Agreement?***

   Nuclear energy remains the second largest source of low carbon electricity globally and has historically avoided around 70 billion tonnes of carbon dioxide (CO_2) over recent decades (IEA 2022a). With over 400 nuclear power reactors in operation and more than 50 under construction (IAEA 2023a), nuclear power is continuing its proven role in mitigation, underpinning electricity sector decarbonization by operating reliably, on demand, and supporting increased shares of other low carbon generation, particularly variable renewable sources such as solar PV and wind (IEA 2019; 2022a).

   In addition to continued operation and new construction of nuclear power plants, important progress has been made around the world in extending the operating lifetimes of existing plants, maintaining "a solid foundation on which to build clean energy transitions" (IEA 2022a). From 2019 to 2022, policy and regulatory decisions have granted lifetime extensions to over 50 gigawatts (GW) of nuclear capacity, with decisions pending for a similar capacity (IEA 2022a).

   Overall progress in terms of potential ambition in mitigation is reflected in the IAEA's latest projections of nuclear power deployment to 2050 (IAEA 2022a). The high case projections, which consider country policies on climate change and the expressed intentions of countries for

[1] Article 2.1(a) of the Paris Agreement: "Holding the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels, recognizing that this would significantly reduce the risks and impacts of climate change"

[2] Article 4.1 of the Paris Agreement: "In order to achieve the long-term temperature goal set out in Article 2, Parties aim to reach global peaking of greenhouse gas emissions as soon as possible, recognizing that peaking will take longer for developing country Parties, and to undertake rapid reductions thereafter in accordance with best available science, so as to achieve a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of this century, on the basis of equity, and in the context of sustainable development and efforts to eradicate poverty."

expanding the use of nuclear power, see a doubling of world nuclear capacity by 2050 (to 873 GW). On the other hand, the low case projections see nuclear capacity in 2050 at around 400 GW (essentially the same as today), assuming current market, technology and resource trends continue and there are few additional changes in explicit laws, policies and regulations affecting nuclear power.

2. ***Taking into account nationally determined contributions, long-term low GHG emission development strategies and relevant commitments and initiatives, what are the projected global GHG emissions, and the emission reductions still needed, in 2030 and 2050 in order to achieve the goals defined in Articles 2.1(a) and 4.1 of the Paris Agreement?***

According to the Intergovernmental Panel on Climate Change (IPCC 2022a), International Energy Agency (IEA 2022b) and UN Environment Programme (UNEP 2022), nationally determined contributions (NDCs) remain inadequate relative to the goals outlined in Articles 2.1(a) and 4.1. With full implementation of unconditional NDCs, it is estimated by UNEP that emissions would be 15 and 23 billion tonnes of CO_2-equivalent above the level required in 2030 for 2°C and 1.5° degrees, respectively, and 24-36 Gt CO_2-equivalent above in 2050 (UNEP 2022). Assuming net zero commitments of G20 members plus nine other large emitters are achieved, warming would be limited to below 2°C in 2050, with a gap of around 12 Gt CO_2-eq for 1.5°C in 2050 (UNEP 2022).

3. ***What efforts are being undertaken to plan, implement and accelerate mitigation action towards achieving the goals defined in Articles 2.1(a) and 4.1 of the Paris Agreement?***

According to nationally determined contributions (NDCs) and long term strategies (LTSs) (UNFCCC 2023a; 2023b)), around 30 Parties are planning, implementing and/or accelerating action capitalizing on the substantial mitigation potential of nuclear energy (see Table 1). This includes 14 Parties that have assigned an important role to nuclear energy in their latest NDCs and close to 20 Parties including nuclear energy in their LTSs.

Table 1: Nuclear energy in national commitments and strategies, mid-2022

	Using nuclear power today	Constructing first nuclear power plant	Other countries
Nuclear energy in NDC and LTS	Canada, China, Ukraine, UK, USA		
Nuclear energy in NDC only	Argentina, Armenia, India, Iran (Islamic Rep.), Russian Fed., United Arab Emirates	Türkiye	Korea (DPR) Ghana
Nuclear energy in LTS only	Czech Rep., Finland, France, Hungary, Japan, Mexico, Netherlands, Slovakia, Slovenia, Sweden		Australia, Colombia, Morocco, Singapore
Nuclear energy not included in NDC or LTS (or mentioned in the context of moratoria or phase-outs)	Belarus, Belgium, Brazil, Bulgaria, Germany, Korea, Rep., Pakistan, Romania, Switzerland, South Africa, Spain	Bangladesh, Egypt	Rest of the world

Source: UNFCCC 2023a; 2023b. Note, the Republic of Korea recently announced plans to revise its NDC and LTS to increase the role of nuclear power (Republic of Korea 2022).

Together, these Parties account for over 70% of global energy related emissions (IEA 2022c). Across these NDCs, the commitments to plan, implement and accelerate mitigation action include quantitative and project-oriented targets to expand nuclear energy capacity, measures to develop and utilize new nuclear energy technologies (including small modular reactors and the production of low carbon heat and hydrogen), general statements of intent to develop, deploy and use nuclear energy to reach mitigation goals, and targets to support developing countries and nuclear industry workforce diversity.

Beyond NDCs and LTSs, an additional 50 or so Parties are pursuing nuclear energy, ranging from countries that have expressed an interest to those currently constructing their first power plants.

The IAEA is also supporting Parties to enhance NDC ambition by assisting countries in assessing nuclear for their decarbonization strategies, including by supporting Parties build capacity in energy planning and conduct research on this topic (IAEA 2021b).

