EUROPEAN
COMMISSION

Brussels, 4.4.2016
COM(2016) 177 final

COMMUNICATION FROM THE COMMISSION

Nuclear Illustrative Programme

presented under Article 40 of the Euratom Treaty for the opinion of the European Economic and Social Committee
{SWD(2016) 102 final}

1. INTRODUCTION

This Communication on a Nuclear Illustrative Programme (PINC), a requirement under Article 40 of the Euratom Treaty, provides an overview of investments in the EU for all the steps of the nuclear lifecycle. It is the first presented by the Commission after the Fukushima Daiichi accident in March 2011.

Nuclear energy is part of the energy mix of half of the EU Member States. In those countries that chose to use it, nuclear has a role to play in ensuring the security of electricity supply. In this context, the Energy Union Strategy[1] and the European Energy Security Strategy[2] stressed that Member States need to apply the highest standards of safety, security, waste management and non-proliferation as well as diversify nuclear fuel supplies. Doing so will help achieve the objectives of the 2030 climate and energy framework.

With 27% of electricity produced from nuclear energy and 27% from renewable sources[3], the EU is currently one of the three major economies[4] that generate more than half of their electricity without producing greenhouse gases.

The PINC provides a basis for discussing how nuclear energy can help achieve the EU's energy objectives. As nuclear safety remains the Commission's absolute priority, it specifically includes investments related to post-Fukushima safety upgrades and those related to the long-term operation of existing nuclear power plants. In addition, with the EU nuclear industry moving into a new phase characterised by increased activities in the back-end of the lifecycle, it will contribute to an informed debate on the associated investment needs and the management of nuclear liabilities.

The PINC also addresses issues related to investment in research reactors and the associated fuel cycle, including the production of medical radioisotopes.

2. NUCLEAR ENERGY

2.1. Recent nuclear policy developments

There are 129 nuclear power reactors in operation in 14 Member States, with a total capacity of 120 GWe and an average age close to 30 years. New build projects are envisaged in 10 Member States, with four reactors already under construction in Finland, France and Slovakia. Other projects in Finland, Hungary and the United Kingdom, are under licensing process, while projects in other Member States (Bulgaria, the Czech Republic, Lithuania, Poland and Romania) are at a preparatory stage. The United Kingdom has recently announced its intention to close all coal-fired power plants by 2025 and to fill the capacity gap mainly with new gas and nuclear power plants.

Many countries in Europe and in the rest of the world will rely on nuclear energy to produce part of their electricity for the coming decades. The EU has the most advanced legally binding and enforceable regional framework for nuclear safety in the world and, despite diverging views among Member States on nuclear electricity, a shared recognition exists of the need to ensure the highest possible standards for the safe and responsible use of nuclear power and the protection of citizens from radiation.

---

[1] COM(2015)80
[2] COM(2014)330
[3] Eurostat, May 2015
[4] The others are Brazil and Canada

Since the previous PINC update in 2008, the EU nuclear landscape has undergone significant changes with the organisation of the comprehensive risk and safety assessments (*stress tests*) of the EU nuclear power reactors after the Fukushima Daiichi accident and the adoption of landmark legislation on nuclear safety[5], radioactive waste and spent fuel management[6] and radiation protection[7].

While the *stress tests* found that the safety standards of nuclear power plants in the EU, Switzerland and the Ukraine were high, further improvements were recommended. Nuclear operators are implementing them in accordance with their national action plans as assessed by ENSREG.

The amended Nuclear Safety Directive[5] brings the nuclear safety standards to a higher level. It sets a clear EU-wide objective to reduce the risk of accidents and avoid large radioactive releases. It also introduces the requirement for a European system of peer reviews, with specific safety issues to be reviewed every six years. These requirements must be always taken into account when investing in new nuclear installations and wherever reasonably practicable when upgrading existing installations.

In early 2015, Euratom played a key role in ensuring the adoption of the "Vienna declaration". This commits the contracting parties of the International Atomic Energy Agency Convention on Nuclear Safety to achieving standards of safety comparable to those laid down in the amended Nuclear Safety Directive. With the expansion of nuclear energy across all continents and with many vendors coming into play, it is important to ensure that high safety standards are applied worldwide and these are not undermined by the use of cheaper or outdated technology.

