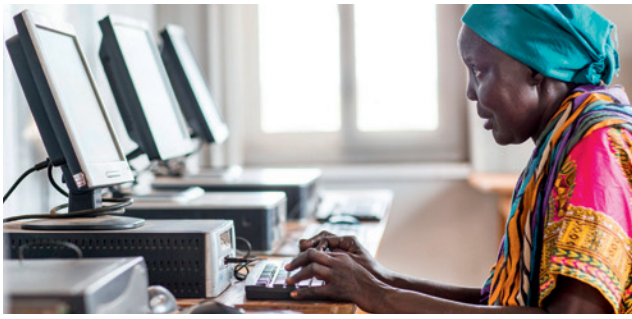
Nuclear Power
and the Paris Agreement



SUSTAINABLE DEVELOPMENT GOALS

IAEA

60 Years

Atoms for Peace and Development

Nuclear Power
and the Paris Agreement

All low-carbon energy technologies, including nuclear power, are needed to meet the Paris Agreement goal of limiting the rise of global temperatures to below 2°C. This paper summarizes the potential role of nuclear power in climate change mitigation and sustainable development.

NUCLEAR POWER AND THE NEW CLIMATE POLICY FRAMEWORK

How can we meet the climate target set by the Paris Agreement?

In November 2015, world leaders came together to agree on firm climate targets[1]: holding the increase in global average temperature from pre-industrial levels to well below 2°C, the threshold at which most experts believe the worst impacts from climate change can still be avoided, and pursue efforts to limit the rise to 1.5°C (Fig. 1).

A first step towards achieving the Paris Agreement goal is for all countries to meet their initial INDC pledges.

The Intended Nationally Determined Contributions (INDCs) submitted in support of the Paris Agreement are aimed at reducing or mitigating greenhouse gas emissions over a span of 10 to 15 years. As of the end of October 2016, 163 INDCs were submitted, representing 190 countries and covering almost 99% of global emissions.

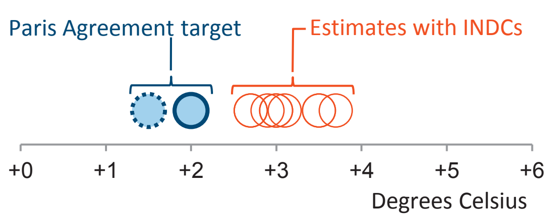


Figure 1. Estimates for global temperature rise with INDCs out to 2100.[2]

However, initial INDCs fall well short of meeting the Paris Agreement targets. Meeting pledges and turning plans into action are only the first steps towards achieving the decarbonization of economies. Continued motivation to increase the efforts to meet the 2°C target is the "ambition" coined in the Agreement. Hence, the Paris Agreement stipulates what is now referred to as the Nationally Determined Contributions (NDC) to be progressively revised every five years starting from 2020.

What does it take to decarbonize the energy sector?

Energy-related emissions make up three-quarters of global greenhouse gases (GHG). Implementing the Agreement thus implies a radical transformation of energy production and usage. Three essential components of any climate strategy are:

1. An across-the-board adoption of energy conservation measures to decrease consumption, particularly of fossil fuels, in every energy end-use and transformation sector;

2. The substitution of fossil fuel-based electricity with low-carbon sources such as nuclear or renewable energy or with fossil fuel power plants equipped with carbon capture and storage (CCS) technology;

3. The electrification of energy use in buildings, industry and transport sectors, whenever possible.

What is the role of nuclear power in current national climate mitigation strategies?

In the INDC submissions, ten countries explicitly listed nuclear power in their national climate strategies, including five countries currently with nuclear power programmes (Argentina, China, India, Islamic Republic of Iran, Japan), two with reactors under construction (Belarus, United Arab Emirates), and three prospective users (Jordan, Niger, Turkey). Driven by its rapidly growing electricity needs, India has the most ambitious nuclear deployment plans, with an eight-fold increase in nuclear capacity relative to current levels, in order to meet their national climate objective. Also, the targets set by China, in its 13th Five Year Plan, pave the way for a five-fold increase in nuclear capacity by 2030 relative to current levels. Additional countries are expected to further define roles for nuclear power in their NDC submissions. In particular, the United States and the European Union are expected to replace some retiring reactors and could add new units to complement other low-carbon measures.