4. ***How adequate and effective are the current mitigation efforts and support provided for mitigation action towards achieving Articles 2.1(a) and 4.1 of the Paris Agreement?***

Global mitigation pathways from the IPCC Sixth Assessment Report (Riahi, K., Schaeffer, R. et al. 2022; IPCC 2022a) consistently highlight an important role for nuclear energy in transition scenarios compatible with achieving the goals of the Paris Agreement — the majority of AR6 low carbon pathways compatible with Article 2.1(a) of the Paris Agreement project at least a doubling of global nuclear electricity generation by 2050 (Turton 2023). While nuclear power continues to provide the second largest source of low carbon electricity worldwide, in many regions and countries, policies, efforts and support provided for mitigation action utilizing nuclear energy are not aligned with realizing Articles 2.1(a) and 4.1 as reflected in the IPCC pathways. That is, even with important progress and ambition outlined in the responses to Guiding Questions 1 and 3, support for deployment of nuclear power and lifetime extension of existing plants remains inadequate, and in some cases, inconsistent vis-à-vis the goals of the Paris Agreement.

5. ***In order achieve the goals defined in Articles 2.1(a) and 4.1 of the Paris Agreement:***

a) What further action is required?

Please see combined response to 5a and 5b below.

b) What are the barriers and challenges, and how can they be addressed at national, regional and international levels?

In response to 5a and b:

In the context of energy sector mitigation, to achieve the goals defined in Articles 2.1(a) and 4.1, and address barriers and challenges at different levels, foremost a coherent set of policy, regulatory, infrastructure and other measures is required (IAEA 2021a, IAEA 2022b, IEA 2022b) addressing:

- **Markets and regulation:** policymakers and regulators can seek to reduce existing energy and investment market barriers and distortions, such as those related to electricity market design and regulation, poorly targeted subsidies, insufficient carbon prices and the absence of mechanisms to value and remunerate system services (including flexibility and reliability) provided by energy producers, including nuclear power plants. Approval processes for low carbon energy projects could also be more closely aligned with the need for urgent action on both climate and energy security.

- **Guiding investment:** the definitions of ESG criteria aimed at directing public and private investment towards low carbon options, including in taxonomies developed by governments, should have a strong scientific basis and avoid arbitrary barriers. By adopting objective and transparent technology neutral criteria, investment can be mobilized and guided to maximize the likelihood of realizing net zero emissions while responding to other aspects of sustainable development.
- **Management of clean energy project risks:** decision makers can adopt coherent targeted policy measures to help mitigate the risks confronting investors in relation to capital intensive, long lived, low carbon energy projects. In particular, such measures can support projects that face long lead times, complex regulatory processes and political uncertainty, as well as those providing substantial non-market benefits such as enhanced long term energy security. Policymakers can facilitate and leverage private investment through measures to manage and share risks during construction (such as via direct public financing or guarantees to debt and equity providers, including regulated asset-based approaches) and schemes to share revenue and pricing risks, such as contracts for difference or power purchase agreements.
- **Coordination and cooperation:** policymakers will need to coordinate, and potentially finance, the development of hard infrastructure (e.g. energy grids and secure supply chains for critical commodities) and soft infrastructure (e.g. human capital, institutions and legal frameworks) to support the energy transition, enhance international financial cooperation and expand technology neutral financing from MDBs and CFIs — particularly to facilitate flows for energy projects in developing countries — and support local capital market development.
- **Supporting new technologies:** continued public and private investment in R&D and demonstration projects to support technology innovation will be critical to reach net zero, given that substantial emission reductions are expected to come from emerging technologies, including advanced nuclear energy systems (IEA 2020a).

In addition to the above elements, temporary targeted measures may be warranted to avoid premature retirement of low carbon energy capacity, such as existing nuclear power plants, and to discourage investment that would lead to the lock-in of long lived energy supply infrastructure that is incompatible with the goals of the Paris Agreement.

c) What are the opportunities, good practices, lessons learned and success stories?

The successful rapid deployment of large scale low carbon nuclear generation by the United Arab Emirates provides an exemplary illustration of good practices and opportunities for enhanced and accelerated mitigation. The Barakah Nuclear Energy Plant alone is expected to produce around 25% of the UAE's electricity by 2025, largely replacing natural gas generation, nearly halving power sector emissions in the Emirate of Abu Dhabi (IAEA 2022b; EWEC 2022). With construction starting in 2012, this represents a rapid decarbonization, similar to experiences in

France, Sweden and other countries which successful and rapidly decarbonized their electricity sectors with nuclear energy in earlier decades.

The success of China in deploying new nuclear technologies to decarbonize the heat supply provides additional lessons, demonstrating the potential of nuclear energy to not only decarbonize electricity production but also its capacity to provide low carbon heat to reach mitigation goals in non-electric applications and hard-to-abate sectors (WNN 2022). Examples include the Haiyang nuclear power plant (delivering commercial scale district heating since 2020 and now expanding to meet the heating needs of 1 million residents (WNN 2023)), the Qinshan nuclear power (providing industrial heat), the soon-to-be-completed Tianwan plant (which will supply steam to the petrochemical industry), and plans for dedicated reactors for clean district heating in Liaoyuan (CNNC 2021).

On the policy front, the UK provides an example of good practices, having implemented an integrated package of policies and measures to support investment in low carbon options, including nuclear energy, in line with ambitious climate goals. Complemented by a comprehensive strategy for the nuclear industry (UK BEIS 2018), measures that have been implement or are under consideration include:

- contracts for difference to stabilize revenues for investors in low carbon electricity projects (UK BEIS 2020a);
- a capacity market for dispatchable generation to ensure reliable and affordable electricity supplies (UK OFGEM 2020);
- a final investment decision process to accelerate energy investment;
- a loan guarantees scheme to support infrastructure project finance and investment (UK IPA & Treasury 2017);
- government financing during project construction; and
- regulated asset base models that provide a regulated return to investors (UK BEIS 2020b).