The EU legal framework requires increased transparency and public participation in nuclear issues, as well as improving cooperation between all stakeholders. The directives on nuclear safety, radioactive waste and radiation protection referred to above all lay down requirements on availability of information and public participation. Cooperation among the nuclear safety authorities of EU Member States is now well in place through the European Nuclear Safety Regulators Group. In addition, the Commission will continue to promote the dialogue between stakeholders in the European Nuclear Energy Forum.

2.2. EU nuclear market and main developments

The EU nuclear energy market needs to be examined in the global context, given the potential impact of developments in other regions on the EU nuclear industry, global safety, security, health and on public opinion. Cooperation should be further enhanced with the EU candidates and neighbourhood countries, in particular Ukraine, Belarus, Turkey and Armenia. Safety stress tests have already been conducted in Ukraine, are to be completed in Armenia in 2016 and are planned in Belarus and Turkey.

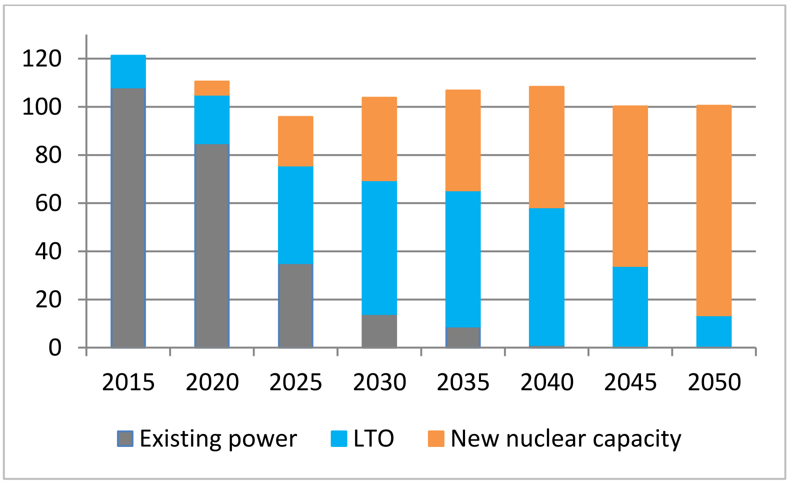
The EU nuclear industry has developed into a global technology leader in all nuclear industry segments and directly employs between 400 000 and 500 000 persons[8], while facilitating around 400 000 additional jobs[9]. Such leadership can be an important asset worldwide. Nuclear-related investment needs in the global market are estimated at around EUR 3 trillion

[5] OJ L 219, 25.7.2014, p. 42–52
[6] OJ L 199, 2.8.2011, p. 48–56
[7] OJ L 13, 17.1.2014, p. 1-73
[8] SWD(2014)299
[9] http://ec.europa.eu/research/energy/euratom/publications/pdf/study2012_synthesis_report.pdf

by 2050[10], with the majority expected in Asia. The number of countries operating nuclear power reactors and the global nuclear installed capacity is expected to increase by 2040. China's nuclear installed capacity alone is projected to increase by 125 GWe, a value higher than the current capacity in the EU (120 GWe), the United States (104 GWe) and Russia (25 GWe).

The Commission predicts a decline in nuclear generation capacity at EU level up to 2025, taking into account the decisions of some Member States to phase out nuclear energy or to reduce its share in their energy mix[11]. This trend would be reversed by 2030 as new reactors are predicted to be connected to the grid and the life time extensions of others will be pursued. Nuclear capacity would increase slightly and remain stable at between 95 and 105 GWe by 2050[12] (Figure 1). Since electricity demand is expected to increase over the same period, the share of nuclear electricity in the EU would fall from its current level of 27% to around 20%.

Figure 1 - Total EU nuclear capacity (GWe)



Capacity replacement investment up to 2050 will most likely be in the most advanced reactors, such as EPR, AP 1000, VVER 1200, ACR 1000 and ABWR.