NUCLEAR POWER AS A LOW-CARBON TECHNOLOGY

Is nuclear power a suitable option to address climate change mitigation?

Nuclear power, along with hydropower and wind energy, produces one of the lowest GHG emissions per unit of electricity generated on a life cycle basis (i.e. construction, operation, decommissioning, waste management) (Fig. 2) (IAEA, 2016a).

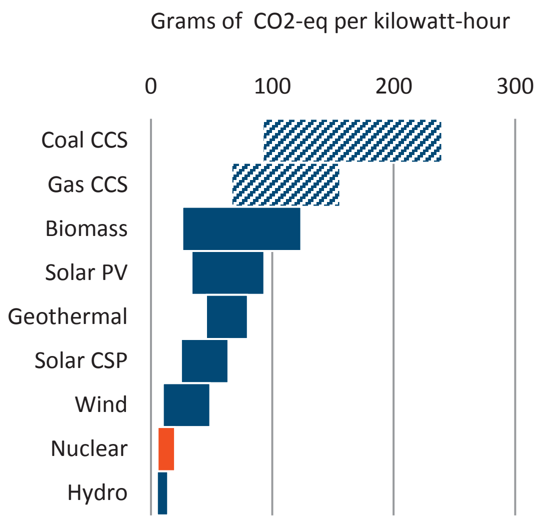


Figure 2. Life cycle greenhouse gas emissions from low-carbon electricity sources.[3]

Nuclear power can be an effective technological option in mitigating climate change, as emphasized in long-term projections by the Intergovernmental Panel on Climate Change and the International Energy Agency. Decarbonization of the power sector also calls on significant use of coal and natural gas with CCS. However, CCS produces higher GHGs emissions than nuclear power and many technical and economic uncertainties remain.

Nuclear power, together with hydropower and wind-based electricity, is among the lowest greenhouse gas emitters.

Whether nuclear power is used to mitigate climate change remains the sovereign right and decision of each country. All countries have the right to use nuclear technology for peaceful purposes, as well as the responsibility to do so safely and securely.

How has nuclear power contributed to low-carbon electricity historically?

Since the 1970s, low-carbon electricity supply has undergone several waves of transformation. The large scale deployment of nuclear capacity in the 1970s and 1980s made nuclear power, along with hydropower, key contributors to low-carbon electricity worldwide (Fig. 3). Nuclear power saves almost 2 billion tonnes of carbon dioxide and other GHG emissions each year and has avoided more than 60 billion tonnes of emissions over the 1970-2015 period. The Fukushima Daiichi nuclear accident in 2011 led to a temporary decline in the number of construction starts on new reactors due in part to public concerns about nuclear safety, in addition to weak economic conditions. Having seen the fastest global deployment in recent years, wind and solar capacity currently accounts for about 4% of global electricity supply.

Presently, total low-carbon supply accounts for only about 30% of electricity worldwide. The pace of investment in low-carbon generation needs to accelerate in order to achieve 100% decarbonized power supply by mid-century to be in line with the 2°C target.

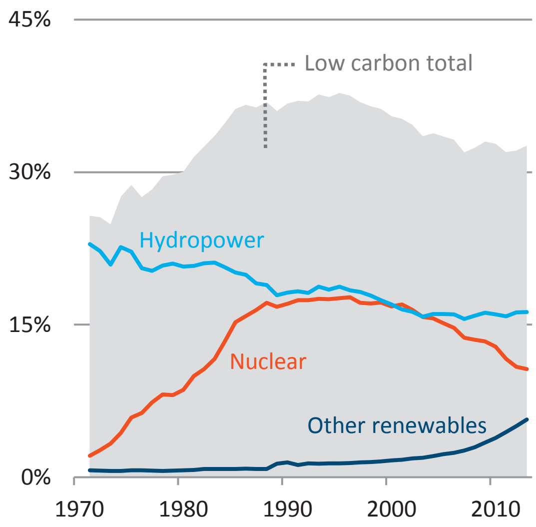


Figure 3. Low carbon electricity generation share in world total generation.[4]