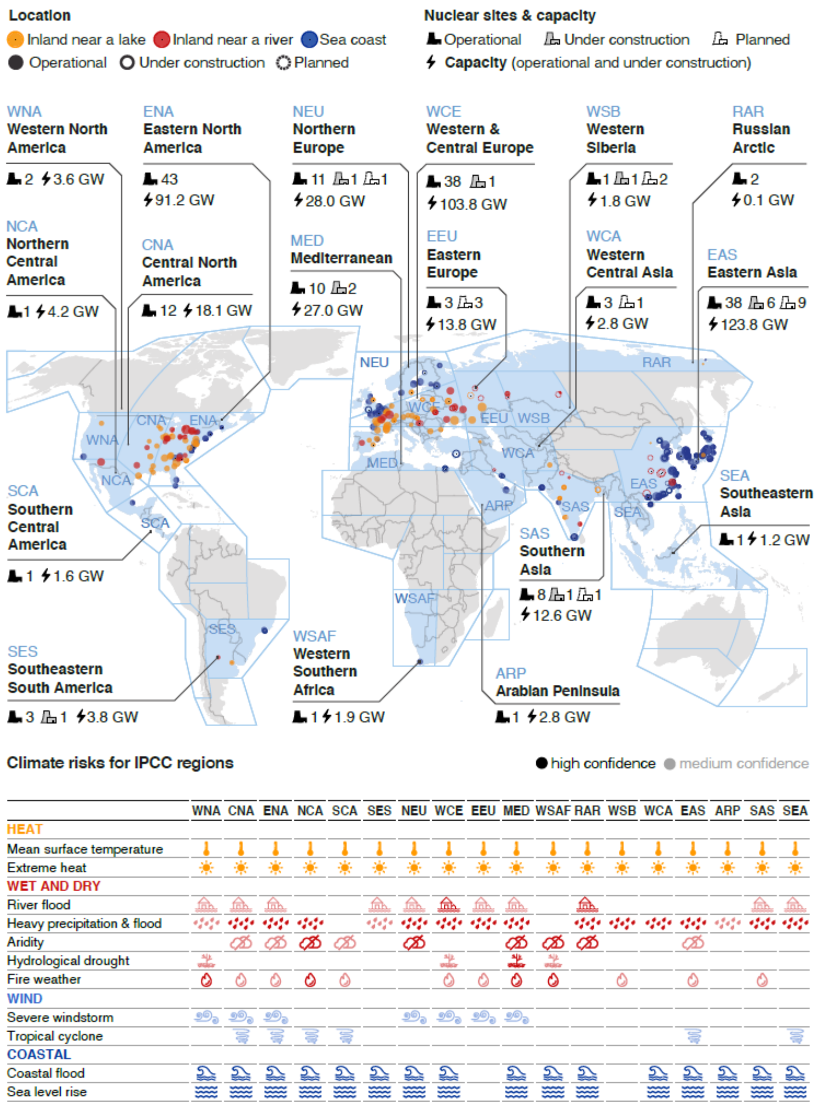
Moreover, the UK recognized the potential of low carbon nuclear energy to also support broader social and economic development objectives in the recovery measures in its Ten Point Plan for a Green Industrial Revolution, providing over UK £400 million for small modular nuclear reactors (and mobilizing private funding), research and development of advanced modular reactors, developing regulatory frameworks and supporting supply chains (UK 2020).

Adaptation guiding questions

6. *What is the collective progress in terms of the current implementation of, and ambition in, adaptation actions towards achieving the goals defined in Articles 2.1(b)[3] and 7.1[4] of the Paris Agreement?*

Global energy infrastructures are, and will increasingly be, exposed to frequent and severe climate hazards (IPCC 2022b). The nuclear energy sector is well prepared to face changing environmental conditions — driven by multiple climate impacts (see Figure 1) — in the foreseeable future (IAEA 2022b). Refer also to the responses to Guiding Questions 7–9.

Figure 1: Regional climate risks and climatic impact drivers



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3 Article 2.1(b) of the Paris Agreement: "Increasing the ability to adapt to the adverse impacts of climate change and foster climate resilience and low greenhouse gas emissions development, in a manner that does not threaten food production".

4 Article 7.1 of the Paris Agreement: "Parties hereby establish the global goal on adaptation of enhancing adaptive capacity, strengthening resilience and reducing vulnerability to climate change, with a view to contributing to sustainable development and ensuring an adequate adaptation response in the context of the temperature goal referred to in Article 2".

Source: based on climate data from IPCC (Gutiérrez and Jones et al. 2021; IPCC 2022b) and nuclear data from IAEA (2023a). Note, nuclear sites with additional reactors under construction or planned are counted as a single plant site.

7. What efforts are being undertaken to plan, implement and accelerate adaptation action towards achieving the goals defined in Articles 2.1 (b) and 7.1 of the Paris Agreement and with a view to recognizing the adaptation efforts of developing country Parties, what efforts have been undertaken by these Parties towards achieving these goals?

Climate related hazards (e.g. meteorological, hydrological, fire related) have the potential to affect all types of nuclear installations worldwide. Against this backdrop, the IAEA has initiated a technical project that draws on the most recent experience of Parties in the application of climate predictive methods for the assessment of site hazards and safety issues related to existing and new nuclear sites (IAEA 2022b). The project combines statistical and numerical methods with meteorological and hydrological approaches to assess time dependant hazards through the lens of sustainability, drawing on special methods to assess the evolution of climate hazards over long time frames. The expected outcomes include identification of safety relevant actions for on-site hazards and the design of new protection measures for both existing installations and new designs. Measures will aim at increasing the robustness and resilience of nuclear power plants in the face of climate change, combining engineering provisions (e.g. improved barriers) and operational, performance related procedures (e.g. preventive shutdown).

8. How adequate and effective are the current adaptation efforts and the support provided for adaptation towards achieving the goals defined in Articles 2.1(b) and 7.1 of the Paris Agreement?[5]

While the number of reported disruptions to nuclear power plant operations due to adverse weather conditions have increased substantially over recent decades, the associated production losses have remained modest (<0.5% of total plant output), with plants continuing to achieve very high annual capacity factors (IAEA 2023a). A majority of reported climate-related disruptions occurred at plants located by rivers or lakes, where continuity in production directly depends on strictly regulated access to water bodies, ensuring minimal impact on ecosystems.