3. NUCLEAR INVESTMENT TOWARDS 2050

Significant investments will be needed to support the transformation of the energy system in line with the Energy Union Strategy. Between EUR 3.2 and EUR 4.2 trillion will need to be invested in the EU energy supply between 2015 and 2050[13].

Under Article 41 of the Euratom Treaty, new nuclear investment projects must be notified to the Commission. Since 2008 a total of 48 projects have been notified. Nine were for facilities dedicated to front-end activities, 20 for major modifications or upgrades in nuclear power plants related to long term operations or to post Fukushima improvements, seven for new commercial or research reactors and 12 for back-end installations. All

[10] Source: Nuclear Energy Agency and International Energy Agency, 2015 (USD 1 = EUR 0,75)
[11] Such as the decision of Germany and the new French energy transition law
[12] Estimate within the range of the analysis performed by the Commission during the preparation of the 2030 Climate and energy framework. See SWD(2014)255 and SWD(2014)15
[13] SWD(2014)255. This includes power grid investment, investment in power plants (including electricity and CHP) and steam boilers. All figures in this Communication are expressed in constant values unless stated otherwise.

projects received a non-binding Commission opinion, providing the Member State with comments and/or suggestions for improvements to be taken into account when authorising the projects. Particular attention was paid to safety, waste management, safeguards, and security of supply issues.

Later this year the Commission will propose an update and better definition of the requirements for these notifications which, together with the Recommendation on the application of Article 103 of the Euratom Treaty, will strengthen the ability of the Commission for ensuring that new investments and bilateral agreements with third-countries in the field of nuclear energy comply with the provisions of the Euratom Treaty and reflect the most recent security of supply considerations.

3.1. Investments in the front end of the fuel cycle

The process of fabricating fuel (front end of the fuel cycle) includes different steps from uranium ore exploration and mining to fabrication of fuel assemblies.

While uranium mining activities are limited in the EU, abundant uranium resources are available worldwide. European companies rank among the world's major producers of nuclear fuel.

EU demand for natural uranium represents approximately one third of the world demand and is obtained from a diversified range of suppliers. Kazakhstan (27%) was the main supplier in 2014, followed by Russia (18 %), and Niger (15 %). Australia and Canada accounted for 14 % and 13 % respectively.

In accordance with the European Energy Security Strategy, the Commission is taking actions to ensure a well-functioning internal market for nuclear fuels and to further enhance security of supply. The Euratom Supply Agency (ESA) continuously assesses these matters in its decisions on supply contracts, with particular attention to new build projects.

While some companies offer integrated packages with services spanning the nuclear fuel cycle, the Commission will ensure that this ability will not act as a barrier to other companies that operate in a single segment of the nuclear cycle, as this would limit competition in the market.

Major investments in conversion and enrichment capabilities have been done in the past, and the focus in the coming years will be put in modernising them in order to maintain the EU technological leadership. Regarding the fabrication of nuclear fuel, the EU-based capacity would be able to cover all its needs for western-design reactors, whereas developing and licensing fuel assemblies for Russian design reactors would take a few years (provided that a sufficient market is available to make the investment attractive for the industry). The Commission will continue to monitor the front end of the fuel cycle and use all instruments available at its disposal to ensure security of supply in the EU, diversification and global competition.

3.2. Investments and business environment for new nuclear power plants

All Member States operating nuclear power plants are investing in safety improvements. Due to the average age of the EU nuclear fleet, several Member States are also faced with policy decisions on the replacement or the long term operation of their nuclear power plants.

As shown in Figure 1, without long term operation programs around 90% of the existing reactors would be shut down by 2030, resulting in the need to replace large amounts of capacity. When Member States decide to proceed with the long term operation of reactors, national regulatory approval and safety upgrades are needed to ensure compliance with the Nuclear Safety Directive. Whichever options Member States chose, 90% of the existing nuclear electricity production capacity will need to be replaced by 2050.

Maintaining a nuclear generation capacity of between 95 and 105 GWe in the EU until 2050 and beyond would require further investments over the next 35 years. Between EUR 350 and 450 billion would have to be invested in new plants to replace most of the existing nuclear power capacity. Since new nuclear power plants are designed to operate for at least 60 years, these new plants would generate electricity until the end of the century.