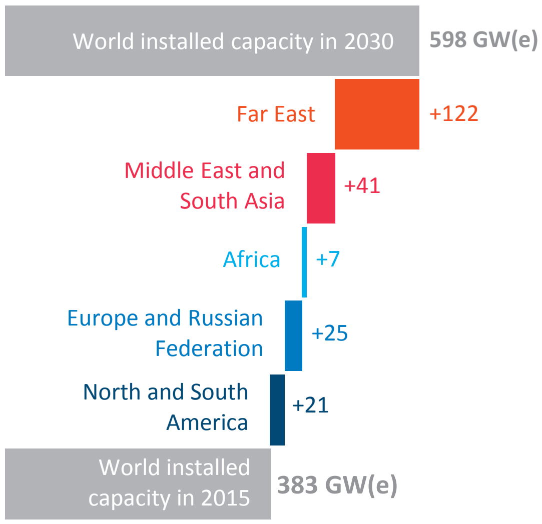


Figure 4. Changes in net installed nuclear capacities by region in 2030 in the IAEA high case, in line with the Paris Agreement 2°C goal (IAEA, 2016b).

THE PROSPECTS OF NUCLEAR POWER

What potential for nuclear power deployment does the IAEA see in the mid-term?

Climate change mitigation is one of the leading reasons for the deployment of nuclear power. The IAEA 2016 high case projection shows nuclear power potentially reaching about 600 GW(e) of net installed capacity by 2030 and about 900 GW(e) by 2050, more than double the current worldwide capacity of 383 GW(e).[5] This level is derived from a country-by-country assessment of development potential, political objectives and orientations as well as anticipated electricity requirements (IAEA, 2016b). The IAEA high case (Fig. 4) broadly follows the nuclear power projections in the 2°C scenario of the International Energy Agency.[6]

The nuclear capacity required to support the Paris Agreement 2°C goal is more than double the current level worldwide.

In the IAEA projections, the Far East will see the biggest expansion, especially in China and the Republic of Korea, while India is leading the expansion in the Middle East and South Asia. There is also sizeable potential for nuclear expansion in the Russian Federation. By contrast, the prospects for new constructions are lower in North America and Western Europe.

The IAEA's high case projection of about 900 GW(e) capacity in 2050 translates into an annual pace of capacity constructions close to the peak seen in the early 1980s. However, this pace would need to be sustained for decades, likely aided by governmental support (IAEA, 2016a).

Is the potential for growth of nuclear power the same across countries?

Drivers for nuclear growth change over time and geographies. Currently, nuclear power provides 32% of the total low-carbon power worldwide, with shares above 50% in the United States and the European Union. Growth of nuclear power is expected in emerging markets, notably China and India, seeking low-carbon alternatives to coal and natural gas-fired power stations, with a joint objective to address acute local pollution. Ongoing development plans in the Russian Federation highlight the key role of nuclear power in low-carbon electricity supply. Moderate nuclear growth in the United States and stagnation in the European Union, together with swift developments in renewable electricity, translate into lower nuclear shares in low-carbon electricity by 2030 (Fig. 5).

Nuclear power can potentially maintain an important share of low-carbon electricity worldwide by 2030.

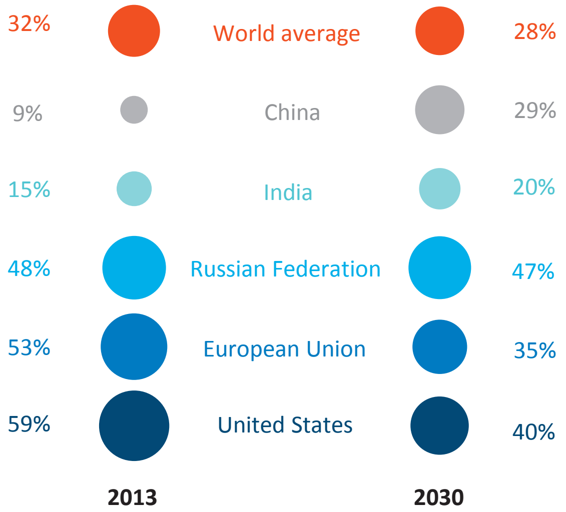


Figure 5. The contribution of nuclear power to low-carbon electricity generation in selected countries in line with the Paris agreement 2°C goal.[7]