The effectiveness of current adaptation efforts is likely attributable to revisions to regulatory regimes and improved operational experience. On the former, the evolving nature of weather events has led many countries and regulators to revise safety guidelines so as to maintain or strengthen the overall resilience of nuclear operations (IAEA 2022b). Episodes of extreme heat, lack of cooling water, frazil ice phenomena or floods were at the origin of specific adaptation measures (OECD NEA 2021). Plant designs have been adapted with a variety of engineering solutions: (i) a reduction of the usage and consumption of cooling water; (ii) modification of water intake; (iii) investigation of on-site water production; (iv) increase and more efficient use of heat exchanger capacity; and (v) the redesign of condensers to offset river intake of warmer water.

9. How can the implementation of adaptation action towards achieving the goals defined in Articles 2.1(b) and 7.1 of the Paris Agreement be enhanced, taking into account the adaptation communication referred to in paragraph 10 of the Paris Agreement?[6]

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[5] Article 7.14 (c) of the Paris Agreement.

[6] Article 7.14 (b) of the Paris Agreement; Decision 11/CMA.1, paragraph 9.

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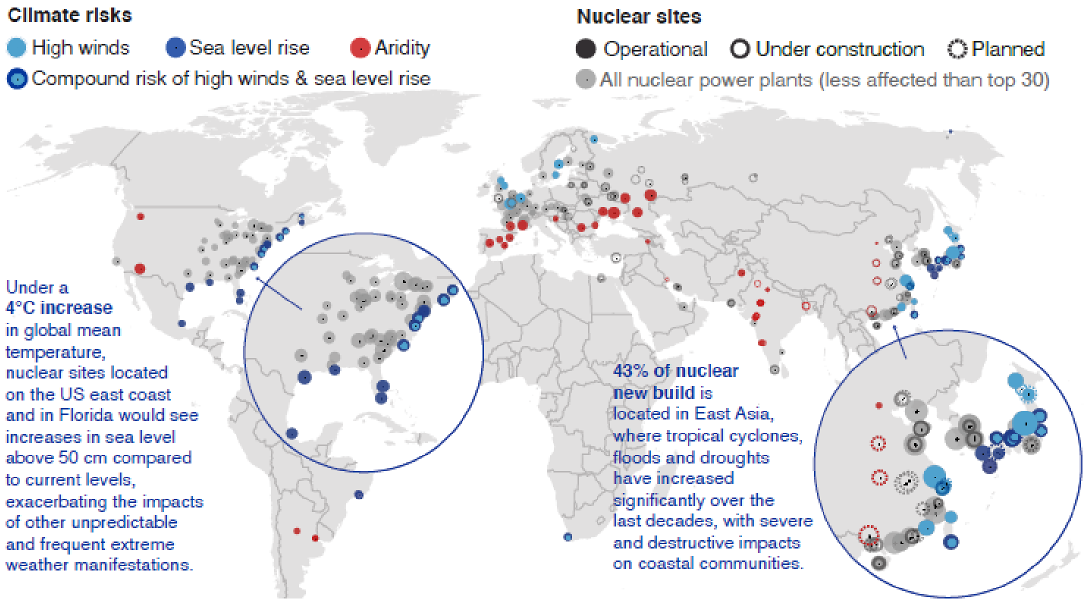
Beyond continuing the successful adaptation approaches outlined in the responses to Guiding Questions 7 and 8, adaption efforts can be further enhanced. Anticipating weather and water related events, for example with seasonal and sub-seasonal forecast models, can inform the identification of priorities, implementation and support needs, and support planning and actions to ensure the availability of individual power infrastructure assets (see Figure 2) and the design of measures to mitigate the economic and societal impacts of such events. Refer also to response to Guiding Question 7.

Figure 2: Global overview of the most significant environmental changes around selected nuclear power plant site locations



Source: based on climate data from IPCC (Gutiérrez and Jones et al. 2021) and nuclear data from the IAEA (2023a). Note: m/s — metres per second, m — metres.

10. In order to achieve the goals defined in Articles 2.1(b) and 7.1 of the Paris Agreement:

a) What further action is required?

b) What are the barriers and challenges, and how can they be overcome at national, regional and international levels?

c) What are the opportunities, good practices, lessons learned and success stories?

In response to 10a, b and c:

New climate hazards, including compounded risks resulting from cascading, low probability, extreme weather events, must be included in the siting and design of new nuclear installations, particularly in countries embarking on new nuclear power programmes. Integrating the latest advances in climate science, including the better representation of future climate risks at the local scale, can greatly contribute to strengthening the climate resilience of nuclear infrastructures and reinforce the security of the electricity supply (IAEA 2022b).

Nuclear power plants in Sweden and Finland have successfully prepared for a changing climate well beyond 2050 (Unger et al. 2021; IAEA 2021a). Actions initiated in the aftermath of the

Fukushima accident and the overall high level of safety in the nuclear sector ensure a robustness to meet extreme events in general, including extreme weather events. Recent investments in independent core cooling in plants in Sweden have further strengthened durability.

