Position Paper

FORATOM
THE VOICE OF THE EUROPEAN NUCLEAR INDUSTRY

FORATOM position regarding the EC PINC Communication 2015 – a forward look on investment needs in the nuclear sector

The European Atomic Forum (FORATOM) is the Brussels-based trade association for the nuclear energy industry in Europe. The membership of FORATOM is made up of 16 national nuclear associations. Through these associations, FORATOM represents nearly 800 European companies working in the industry and supporting around 800,000 jobs.

1. Introduction

Following the Energy Union Communication of February 2015, the European Commission has committed itself to produce a new Nuclear Indicative Programme (PINC) by the end of 2015. FORATOM wishes to contribute with this position paper with views from its members on the most relevant issues to be taken into consideration.

The EURATOM Treaty sets out the requirement (in Article 40) for the European Commission to periodically publish indicative targets and programmes for nuclear production and the corresponding investment required. Since the last such publication in 2007 (updated in 2008), the situation for nuclear power, both within the EU and globally, has changed considerably. The financial crisis has restricted the ability of industry to invest in any large infrastructure projects, including in nuclear power plants; the Fukushima nuclear accident shook public confidence, albeit temporarily in most countries, but has had lasting political effects in others and has led to delays in starting new construction projects as well as to shrinkage of the nuclear fuel market. On the other hand, the Ukraine situation has reminded many States of the value of nuclear power for security of energy supply, and the developing world eyes nuclear power as an important contributor towards less reliance on fossil fuels and consequent reductions in GHG emissions. There are currently more nuclear power plants under construction around the world than there have ever been.

Nuclear power is affirmatively a low carbon source of electricity. A partnership between nuclear and renewables makes perfect sense if we are to decarbonise the bulk of the EU's economy by 2050, as agreed by Council. Nuclear is the low carbon baseload technology that can replace high CO_2 emitting that compromise the EUs commitment to decarbonising its economy. Closing down nuclear power plants only to have to replace them with other low-carbon sources is like walking uphill in the sand. Therefore the EU should maintain at least the current capacity of nuclear generation up to and beyond 2050.

In order to achieve this, major investments will be required in nuclear new build, longterm operation, safety upgrades, and the associated fuel cycle operations, as well as in decommissioning and waste management. Although detailed cost estimates are not always available, this report attempts to give an overview of the types of investment required and their order of magnitude, at the same time setting out the rationale for going ahead with these investments. Finally, some indications are provided as to the new EU electricity market design principles that would help to motivate the investors, just as are needed for all low-carbon generation projects with low marginal but high up-front capital costs. The major European utilities are agreed that the current EU electricity market is failing to provide the necessary incentives and needs to be modified[1].

2. Investment targets

In 2011, the European Commission issued its Energy Roadmap 2050 in which 5 scenarios analysed the different perspectives for the decarbonisation of the EU economy. Nuclear power continued to have an important role in electricity generation in 2050 in the majority of these scenarios. In the 'Delayed CCS' scenario, which appears to reflect most accurately the present situation, nuclear power was assumed to generate around 20% of the EU's electricity in 2050. Commission Vice-President Šefčovič confirmed this 20% target in his speech at the May 2015 ENEF Plenary in Prague. Given the expected increase in the use of electricity by 2050 (for power, heating, cooling and increasingly for transport), the 20% level in 2050 equates to approximately the same total nuclear capacity as we have in the EU today. The Commission should therefore target for 122 GW_e of nuclear new build by the year 2050. Also to note that in its Communication on a "Policy framework for climate and energy in the period from 2020 to 2030" dated January 2014, the European Commission acknowledges that nuclear contributes to a competitive, secure and sustainable energy system in the EU[2].