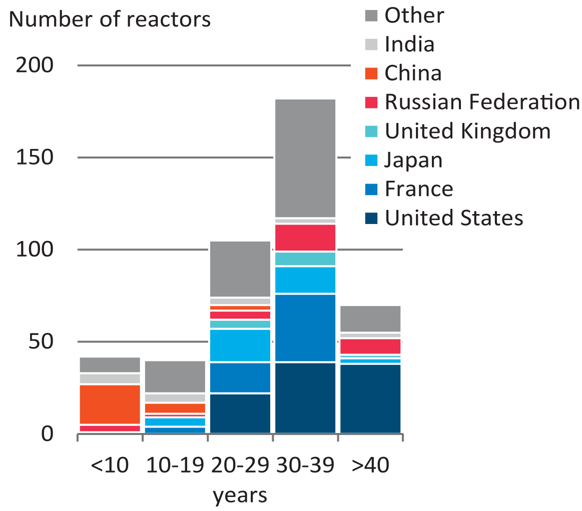


Figure 6. Age distribution of operating nuclear power plants (IAEA PRIS database).[8]

What is the challenge for the existing nuclear fleet?

Although nuclear power has made a significant contribution to avoiding carbon emissions for the past 45 years, the challenge ahead is to keep pace with the demand for low-carbon energy to meet the 2°C goal. Rapid deployment is constrained by long-term planning and construction times as well as industrial production limitations, especially for nuclear power plant components. In terms of unit construction requirements, the challenge is two-fold: replacing retiring units while also ramping up capacity in new markets. Replacing ageing capacity without causing a break or loss in output is a pressing issue for countries with the oldest nuclear power programmes.

Nuclear power made significant contributions to carbon avoidance in the past, but its continued role faces many challenges in supporting the 2°C target.

Almost two thirds of nuclear power plants are more than 30 years old, with 60% of them located in France, Japan and the United States (Fig. 6). Alternatively, nuclear reactors in China account for one third of total capacity less than 20 years old. Assuming licence extensions to 60 years (the United States is even considering further extensions), less than a third of currently installed nuclear capacity would still be operating by mid-century.

Public support plays a key role in any nuclear power programme. The public must be confident that existing plants will continue to operate safely, and that new plants will be held to the highest of safety standards. Importantly, a robust safety culture at nuclear power plants must be maintained through continuous capacity building and open communication with stakeholders. To protect people and the environment from the harmful effects of ionizing radiation, the IAEA helps countries strengthen nuclear safety, emergency preparedness and radiation protection.

THE NEED TO FOSTER LOW-CARBON INVESTMENTS

Do current trends in investments, technological developments and supporting policy measures place us on the right track for a timely transition towards the 2°C goal?

In order to pave the way for a low-carbon economy, countries need to effectively implement their planned strategies and financial commitments into clean energy investments. In 2014, investments in energy efficiency, renewables, nuclear power and carbon capture and storage in the power and industry sectors, reached US$470 billion. US$130 billion were dedicated to energy efficiency, on par with current levels of investments in new coal and natural gas power capacity.

On average, about US$80 billion would need to be invested in nuclear power annually through to 2030 to meet the 2°C goal.

According to the International Energy Agency, by 2030, the transition requires a more than doubling in low-carbon investments, or more than US$1,100 billion invested annually over the 2015–2030 period. Almost two thirds (US$700 billion) of total investments during this period are required annually for the implementation of energy efficiency measures. In other words, the 28% share of energy efficiency investments within total low-carbon investments would need to go up to 62% by 2030. Low carbon power supply makes up for the remaining third of total investments but still amounts to US$400 billion per year. Almost a fifth of this investment (US$80 billion annually) would go towards nuclear power plants. This level triples current levels of nuclear investments and compares with cumulative nuclear investments in China through to 2020 (Fig. 7).

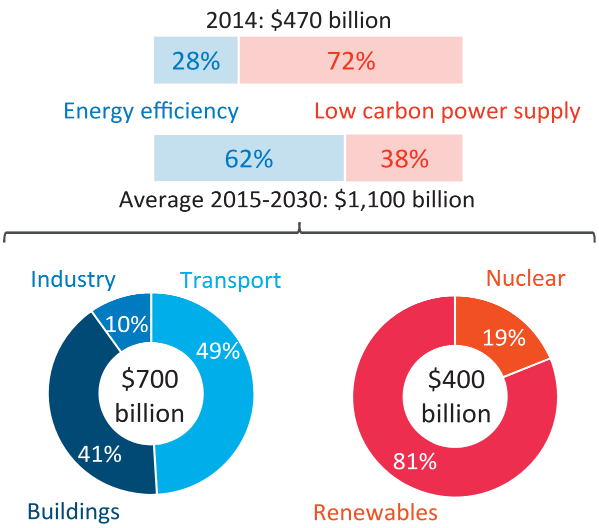


Figure 7. Low carbon capital investments in line with the Paris Agreement 2°C goal.[9]

Where are the investments for full-scale nuclear power deployment being made?