A number of factors influence the availability of finance for investments in new nuclear capacity. For the two main cost components, overnight cost[14] and financing cost, the expected construction time and the project discount rate play a big role.

Different financing models are being examined or used in several EU Member States, such as the Contract for Difference[15] scheme proposed for the Hinkley Point C project in the UK or the Mankala model[16] proposed for the Hanhikivi project in Finland.

Some new, first of a kind projects in the EU have experienced delays and cost overruns. Future projects using the same technology should benefit from the experience gained and cost-reduction opportunities, provided that an appropriate policy is established.

This policy should focus on enhancing cooperation between regulators when **licensing** new reactors and on encouraging **standardisation** of nuclear reactor designs by the industry. In addition to cost efficiency, this would help make new nuclear power plants safer.

The **licensing** process, while being the exclusive competence of national safety regulators, presents opportunities for enhanced cooperation, e.g. in the pre-licensing steps or in design certification.

The aim of collaboration on licensing requirements should be to ensure that a design that is considered safe in one country does not have to be substantially modified to meet licensing requirements elsewhere, therefore reducing time and costs. In this area the Commission intends to consult the European Nuclear Safety Regulators Group and the European Technical Safety Organisations Network.

On **standardisation**, construction codes are used as a common reference by all actors involved in the design and construction of power plants and other nuclear facilities[17]. Given the emergence of potential new vendors and the need to ensure control of any new model/technology, it would be beneficial to encourage vendors and suppliers to engage in an initiative to standardise to a higher degree their components and codes in order to ensure (a) faster procurement process; (b) higher comparability and more transparent and higher safety standards; (c) increased capacity of operators to control technology and knowledge management. Given the emphasis on optimising the use of existing resources

---

[14] The overnight construction costs include: construction, major equipment, instrumentation and control, indirect costs and owners cost

[15] Contracts for difference entail a variable Premium in view of the market price for electricity

[16] An agreement similar to the cooperative system of undertaking known in other European countries. This model operates on a zero-profit basis; the shareholders receive a relative share of the electricity produced by the nuclear power plant at cost price

[17] This includes suppliers of the technology, architects, engineers, operators, as well as inspectors and safety authorities

as well as on mutual recognition to open up more opportunities, the Commission is closely following the work of the European Committee for Standardization to see what potential policy options are needed at EU level.

3.3. Investments and business environment related to safety upgrades and the long term operation of existing nuclear power plants

In order to continuously improve nuclear safety, regular efforts are made to increase the robustness of nuclear power plants, especially following specific reviews, periodic safety reviews or peer reviews such as the EU stress tests.

Many operators in Europe have expressed their intention to operate their nuclear power plants longer than foreseen by their original design. From a nuclear safety point of view, continuing to operate a nuclear power plant requires two things: demonstrating and maintaining plant conformity to the applicable regulatory requirements; and enhancing plant safety

In the light of information provided by Member States, an estimated EUR 45-50 billion will have to be invested in the long term operation of existing reactors by 2050. The related investment projects will need to be communicated to the Commission in accordance with Article 41 of the Euratom Treaty on which the Commission will issue its views.

Depending on the model and age of the reactor, national regulators assume that granting long term operation programs will mean extending lifetime by 10 to 20 years on average.

Utilities and regulatory bodies need to prepare, review and approve the safety cases associated with these plans in accordance with the amended Nuclear Safety Directive. Enhancing cooperation among the regulators in the licensing processes, for example by setting common criteria, will help ensure an adequate and timely response to the challenge.

3.4. Increased activities in the back-end of the fuel cycle: challenges and opportunities

The back-end of the fuel cycle will need increasing levels of attention. It is estimated that more than 50 of the 129 reactors currently in operation in the EU are to be shut down by 2025. Careful planning and enhanced cooperation among Member States will be needed. Politically sensitive decisions will have to be taken by all EU Member States operating nuclear power plants regarding geological disposal and long-term management of radioactive waste. It is important not to postpone actions and investment decisions on these issues.

3.4.1. Spent fuel and radioactive waste management

The Spent Fuel and Radioactive Waste Directive establishes legally binding requirements for the safe and responsible long-term management of radioactive waste and spent fuel, with the objective of avoiding undue burdens on future generations.