Nuclear power provided an average 27% of EU electricity in 2013 (more than 40% in several MS) and ensures 50% of its low carbon electricity. However, the number of operational power reactors has fallen from 152 in 2007 to 131 at the end of 2014 (14% decline), and the installed capacity has fallen from 132 GW to 122 GW (8% decline). Important also to note is that almost half of the nuclear fleet will attain 40 years of operation in the next 5 to 10 years. The majority of the operational nuclear plants operating today in Europe were commissioned

[1] https://www.gdfsuez.com/wp-content/uploads/2014/03/recommendation-for-the-european-council-from-ceos.pdf Recommendation 6

[2] Communication on "A policy framework for climate and energy in the period from 2020 to 2030"; COM/2014/015 final; February 2014

in the 1970s and 1980s and have therefore been operating for at least 25 years. Extending the operation of existing nuclear power plants is a viable economic option in most cases, although operation of NPPs cannot be extended indefinitely and new build has to be contemplated at some point. In France, EDF is planning to extend the lives of most of its fleet of 58 reactors from 40 years to 50 years, subject of course to regulatory approval. FORATOM believes that the Commission should target LTO for at least half of the EU's existing fleet of 131 reactors.

Regarding decommissioning, any existing reactor that entered commercial operation before 2000 can be expected to have retired and gone into decommissioning by 2050. All the current reactors along with their start-up dates and age are listed by country in Appendix 1. As can be seen, only 8 of these reactors began operation during or after the year 2000, so the Commission should target that an additional 123 of the EU's 131 currently operating reactors will go into decommissioning by 2050. This is in addition to the 88 power reactors in the EU that have already been permanently shut down.

3. Investment Requirements

New Build

The Lisbon Treaty confirmed (Article 194) that Member States have the right to determine how their energy resources should be exploited, the choice between energy sources and to decide on the structure of their energy supply. Member States have therefore the right to choose the use of nuclear energy should they wish to do so.

In order to keep the 122GW_e of nuclear mentioned above, around 100 new units, to be commissioned between 2025 and 2045, will need to be connected to the grid.

Of the 14 EU Member States presently hosting operating nuclear power plants, 2 (Germany and Belgium) have committed to nuclear phase out by 2022 and 2025 respectively, whereas 2 others (Poland and Lithuania) are planning to start or restart nuclear power production. The following table indicates new build currently underway or firmly planned within the EU Member States:

Country	Current Installed capacity (MW)	Proposed new capacity (MW)	Site and proposed new capacity (MW)	Planned date of first new unit operations	Project stage
UK	10,892	Up to 15500 in 5 sites with 11 new reactors	Hinkley Point C (3300) Sizewell C (3300) Wylfa (2700) Oldbury (2700)	2023 (being reviewed)	Pre-construction work / Planning

			Moorside (3330)		
BG	2,000	1110	Kozloduy 7 (1110)	2025	Planning
CZ	4133	Up to 3600	Dukovany 5 (1200) Temelin 3&4 (2400)	2035	Planning
FR	65,880	1650	Flamanville 3 (1650)	2018	Construction
HU	2000	2400	Paks 5&6 (2400)	2023	Planning
LT	0	1350	Visaginas 1 (1350)	2022	Pre-construction work
PL	0	3000	Choczewo or Żarnowiec (3000)	2024	Planning
RO	1411	1440	Cernavoda 3&4 (1440)	2019	Planning
SK	1950	942	Mochovce 3&4 (942)	2016	Construction
FI	2860	2800	Olkiluoto 3 (1600) Hanhikivi-1 (1200)	2018	Construction / Pre-construction work

(sources: IAEA PRIS Database and individual utility websites)

In addition to the above, energy policy discussions are currently underway in Spain, Sweden, The Netherlands and Slovenia/Croatia, and, subject to political and financial considerations, FORATOM confidently expects these four countries to remain committed to nuclear power production for the foreseeable future, at least until the existing reactors in those countries reach the end of their economic lives. Altogether, we can expect 14 EU Member States to still be operating nuclear power plants in 2050.

Recent experience of new build construction in Europe has experienced cost and time over-runs as those reactors have been First-Of-A-Kind investments in Generation III reactors. The industry is learning the lessons experienced from those reactors and also from new build projects outside the EU.