A full-scale deployment of nuclear power would mean the realization of all proposed nuclear projects worldwide by 2030, which would correspond to the IAEA's high projections. Two thirds of nuclear investments are foreseen in fast-growing economies. Driven by considerable need for power and air pollution imperatives, China's nuclear constructions may attract a third of investments during the next decade. In the longer run, policy orientations towards diversification of energy supply in conjunction with decarbonization and economic stimulation strategies may boost the development of nuclear infrastructure programmes in India and other Southeast-Asian countries and potentially in Africa. Those countries may become key recipients of global nuclear investments.

COMPETITIVENESS AND FINANCING OF NUCLEAR POWER

What are the necessary conditions for a competitive nuclear power sector?

A long-term perspective is needed when evaluating investments in nuclear power plants, including the economic and environmental benefits that accrue over the lifetime of a project. Large nuclear power plants have high up-front capital costs and long lead times, which are common to major infrastructure projects such as hydroelectric dams or airports. This makes the economics of nuclear power projects highly dependent on the cost of capital, requiring careful management and allocation of project risks to secure financing at favourable terms. Exposure to market risks can be highly detrimental to project feasibility, and nuclear projects in liberalized markets may require contractual arrangements to remove or significantly reduce such risks. Various financial arrangements are emerging, ranging from government-to-government financing model to loan guarantees, vendor-financing schemes or power purchase agreements (IAEA, 2016c-d).

Investments in nuclear power cannot be short-sighted but must account for the long-term economic and environmental benefits.

Which economic and environmental factors should be considered in comparing energy technologies?

The economics of nuclear power improves significantly when total system costs of different generating technologies are considered. These include not only the generation costs at the plant level but also grid-level and environmental costs. Grid-level costs include the additional investments to extend and reinforce transport and distribution grids, to connect new capacity to the grid. They also include the cost for increased short-term balancing and for maintaining long-term adequacy of electricity supply in face of variable renewables. These are real monetary costs that are incurred by producers, consumers and transport grid operators. A comprehensive assessment of the economics of generation technologies would also factor in environmental aspects or effects on the wider economy.

Which instruments and market mechanisms could support nuclear competitiveness? What is the role of carbon pricing?

The Paris Agreement establishes an international policy framework that is expected to create more favourable and predictable conditions for low-carbon investments. For an effective transition to a low-carbon economy, it is essential that consumer prices reflect any environmental damage caused. Possible solutions include progressively removing government support to high-carbon consumption and production, and putting a price on carbon emissions.

Carbon prices would improve the economics of nuclear power.

A careful implementation of carbon pricing mechanisms encourages polluters to reduce emissions in favour of low-carbon alternatives. Carbon pricing can compensate for cheap fossil fuel electricity generation that deter renewable and nuclear power operations. Almost half of INDCs submitted to date mention the reliance on carbon markets.[10] Initiatives such as the Carbon Pricing Leadership Coalition, which brings together governments, businesses and civil society groups, are gaining momentum.

In the Paris Agreement, domestic policies and carbon pricing are recognized as important factors in advancing emission reductions. In addition, a new market mechanism currently under negotiation would create linkages between various climate mitigation measures.

Would ambitious climate action facilitate the financing of nuclear power?

The Paris Agreement and subsequent negotiations may give rise to innovative and more secured financing schemes at competitive terms. Most importantly, governmental action to timely implement domestic climate strategies will provide investors with clear incentives to scale up their low-carbon projects, which could improve the financing of nuclear power projects.

What is the role for nuclear technology innovation in climate change mitigation?