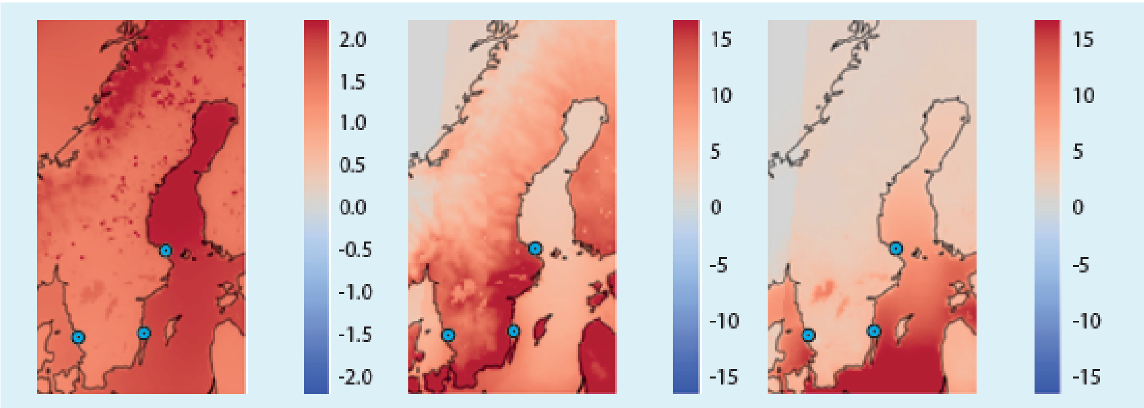
Nonetheless, climate and weather related events with the potential to affect the operation of nuclear power plants have occurred historically and are expected to increase in frequency and severity in the future (see Figure 3). For instance, all Nordic nuclear power plants are situated by the sea, making them potentially vulnerable to rising sea levels, although this effect is partly offset by land uplift at most of the nuclear sites. It is estimated that current safety margins can accommodate the impact of sea level rise caused by climate change and extreme weather conditions for many decades to come — for example, plants in Sweden can cope with a sea level rise of up to 3 metres above the current normal level.

A number of other climate or weather related events may also potentially affect the operation of nuclear power plants in Nordic countries. These include, for example, lightning strikes that may impact the electricity grid at the plant site and externally. Another example is higher seawater temperature, which in extreme cases may lead to power reduction or even require a temporary shutdown. In the summer of 2018, the production in both the Ringhals and Loviisa nuclear power plants was impacted by high cooling water temperatures.

A warmer sea also increases the risk of marine organisms obstructing cooling water intakes, as evidenced by jellyfish intrusions at the Oskarshamn nuclear power plant in 2005 and 2013. Furthermore, frazil ice, a phenomenon that may occur in subcooled moving water, led to the clogging of the cooling water inlet at the Olkiluoto nuclear power plant in 2008.

The potential impacts of climate change outlined above are not considered threats to plant safety, at least for a foreseeable future, and hence are more relevant for plant economics and electricity supply security. The effect of high seawater temperatures can be mitigated by increasing the capacity of the heat exchangers or installing a deep water inlet, which can also reduce potential disturbances from frazil ice and jellyfish, albeit at a high cost. Measures can also be implemented to monitor for, screen and clear marine organisms. To protect the facilities from lightning strikes several different types of protections have been installed, both in the plants and in the grid.

Figure 3: Projected changes in climate indices of relevance for high sea water temperatures at +2°C global warming compared to pre-industrial conditions



Source: IAEA 2021a. Note, blue dots denote operational nuclear power plants. From left to right changes in: maximum temperature (°C), consecutive warm days in June–August (days), and tropical nights (i.e. days when nighttime temperatures remain above 20°C).

Another important example of opportunities is provided by the Palo Verde nuclear power plant in the Arizona desert in the USA. Even under moderate climate change scenarios, it is estimated that this plant could experience around 60 days of extreme temperatures above 40°C per year later this century, increasing to close to 100 days under scenarios with higher warming (Gutiérrez and, Jones et al. 2021). In this context, the Palo Verde plant provides a unique example of a successful design adapted to withstand and operate under severe environmental conditions, including utilizing wastewater from surrounding sewage stations, cutting freshwater consumption needs drastically (IAEA 2022b).

Finance flows and means of implementation guiding questions

11. What is the collective progress in terms of the current implementation of, and ambition in, making finance flows consistent with a pathway towards low greenhouse gas emissions and climate-resilient development towards to achieving the goal defined in Article 2.1 (c) of the Paris Agreement?[7]

To achieve net zero emissions by 2050, the International Energy Agency (IEA) estimates that global electricity sector investment will need to more than double from recent level to over US $2 trillion annually between 2023 and 2030 (IEA 2022a). This includes an almost 2.5 fold increase in annual nuclear energy investment to over US $100 billion by 2030, and more than US $2 trillion by 2050 — primarily in the Asia Pacific (especially in China), Europe and North America (IEA 2022b).

Despite some positive developments (IAEA 2021c), including an increasing recognition of the role of nuclear energy in meeting national climate commitments (see response to Guiding Question 3), recent trends indicate that the current market and policy environment may be unable to mobilize the scale of investment needed to achieve the Paris Agreement goals. For instance, many national government responses to COVID-19 continued to direct financial resources towards the production and consumption of fossil fuels: among G20 countries over 40% of the more than US $1 trillion in public finance committed to energy investment in pandemic recovery packages is allocated to fossil energy (Energy Policy Tracker 2023), jeopardizing the goals of the Paris Agreement. In comparison, around US $12 billion has been committed to nuclear energy investment — mainly in the USA, UK, France and Canada (IAEA 2021a).

Nevertheless, in the face of these challenges, important progress is being made in terms of initiatives to address the current misallocation of financial resources by providing investors with additional guidance on which activities are compatible with long term climate and sustainability goals. For example, governments and the financial sector are adopting sustainable investment taxonomies and similar frameworks to direct and mobilize private financial flows towards sustainable investment, including low carbon nuclear energy. This is elaborated further in response the Guiding Question 15.

12. What is the collective progress in terms of the implementation of, and ambition in, the provision and mobilization of scaled-up financial resources from a wide variety of sources, instruments and channels towards achieving the goals defined in Article 9 of the Paris Agreement, noting the significant role of public funds, and aiming to achieve a balance between finance for adaptation and mitigation?[8]

Annual investment in nuclear energy has risen gradually from around US$ 35 billion in 2017–2019 to almost US$ 50 billion in 2022 (IEA 2023). This acceleration can be attributed to construction of new reactors in China, Europe and Pakistan, and refurbishment and lifetime extensions in a number of other countries.