Nuclear new build is capital intensive, and construction risks must be managed effectively. Application of rigorous disciplines of cost and schedule control is crucial, and learning from experience should deliver a positive learning effect with series build. It is up to the nuclear sector to demonstrate that cost-effective construction can be achieved. When built, new nuclear power stations have many advantages in the electricity market: they are designed for long term operation; have relatively low fuel and other operating costs; can be centrally dispatched and provide predictable output, and do not impose high system costs.

A recent study for the European Commission[3] provides estimates of the costs of new build. The conclusions of this comprehensive study give a central estimate of the levelised cost of electricity (LCOE)[4] of:

- For the first of a kind twin reactor project on a brownfield site: €$_{2012}$48/MWh to €$_{2012}$84/MWh (falling to €$_{2012}$43/MWh to €$_{2012}$75/MWh for a series build) (with discount rate assumption of respectively 5% and 10% real).

Long Term Operation

Investments for LTO depend on the type of plant, the extent of long term operation and its age. In France, EDF has identified a major refurbishment across its operating fleet of 58 reactors, the 'Grand Carénage', requiring a total estimated investment of €$_{2013}$ 55 billion[5]. Of this amount, some €45 billion, i.e. approximately €780 million per reactor, represents the cost of refurbishments and regular maintenance required to add an additional 10 years of operation. Similar estimates in Japan indicate that the cost would be around €600 million per reactor.

The study for the European Commission mentioned above provides the following estimate of the cost of electricity following refurbishment for long term operation:

- LCOE after LTO refurbishment: €$_{2012}$23/MWh to €$_{2012}$26/MWh (with discount rate assumption of respectively 5% and 10% real).

This suggests that LTO is a very competitive option compared with other low CO_2 sources of energy.

An earlier study published by OECD-NEA[6] on the levelised costs of electricity generation after refurbishment ($LCOE_{EO}$), gives a range of USD_{2010} 30-58/MWh in the case of continued operation for 20 additional years, and a range of USD_{2010} 30-71/MWh in the case of continued operation for 10 additional years (estimates for Belgium, France, Hungary, Republic of Korea, Switzerland and the United States). As also stated in its conclusions, the study indicates that "in most cases, the continued operation of NPPs for at least ten more years is profitable even taking into account the additional costs of post-Fukushima modifications, and remain cost effective compared to alternative replacement sources".

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[3] Synthesis on the Economics of Nuclear Energy, William D'haeseleer, November 2013. https://www.mech.kuleuven.be/en/tme/research/energy_environment/Pdf/wpen2013-14.pdf

[4] LCOE includes all plant-level costs (investments, fuel, emissions, operation and maintenance, dismantling, etc.)

[5] EDF Group Annual Results Statement 2014 http://press.edf.com/fichiers/fckeditor/Commun/Finance/Publications/Annee/2015/resultats_annuels/va/cp_20150212_resultats_va.pdf

[6] The Economics of Long-term Operation of Nuclear Power Plants, OECD-NEA, December 2012 https://www.oecd-nea.org/ndd/reports/2012/7054-long-term-operation-npps.pdf

Safety Upgrades

Nuclear operators, along with the national regulators, have undertaken comprehensive reviews of risk and resilience against extreme events following the tsunami that triggered the events at Fukushima Daiichi in March 2011. Plans for safety upgrades have been drawn up in consultation with the regulators, and where necessary additional protection measures have been or shortly will be implemented. The estimated costs of the safety upgrades will depend on the type of works to be undertaken. EDF have stated that of the €55 billion for their 'Grand Carénage', €10 billion can be attributed to post-Fukushima safety upgrades, i.e. approximately €170 million per reactor. This compares with an estimate given by the Commission in 2013 of €200 million per reactor, i.e. €25 billion for the whole EU reactor fleet.

Decommissioning

All NPPs in the EU will have to be dismantled once they have reached the end of their operating lives. Differences in the time required and the estimated costs for decommissioning can be observed depending on reactor type. Some examples of costs can be given that vary from €135 million per reactor, excluding used fuel removal and radioactive waste management, to around €1 billion taking into consideration all costs from final shut down of the plant to restoration of a green-field site, including the costs for the post-operational phase, the dismantling and the waste management of decommissioning waste but excluding disposal. EDF have stated that their decommissioning provisions as at 31/12/2014 amounted to €13.9 billion, i.e. €240 million per reactor in France.