Innovation is essential to foster the deployment of more affordable and more sustainable low-carbon technologies. For nuclear power, advancements can improve performance and safety and can help extend the operation life of reactors. Currently, nuclear power mainly supplies electricity, but innovation opens up additional areas to contribute to emission reduction, including non-electric applications such as desalination, process heat and energy storage. The Paris Agreement provides a platform for enhanced technological innovation and supports cooperation as well as knowledge transfer. There are many opportunities for innovation to advance nuclear energy in addressing climate change, including new reactor designs such as small modular reactors (IAEA, 2016e) and advanced fuel cycles. Some designs for innovative nuclear plants exist and many others are in development. However, more investment in research, development and demonstration is needed.

NUCLEAR POWER AND THE SUSTAINABLE DEVELOPMENT AGENDA

How does nuclear power contribute to the Sustainable Development Agenda?

In addition to the Paris Agreement, the year 2015 saw the adoption of the United Nations resolution *Transforming our world: the 2030 Agenda for Sustainable Development.* This Agenda calls on countries to begin efforts to achieve 17 Sustainable Development Goals (SDGs) over the next 15 years, focusing on five elements: people, planet, peace, prosperity and partnership. Taking urgent action to combat climate change and its impacts is at the heart of the overall sustainable development vision.[11] Meeting the Paris Agreement goal would contribute to the economic, environmental and social benefits that will help meet every other SDG, particularly in African countries (IAEA, 2015, 2016f).

Nuclear power can contribute to the achievement of multiple sustainable development goals.

Nuclear power is not only an important source of electricity; it contributes to many of the sustainable development goals (Fig. 8). Constructing and operating nuclear plants helps stabilize electricity prices, thus moderating electricity bills for households and businesses. It creates jobs, boosts the local economy and produces no local air pollution. For a number of sustainable development indicators, nuclear power compares favourably with other power generation technologies (IAEA, 2016g). Beyond the power generation domain, nuclear science and technologies can also help address multiple SDGs and offer enormous benefits in many areas of our lives, including medicine, food and clean water production.

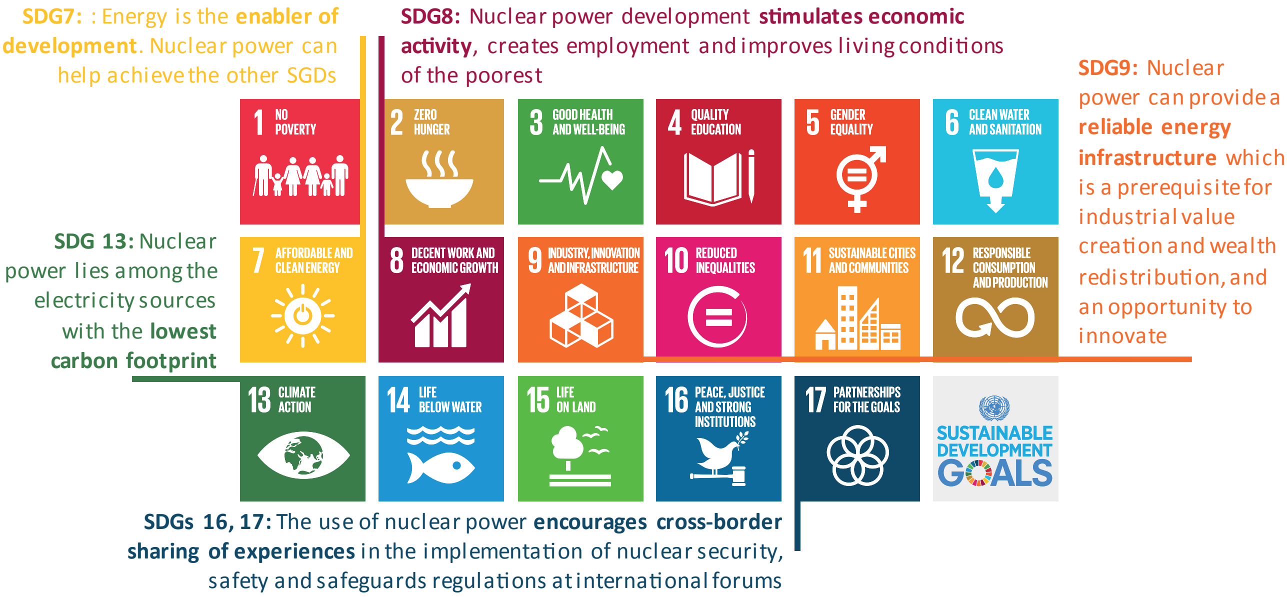


Figure 8. Focus areas for nuclear power in helping to achieve the UN 2030 Agenda for Sustainable Development Goals.