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[7] Article 2.1(c) of the Paris Agreement: "Making finance flows consistent with a pathway towards low greenhouse gas emissions and climate-resilient development"

[8] Article 9.3 and 9.4 of the Paris Agreement; Decision 19/CMA.1, paragraph 36(d).

13. What is the collective progress in terms of the state of current implementation of, and ambition in, technology development and transfer towards achieving the vision defined in Article 10.1 of the Paris Agreement?[9] What is the state of cooperative action on technology development and transfer?

The response below addresses Guiding Questions 13 and 14.

The IAEA assists its Member States in using nuclear science and technology for peaceful purposes and facilitates the transfer of such technology and knowledge in a sustainable manner (IAEA 2023b).

Interventions to establish and maintain a robust system of institutional, regulatory, legal, industrial and other infrastructure (including human capital) are critical to supporting technology transfer for the energy transition (as well as R&D for new technologies). Directly addressing this need, the IAEA has developed and implemented a comprehensive Milestones Approach to assist countries considering or planning to utilize nuclear power, incorporating technical education to train the workforce for the energy transition and ensuring a robust scientific basis to regulation, planning and policy, among others. As an example, the development of a nuclear power programme is a key element in the United Arab Emirates' climate change mitigation actions (UAE 2022). To this end, the UAE is enhancing its technical and vocational education system to support the development of the professional workforce fundamental to accelerating the deployment of nuclear and other clean energy technologies (UAE 2017; IAEA 2018).

Further with respect to energy, over more than four decades, the IAEA has provided extensive support to countries to build capacity through training, technical assistance and technology transfer of tools and methodologies for sustainable energy systems analysis and planning, enabling them to evaluate the role of different technologies in meeting their future energy needs while reducing greenhouse gas emissions, in support of Article 10.1. As an illustrative example, over the last decade, the IAEA has provided technical assistance to African Member States to reinforce local energy planning capabilities. This has comprised capacity building and the transfer of tools and methodologies to support the establishment of national planning teams and case studies analysing sub-regional power pools, most recently supporting the development of a Continental Power System Masterplan, in cooperation with the International Renewable Energy Agency (IRENA & IAEA 2021). These case studies, in turn, demonstrated the benefits of cooperation and integrated development of local generation options and grids, in terms of increased access to energy services, stronger economic development and improved electricity affordability. This effective model of technology transfer was also applied in Latin America and the Caribbean between 2015-2020, with IAEA tools and methodologies transferred to over 200 experts in 15 countries to support sub-regional studies on energy and climate change mitigation.

14. What is the collective progress in terms of the state of current implementation of, and ambition in, enhancing the capacity of developing country Parties to implement the Paris Agreement?[10] How effective has been the implementation of capacity-building efforts?

Included in response to Guiding Question 13.

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[9] Article 10.1 of the Paris Agreement: "Parties share a long-term vision on the importance of fully realizing technology development and transfer in order to improve resilience to climate change and to reduce greenhouse gas emissions."

[10] Article 11.3 of the Paris Agreement.

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15. ***In order to achieve the goal defined in Article 2.1(c) of the Paris Agreement as well as scale up the provision and mobilization of means of implementation (including finance, technology development and transfer and capacity-building), including in the short term, both from public and private sources, at the national and international levels to achieve the Paris Agreement goals:***

a) What further action is required?

b) What are the barriers and challenges and how can they be overcome at national, regional and international levels?

c) What are the opportunities, good practices, lessons learned and success stories?

In response to 15a, b and c:

Given the scale of investment required and the current misallocation of financial resources, providing investors with additional guidance on which activities are compatible with long term climate and sustainability goals is a key element in the framework of policies and measures needed to drive the low carbon energy transition.

Taxonomies and similar frameworks represent one important way in which governments and the financial sector are seeking to mobilize and direct private financial flows towards sustainable investment. Such frameworks should have a strong scientific basis and avoid arbitrary technology barriers. Good practices — i.e. objective and transparent technology neutral criteria — have been adopted in relation to nuclear energy in several taxonomies (see Table 2), mobilizing and guiding investment according to Article 2.1(c) to maximize the likelihood of realizing the goals in Articles 2.1(a) and (b) while responding to other aspects of sustainable development.

Table 2: Examples of sustainable investment taxonomies that include nuclear energy, 2022

	Nuclear energy included	**Nuclear energy currently excluded**	**Nuclear energy classification to be determined**
National and regional sustainable finance taxonomies and roadmaps	China, European Union, Japan *(implicit)*, Korea, Rep., Malaysia *(implicit)*, Philippines, Russian Federation	ASEAN, Bangladesh, Canada, Colombia, Kazakhstan, Mongolia, South Africa, Thailand	Chile, Indonesia, Singapore, UK *Under development/ discussion:* Dominican Republic, India, Mexico, New Zealand, Sri Lanka, Viet Nam
Private sector initiatives	Green Bond Principles (ICMA) *(implicit)*	Climate Bonds Standard (CBI)	

Source: IAEA 2022b.

In addition, further public sector interventions and public–private collaboration will also be critical. For example, public sector coordination and financing of infrastructure development is likely to be necessary to leverage private investments and fully unlock the large potential of financial markets (IPCC 2022a). This includes both 'hard' (e.g. energy grids, critical supply chains, physical adaptation measures) and 'soft' infrastructure (e.g. regulatory and legal frameworks, and human capital). The specific coordinating role of the public sector, and the nature of public–private partnerships, will depend on national circumstances and complementary policy measures.

In addition to national, regional and private sector initiatives and policy support, enhanced international financial cooperation will be essential to realize the low carbon transition, given that many developing countries rely on public resources to finance energy projects. Beyond existing commitments to scale up public finance flows to developing countries to US $100 billion under the UNFCCC, opportunities exist to support local capital market development, expand financing through multilateral development banks and specialized climate finance institutions and leverage private capital by increasing the use of public guarantees. The significant barriers that developing countries face in relation to financing nuclear energy projects can be partly addressed through the adoption of a technology neutral approach in the funding decisions of development and green banks for infrastructure and clean energy funds (Teplinksy and Fowler 2020; IAEA 2021a).