Regarding the funding of decommissioning and waste management, a Communication from the Commission to the European Parliament and the Council on the use of financial resources earmarked for the decommissioning of nuclear installations, spent fuel and radioactive waste published in March 2013[7] (also known as the Third Commission report on financing decommissioning) states that "*the systems in all Member States with commercial nuclear operations are based on the model of setting up adequate decommissioning funds on the basis of the revenues obtained from their activities during the lifetime. In general, the rate of accumulation to date appears adequate".*

Research and Innovation

The EU is a leader in nuclear expertise and can claim some of the best nuclear innovation and research in the world, relying on state of the art skills and infrastructures. This applies to all technical fields (including reactors, fuel cycle, management and storage of waste, and radiation protection) and the associated research disciplines. This research concerns not only the safety aspects, but must also meet sustainability and economics demands, and therefore supports the design of future efficient nuclear systems. Europe, through the SNETP, NUGENIA (research on current reactor technologies) and ESNII (the European Sustainable Nuclear Industry Initiative) have set out the research and innovation needs in

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[7] COM(2013) 121 final http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2013:0121:FIN:EN:PDF (accessed 28/5/2015)

the nuclear fission area. NUGENIA focuses on the safety, improved efficiency and long term operation of the existing reactors whereas ESNII has identified three main lines of research toward the implementation of Generation - IV fast reactors: the ASTRID prototype (sodium cooled), ALFRED (the Lead Fast Reactor Demonstrator) and ALLEGRO (a Gas Fast Reactor experimental installation). The realization of such initiatives will constitute a break-through in terms of nuclear energy sustainability in the long term and is believed essential for maintaining European leadership in the nuclear energy sector. In parallel, research and innovation efforts are dedicated towards Small and Modular Reactors (SMR) able to respond to a market niche world-wide. The implementation of all this research requires experimental reactors for studying the behaviour of irradiated materials: Jules Horowitz reactor (in construction) to respond to the needs of the existing fleet support and MYRRHA (in design) to respond to the needs of Generation- IV future nuclear systems. Other specific kinds of facilities are also required (e.g. critical mock-ups for core studies or facilities to manufacture new fuels).

Europe has worked to organize this research through the implementation of the SET Plan (Sustainable Energy Technology – Plan), the Alliance for Energy Research (EERA), European technology platforms like the SNETP (Sustainable Nuclear Energy Technology Platform) and the Industrial Initiatives such as ESNII (European Sustainable Nuclear Industrial Initiative). Financial support to leverage these coordination initiatives at European level is however insufficient. It was estimated by SNETP[8] in 2012 that the funding required for implementing the ESNII projects for example was €11 billion.

The EU's nuclear workforce is ageing and with the large number of retirements expected over the next few years, a considerable amount of knowledge and experience will be lost from the industry. The EU Joint Research Centre recognizes this challenge and states the following; "*In order to avoid loss of related EU expertise and knowledge, action should be taken to preserve and disseminate the acquired knowledge to the new generation of engineers, scientists and other interested parties*". The socio-economic benefits of employment in the nuclear sector include well paid and long-term jobs, sustained financial contributions to local, regional and national economies and support for local businesses and services.

4. Technological leadership and full industrial basis

Across all segments of the nuclear value chain (fuel cycle and reactors), the European nuclear industry has developed and maintains global technology leaderships through substantial investments in its technology portfolio, its qualified workforce and its European industrial assets.