Each Member State remains free to define its fuel cycle policy. The spent fuel can be regarded either as a valuable resource that may be reprocessed or as radioactive waste that is destined for direct disposal. Whatever option is chosen, the disposal of high-level waste, separated at reprocessing, or of spent fuel regarded as waste should be addressed.

France and the United Kingdom have reprocessing facilities in operation, although the later has decided to shut it down by 2018. A number of reactors in Germany, France and the Netherlands used Mixed oxide (MOX) fuel during 2014.

Disposal facilities for low-level and intermediate-level radioactive waste are already in place in most Member States. Operators are moving from research to action with the construction of the world's first geological disposal facilities for high-level waste and spent fuel. These facilities are expected to become operational in Finland, Sweden and France between 2020 and 2030. Other European companies should take advantage of this expertise in order to consolidate the required skills and know-how and develop commercial opportunities at global level.

There is scope for cooperation between Member States, including by sharing of best practices or even through shared repositories. Whereas shared repositories are legally possible under the Directive, several issues remain to be solved, in particular communicating with the public and building public acceptance. Determining the ultimately responsible actor for the radioactive waste to be disposed of in a multinational approach is also a critical step.

Member States operating nuclear power plants currently use facilities for storing waste for between 40 and 100 years. However, the storage of radioactive waste, including long-term storage, is an interim solution and not an alternative to disposal.

3.4.2. Decommissioning

Worldwide there is little experience in decommissioning power reactors. There are 89 nuclear power reactors permanently shut down in Europe as of October 2015, but only 3 reactors have so far been completely decommissioned[18] (all in Germany).

European companies have the opportunity to become global leaders by developing the required skills in the domestic market, which includes measures to encourage the participation of SMEs. The use of best practices in the different stages of the decommissioning process – such as the use of a graded approach allowing the regulatory situation to evolve as to appropriately reflect the radiological hazard levels throughout the process – would bring efficiency and safety improvements. Best practices could be promoted by creating a European centre of excellence, bringing together public and private actors, or be established under the Decommissioning Funding Group.

3.4.3. Funding requirements for spent fuel, radioactive waste management and decommissioning

The Spent Fuel and Radioactive Waste Directive recognises that operators are fully responsible for the management of radioactive waste from generation through to final disposal. Funding has to be accumulated by the operators from the early years of operation and be ring-fenced to mitigate the risk of financial liabilities for governments to the extent possible. Member States guarantee this principle by establishing and maintaining national programmes that include, among other things, an assessment of the costs and the applicable financing scheme.

Based on the latest information provided by Member States,[19] in December 2014 European nuclear operators estimated that EUR 253 billion will be needed for nuclear decommissioning and radioactive waste management until 2050, with EUR 123 billion for decommissioning and EUR 130 billion in spent fuel and radioactive waste management, as well as deep geological disposal.

Member States have also provided data on assets backing these expected investments, which

[18] This means releasing the site from regulatory control

[19] Questionnaires sent to the members of the Decommissioning Funding Group, as well as National Programmes submitted under Directive 2011/70/Euratom, where available

amounted to approximately EUR 133 billion. Typically, these assets are collected in dedicated funds, often combined for decommissioning and radioactive waste management. The most frequently used method to collect funds is a fixed contribution based on the electricity produced by the relevant nuclear power plants.

Member States apply different methods to estimate the costs of completing the back-end activities of the nuclear fuel cycle. The Commission will continue collecting additional data with the help of the Decommissioning Funding Group, and later in 2016 intends to draw up a report on the implementation of the Radioactive Waste and Spent Fuel Directive.

4. NON-POWER APPLICATIONS

Nuclear and radiation technologies have many applications in the medical sector, industry, agriculture and research, with substantial benefits to society in all Member States.

More than 500 million diagnostic procedures using x-rays or radioisotopes are carried out in Europe each year and more than 700 000 European healthcare workers use nuclear and radiation technology on a daily basis. There is a substantial European market for medical imaging equipment, worth more than EUR 20 billion and enjoying annual growth rates of about 5%.