Beyond the need for policy interventions to accelerate the deployment of low carbon technologies in the near term (to 2030), securing net zero emissions over the longer term will also necessitate continued public and private investment in R&D to support technology innovation — the IEA expects nearly half of the emission reductions for net zero to come from technologies yet to have reached the market (IEA 2020a) — including for advanced nuclear energy systems. A key complement to inform the design of R&D and broader energy policy is the robust assessment of long term decarbonization pathways, such as those published by the IEA (2021) and IPCC (Riahi and Schaeffer et al. 2022). Enhancing the representation of low carbon options in such assessments is critical to identifying key mitigation technologies and lower cost pathways to reach net zero (Turton 2023).

Please also refer to the response to Guiding Question 5a and 5b, which outlines a number of actions that support the provision and mobilization of means of implementation to achieve the Paris Agreement goals.

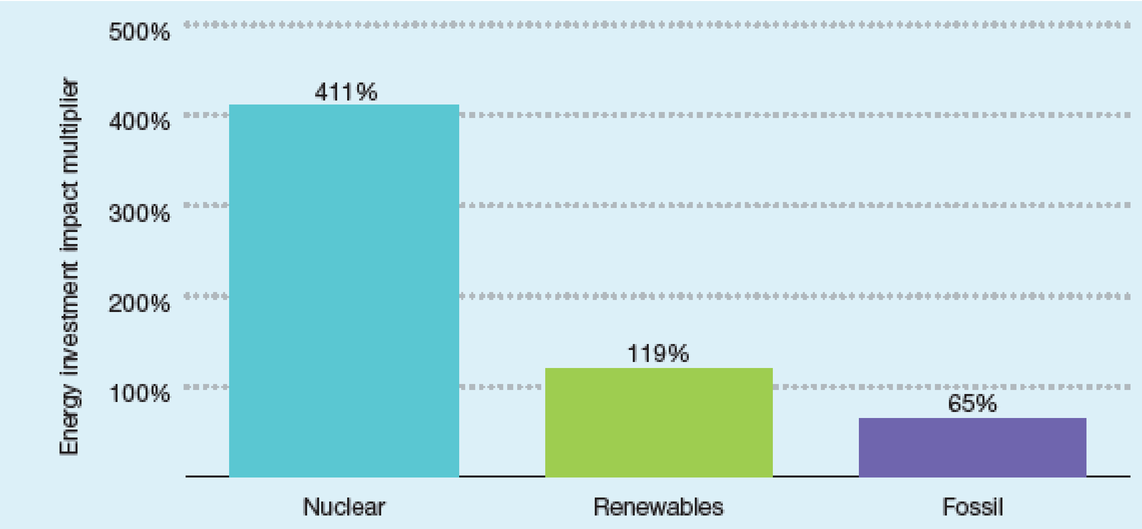
Guiding questions related to efforts referred to in Decision 19/CMA.1, paragraph 6(b), that may be taken into account as appropriate, that:

Address the social and economic consequences and impacts of response measures:

16. ***What is the collective progress in terms of the current implementation of, and ambition in, efforts made that address the social and economic consequences and impacts of response measures while implementing mitigation policies and actions towards the achievement of the Paris Agreement goals?[11]***

According to analysis by the International Monetary Fund, investment in low carbon energy as part of mitigation policies can provide a substantial economic boost (Batini et al. 2021). The spending multiplier — i.e. the change in economic activity (GDP) divided by the change in investment spending — for nuclear energy is estimated to be around six times larger than for fossil energy and around three times larger than the multiplier for renewable energy over the short term, delivering a rapid economic boost (see Figure 4). Spending on nuclear energy is also estimated to stimulate (or 'crowd in') more investment in other parts of the economy and lead to "larger employment of both high- and lower-skilled resources" per unit of spending compared to other low emission energy sources.

Figure 4: Green multipliers for investment in nuclear and other energy sources



Source: Batini et al. 2021; IAEA 2021a

In the near term, investment in projects to extend the operation of existing nuclear power plants can be implemented rapidly and at scale, providing a substantial boost to economic activity and employment, while delivering competitive, low carbon electricity (IEA and OECD Nuclear Energy Agency 2020). In quantitative terms, extending the life of nuclear power plants from 40 to 60 years would retain 95 gigawatts (GW) of low carbon generation by 2025 and an additional 90 GW by 2030 (IAEA 2021d; IAEA 2020). At an estimated investment cost of US $650 per kilowatt for extension projects in much of Europe and the USA, this would be realized with a global investment of around US $120 billion over the next decade and create up to 370,000 jobs (IAEA 2021a; IEA 2019; 2020b; 2022a, IEA and OECD Nuclear Energy Agency 2020).

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[11] Article 4.15 of the Paris Agreement and Decision 19/CMA.1, paragraph 6(b)(i).

Avert, minimize and address loss and damage associated with the adverse effects of climate change:

17. ***What is the collective progress in terms of the current implementation of, and ambition in, efforts made to enhance understanding, action and support towards averting, minimizing and addressing loss and damage associated with the adverse effects of climate change?[12] What further action is required to strengthen these efforts?[13]***

Countries are increasingly recognizing the value of nuclear energy to mitigate and enhance resilience against the adverse impacts of climate change, while ensuring a reliable and security energy supply critical for sustainable development. In addition to the 30 Parties planning, implementing and/or accelerating action to capitalize on the substantial mitigation potential of nuclear energy in their NDCs and LTSs (see response to Guiding Question 3), around 15 LDCs are actively considering or implementing nuclear power programmes. These efforts can be strengthened with additional capacity building (particularly in energy planning and nuclear infrastructure development), technology transfer and financing.

[12] Article 8 of the Paris Agreement and Decision 19/CMA.1, paragraph 6(b)(ii).