[8] 'EU Multi-annual Financial Framework 2014-2020: Aligning nuclear fission R&D budgets to reach SET-Plan targets', SNETP Position Paper, January 2012

4.1 Supply of nuclear fuel

The European nuclear industry is leading on fuel cycle technologies and maintains strategic assets in the EU. The Euratom Supply Agency has an important role in monitoring and ensuring that an effective level of nuclear fuel supply security is achieved. The 2014 Annual Report of the Euratom Supply Agency[9] summarises the current outlook. Over the 2015-2024 period, requirements will average 17,635 tonnes/year for natural uranium and 14,201 SWU/year[10] for enrichment. Ongoing long term investment will be required to maintain and modernize the fuel cycle facilities, and to retain the current level of security of nuclear fuel supply which include investment to secure uranium mining assets to guarantee European security of supply, to upgrade conversion facilities, with a total capacity of 15,000t/year and to improve environmental performances; to increase enrichment capacity and allow supply of Enriched Uranium Product (EUP) to all kinds of European reactors, including VVERs and potential investments in fuel facilities to reduce the dependency of VVER utilities on Russian fuel and extend technical capacity for reprocessing to a wider range of types of used fuel.

4.2 Reactors

The EPR reactor is, for the time being, the only Generation III reactor currently licensed for new build in Europe (in France, Finland and the UK). Other reactor types to be deployed namely in the UK have been presented to the safety authorities for generic design assessment (Westinghouse AP1000 and GE-Hitachi ABWR). The EU is also a worldwide leader in products and services for nuclear reactors currently in operation.

A number of EU Member States intend to progress new nuclear projects deploying a variety of technologies. This includes projects in Romania with improved CANDU 6 reactors (Units 3 and 4 of the Cernavoda NPP), Hungary with Rosatom's VVER technology (Units 5 and 6 at Paks NPP), UK with AREVA EPR , GE-Hitachi ABWRs and Westinghouse AP1000 reactors, as well as projects in the Czech Republic, Finland, Poland and Bulgaria potentially using a combination of the above technologies.

The EPR currently under construction in France and Finland and projected in the UK has already led to a major revival of the European nuclear supply chain. This European supply chain – large and medium-size companies and a considerable number of small companies – is competitive for the nuclear export market outside of Europe. For example, in France, 450+ companies of less than 250 employees specialized in nuclear are generating over half of their revenues on the export market.

4.3 Used Fuel and Waste

The EU is a world leader in the recycling and reprocessing of used fuel, radioactive waste management and final disposal.

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[9] EURATOM Supply Agency Annual Report 2014

[10] SWU/year = Separative Work Units/year, a measure of uranium enrichment capacity.

4.3.1 Used fuel recycling contributes both to resource management and to waste management.

The nuclear fleet in France requires approximately 1200 tonnes of “heavy metal” (i.e. uranium or plutonium) per year, of which 120 tonnes, i.e. 10% are recycled Mixed Oxide (MOX) fuel. In 2012, up to 17% of fuel needs were supplied with recycled material. In the UK, reprocessing of Magnox used fuel has been for a long time supplying a significant amount of recycled uranium. Taking into account that Europe imports uranium, the recycling process significantly reduces the import requirement. Recycling is currently implemented in France, the Netherlands and the UK; it was also used in Belgium and Germany, although it is no longer considered an economically attractive option in those countries.

Recycling of plutonium and uranium also reduces the volume for final disposal, when compared with direct disposal of used fuel. Vitrification yields a very stable ultimate waste, ensuring long term containment of fission products and transuranic elements. Moreover, long term interim storage until final repositories are available can be implemented safely in air-cooled installations: e.g. in La Hague (France) and in COVRA (Netherlands).

Industrial used fuel recycling is based on two highly sophisticated processes: waste vitrification and MOX fuel manufacture, for which European expertise and proven performance, both in France and in UK, is unequalled. Industrial leadership in this area opens the way for international partnerships as well as for export.

4.3.2 EU is a world leader on final geological waste disposal

EU countries such as Finland, Sweden and France are at the forefront in the preparation for final deep geological disposal.

In Finland, construction license for a deep geological repository located in Olkiluoto was introduced in 2012. Preliminary works have begun on the site, authorisation for construction is expected in 2015, with operation planned to start in 2021.