Different types of research reactors are operated in the EU. They are used for material and nuclear fuel testing, as well as basic research and development. Some also produce medical radioisotopes for the diagnosis and treatment of various diseases, including cancers, cardiovascular and brain disorders. Over 10 000 hospitals worldwide use radioisotopes for the *in vivo* diagnosis or treatment of about 35 million patients every year, of which nine million are European.

Europe is the second largest consumer of technetium-99m (Tc-99m), the most widely-used diagnostic radioisotope. Several European research reactors involved in the production of medical radioisotopes are approaching the end of their lifespan, with the supply of medical radioisotopes becoming more fragile and leading to some severe shortages.

Actions have recently been undertaken to coordinate the operation of research reactors, in the European Union and abroad, and minimise interruptions in radioisotope production, for example, the establishment in 2012 of the European Observatory on the Supply of Medical Radioisotopes.[20] Despite these efforts, the issue of medical radioisotope capacity, especially in Europe, still requires full consideration by all stakeholders, as it is essential to ensure key medical diagnosis and treatments in the European Union.

The Commission considers that there is a need for a more coordinated European approach to the non-power uses of nuclear and radiation technology.

5. MAINTAINING EU TECHNOLOGY LEADERSHIP IN THE NUCLEAR DOMAIN THROUGH FURTHER RESEARCH AND DEVELOPMENT ACTIVITIES

The EU must maintain its technological leadership in the nuclear domain, including through the International Thermonuclear Experimental Reactor (ITER),[21] so as not to increase energy

[20] http://ec.europa.eu/euratom/observatory_radioisotopes.html

[21] The International Thermonuclear Experimental Reactor is a large-scale scientific experiment that aims to demonstrate the technological and scientific feasibility of fusion energy being built in France. It is an international collaborative effort between the EU, China, India, Japan, South Korea, Russia and the USA.

and technology dependence, and to give business opportunities for European companies. This will in turn support EU growth, jobs and competitiveness.

The recent Communication for a new Strategic Energy Technology Plan (SET-Plan)[22] further details that the priority for nuclear energy is to support the development of the most advanced technologies to maintain the highest level of safety in nuclear reactors and to improve the efficiency of operation, the back-end of the fuel cycle and decommissioning.

Ongoing Euratom research initiatives include:

- The implementation of the European Sustainable Nuclear Industrial Initiative[23] which aims to prepare the future deployment of the generation IV nuclear system relying on fast neutron technology with a closed fuel cycle. Several reactors are in the research stage (e.g. ALLEGRO, ALFRED, MYRRHA and ASTRID), which may already advance significantly by 2050.

- Research on the safety of small modular reactors, the advantages of which include reduced construction time due to high modularity and integrated design. The United Kingdom has recently announced plans to invest in the development of small modular reactors.

- Support for careers in the nuclear field. It is crucial to develop and maintain appropriate knowledge and expertise in nuclear energy through continuous training and education.

6. CONCLUSION

As a low carbon technology and a significant contributor to security of supply and diversification, nuclear energy is expected to remain an important component of the EU's energy mix in the 2050 horizon.

For those Member States choosing to use nuclear, the highest standards of safety, security, waste management and non-proliferation have to be ensured across the whole fuel cycle. It is crucial to ensure the swift and thorough implementation of the legislation adopted post-Fukushima. Cooperation among national regulators for licensing and general oversight is seen as beneficial.

The nuclear fleet in Europe is aging and significant investments are needed where Member States opt for a lifetime extension of some reactors (and related safety improvements), for the expected decommissioning activities and for the long-term storage of nuclear waste. Investments are also needed in replacing existing nuclear plants, which could partly also go to new nuclear plants. The total estimated investments in the nuclear fuel cycle between 2015 and 2050 are projected to be between EUR 650 and 760 billion[24].

Finally, the fast development of the use of nuclear energy outside the EU (China, India, etc.) also calls for keeping our global leadership and excellence in the technological and safety areas, for which continuous investment in research and development activities will be essential.

[22] COM(2015)6317.

[23] This initiative is included within the Sustainable Nuclear Energy Technology platform (SNETP).

[24] See details in the Staff Working Document.