Nuclear power is a large-scale, low-greenhouse gas energy source that can continue to make a significant contribution to the Paris Agreement 2°C goal and the UN Sustainable Development Goals. To tap the full potential of nuclear energy, significant capital investments are needed. However, deployment is hindered by high capital costs, unfavourable market and finance conditions, and public concerns. The Paris Agreement's impetus for economies to decarbonize should create a favourable environment for nuclear power expansion. Countries that opt for nuclear power can detail its role in their future Nationally Determined Contribution submissions.

To learn more about the role of nuclear power in climate change mitigation, please see:

https://www.iaea.org/OurWork/ST/NE/Pess/

IAEA (2015), *Indicators for Nuclear Power Development*, IAEA Nuclear Energy Series No. NG-T-4.5, STI/PUB/1712, November 2015, IAEA, Vienna.

IAEA (2016a), *Climate Change and Nuclear Power*, IAEA, Vienna.

IAEA (2016b), *Energy, Electricity and Nuclear Power Estimates for the Period up to 2050*, Reference Data Series, No. 1, IAEA, Vienna.

IAEA (2016c), *Managing the Financial Risk Associated with the Financing of New NPP Projects*, IAEA, Vienna.

IAEA (2016d), *Impacts of Electricity Market Reforms on the Choice of Nuclear and Other Generation Technologies*, TECDOC-1789, May 2016, IAEA, Vienna.

IAEA (2016e), *Advances in Small Modular Reactor Technology Developments A Supplement to: IAEA Advanced Reactors Information System (ARIS)*, 2016 Edition, IAEA, Vienna.

IAEA (2016f), *Sustainable Electricity Supply Scenarios for West Africa*, TECDOC-1793, June 2016, IAEA, Vienna.

IAEA (2016g), *Nuclear Power and Sustainable Development*, IAEA, Vienna.

Endnotes

1 Source: United Nations Framework Convention on Climate Change, Paris (2015), *Adoption of the Paris Agreement,* Document FCCC/CP/2015/L.9/Rev.1.

2 Source: Adapted from World Resources Institutes (2015), *INSIDER: Why Are INDC Studies Reaching Different Temperature Estimates?, WRI, Washington, D.C.*

3 Note: CCS: Carbon dioxide Capture and Storage; PV: Photovoltaics; CSP: Concentrating Solar Power.

4 Other renewables include bioenergy, geothermal, wind, solar, ocean and fuel cells energy source. Source: International Energy Agency (IEA) (2015), *Electricity Information,* OECD/IEA, Paris.

5 The IAEA projects about 900 GW(e) of net installed capacity by 2050 in the high estimate. Alternatively, a conservative IAEA Low estimate assumes a lack of incentives for a large scale deployment and only maintains global installed capacity to current levels by 2030.

6 IEA (2016), *Energy Technology Perspectives,* OECD/IEA, Paris.

7 Sources: 2013 data: IEA (2015), *Electricity Information.* 2030 data: IEA 450 Scenario; IEA (2015), *World Energy Outlook,* OECD/IEA, Paris.

8 Sources: IAEA (2016), based on IAEA PRIS database https://www.iaea.org/pris/; IAEA (2016), *Energy, Electricity and Nuclear Power Estimates for the Period up to 2050, Reference Data Series No. 1*, IAEA, Vienna.

9 Sources: IAEA (2016), *Climate Change and Nuclear Power*, IAEA, Vienna. 2030 data: IEA 450 Scenario, IEA (2014), *World Energy Investment Outlook,* OECD/IEA, Paris; IEA (2015), *World Energy Outlook,* OECD/IEA, Paris.

10 Environmental Defence Fund, International Emission Trading Association (2016), *Carbon Pricing, The Paris Agreement's Key Ingredient, EDF-IETA, New York.*

11 In a 1 March 2016 address to the United Nations Association - UK, the United Nations Secretary General Ban Ki-moon stressed: "One important cross-cutting element of the SDGs is the need to combat climate change. The subject of its own Goal 13, climate action is also directly or indirectly related to realising almost all the other goals." http://www.sustainablegoals.org.uk/the-peoples-agenda/

440+

reactors in operation

11%

of world's electricity

>30%

of world's low-carbon electricity

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