[13] Decision 19/CMA.1, paragraph 36(e).

Cross-cutting guiding questions

18. How are fairness considerations, including equity, being reflected in Parties' NDCs?[14]

The IAEA, in partnership with other UN organizations, IGOs, NGOs and experts, is working the Parties to revise and enhance their NDCs, including to address issues of fairness and equity in the context of supporting strategies to ensure a Just Transition to low carbon energy systems.

19. How is climate action respecting, promoting and considering Parties' respective obligations on human rights, the right to health, the rights of indigenous peoples, local communities, migrants, children, persons with disabilities and people in vulnerable situations and the right to development, as well as gender equality, empowerment of women and intergenerational equity?[15]

Mitigation action utilizing nuclear energy is proactively enhancing and promoting gender equality and empowerment of women, who are integral to the nuclear energy sector. The IAEA, member states, industry and NGOs, recognizing the benefits that gender diversity brings to workplace, are active in promoting interest in nuclear engineering, science and other nuclear-related professions among women. For example, in partnership with the European Union, the IAEA Marie Sklodowska-Curie Fellowship Programme seeks to increase the number of women in the nuclear field, supporting an inclusive and diverse workforce to drive global scientific and technological innovation (IAEA 2023c). The UK also provides a leading example of how Parties are explicitly incorporating specific policies and targets to enhance diversity, gender equality and women's participation in the nuclear sector via government–industry partnership agreements.

20. How are Parties recognizing the importance of ensuring the integrity of all ecosystems, including oceans, and the protection of biodiversity,[16] in order to achieve the purpose and long-term goals of the Paris Agreement?

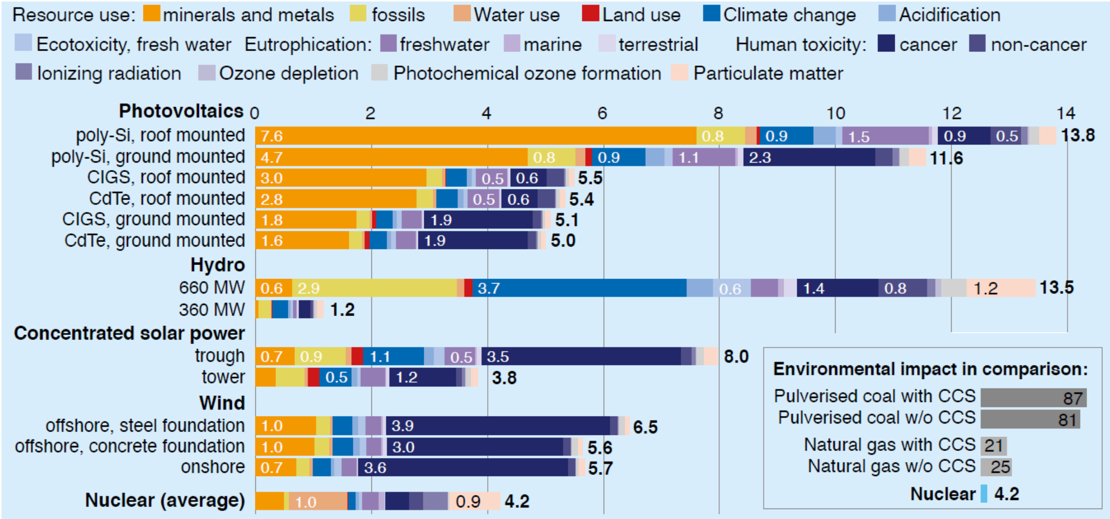
Parties are increasingly recognizing linkages — both synergies and trade-offs — between climate action and other aspects of sustainable development, including protection of ecosystems (incl. oceans) (SDGs 14 and 15). This includes linkages affecting mitigation options for clean energy transitions (IPCC 2022a). To account for such interactions and ensure the integrity of all ecosystems, including oceans, and protect biodiversity, life cycle approaches are increasingly being recognized and applied to develop strategies towards long term energy sector decarbonization (UNECE 2022). Life cycle assessment can account for impacts from the production, operation and disposal of energy technologies across a wide range of environmental and sustainability indictors (for example, eutrophication, acidification and ecotoxicity, distinguishing between impacts on terrestrial, freshwater and marine environments). This is critical to identify and develop strategies to manage or avert potential negative impacts from clean energy transitions on ecosystems and biodiversity, particularly given the relatively large impacts of several clean energy technologies — see Figure 5.

[14] Decision 19/CMA.1, paragraph 36(h).

[15] Preamble of the Paris Agreement.

[16] Preamble of the Paris Agreement.

Figure 5: Normalized and weighted life cycle impacts of renewable and nuclear technologies from production of 1 kilowatt-hour, Europe, 2020



Source: based on data from UNECE (2022). Note: poly-Si, CIGS, and CdTe refer to the type of solar cells.

21. ***In what way are non-Party stakeholders (including subnational governments, indigenous peoples and local communities, youth, non-governmental organizations, international organizations, the private sector, financial institutions and multi-stakeholder initiatives) contributing to the progress made to achieve the purpose and long-term goals of the Paris Agreement?***

As a non-Party stakeholder, the IAEA contributes to the purpose and goals of the Paris Agreement by fostering the efficient, safe, secure and sustainable use of nuclear power by supporting existing and new nuclear programmes around the world, catalysing innovation and building capacity in energy planning, analysis, and nuclear information and knowledge management. The IAEA also carries out climate adaptation and climate monitoring activities, for example through research in its own laboratories and through extended networks of research institutions, academia and reference laboratories. Once vetted, relevant nuclear technologies and techniques are transferred to countries, especially developing countries, through the IAEA Technical Cooperation programme. The TC programme is the IAEA's primary mechanism for helping countries address key development priorities. Over the past decade, the IAEA has supported almost 500 projects related to climate change adaptation in more than 100 countries around the world, disbursing over €110 million in support (IAEA 2022c).

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