In France a site has been selected and a public debate of the CIGEO waste repository project took place through 2013. Start of operation currently planned for 2025.

In Sweden, SKB the waste management agency owned by the operators of power plants, plans to build the repository at Forsmark in the municipality of Östhammar An application for a licence has been submitted. Start of operation is planned for 2025.

At EU level, a major objective is to ensure continuity of availability of expertise in geological disposal. Behind its Strategic Research Agenda dedicated to advanced geological disposal programs, the EU International Geological Disposal-Technological Platform (IGDTP) prepares guidance on RD&D planning towards geological disposal programs offering support to less-advanced programmes with implementation schedules for working towards operational facilities well beyond 2025. Also, and as acknowledged by the Council Directive 2011/70, cooperation at regional level for shared repositories can be envisaged (www.erdo-wg.eu)

All EU member states (whether or not they have chosen to make use of nuclear power) make use of radioactive materials in medicine and other industrial processes, and therefore have a need to manage radioactive waste products safely, and provide for final disposal.

4.4 Funding technology demonstrators for next generation technology

The Industrial Initiative ESNII coordinates the research for Generation IV reactors and its main objective is to maintain European leadership in fast spectrum reactor technologies that will excel in safety and will be able to achieve a more sustainable development of nuclear energy. This includes the development of demonstration facilities for fast reactor technology. These facilities are of a high innovative nature and are essential for Europe in order to maintain its skills and leadership in the international nuclear community. Due to the shared challenge and the high investment costs the European/international dimension is a necessary condition for success. Grant and financing mechanisms at European level are, however, insufficient to catalyse the needed public-private partnerships to develop these facilities.

Expected to have a high competitive advantages, the development and demonstration of fast nuclear reactor technologies should be provided with adequate funding at EU level, taking into account the EU potential in terms of human and financial resources, enabling to support the sodium, lead and gas technologies. The progress made worldwide in these technologies is significant and the gap between EU and other countries will continue to increase.

5. Market Framework

Within the current market frameworks in the EU, nuclear power development is subject to a **combination of market failures** - these affect electricity generation, low carbon generation more specifically, and new nuclear generation in particular. Those market failures are:

5.1 The market does not send a sufficiently strong signal to drive reduction in fossil fuel use

Without intervention, the market does not reduce the production of greenhouse gases associated with fossil fuel combustion – as shown by the record coal use in the EU. The Emission Trading Scheme (the "ETS"), and other fiscal measures, have clear limitations and the low prevailing prices in the ETS are inadequate to drive low carbon investments.

5.2 Total absence of internalization of security of supply benefits by the market

Security of supply has a broad social benefit which is not valued by the market. Thus, market participants are not sufficiently incentivized to provide secure supplies in the medium and long term public interest.

5.3 Diversity of electricity supply externality

Current electricity market design does not create incentives to diversify the generation mix even if such diversification would enhance the robustness of an electricity system to fuel supply shocks, and hence yield macroeconomic and security of supply benefits.

5.4 Innovation and learning benefits of FOAK deployment are not fully captured by first movers

Markets do not favour First of a Kind (FOAK) projects, due to their initial cost premium and technology risks, even if innovation and subsequent learning effects may lead to cost reductions in future. These future benefits will potentially accrue to both the FOAK investor and to the market participants more widely.

5.5 Absence of long-term hedging against electricity prices

Low-carbon technologies are characterised by high upfront capital costs and low marginal operating costs. Furthermore, under current market arrangements, wholesale prices correlate with fossil fuel prices. Hence, investors in low-carbon technologies are exposed to significant price volatility risk, which cannot be efficiently transferred, shared or pooled. This is more acute for nuclear projects due to the large scale of single projects and relatively high technology risks. Thus, there is a market failure for such investments.

5.6 Regulatory risk

Developers are confronted with a certain degree of risk when it comes to long term political commitment. Indeed, governmental decisions taken after investment decisions may lead to different result in terms of expected return on investment. Given that new nuclear projects are capital intensive and take a long time before generating any income, it is desirable for developers to be given assurances that governments through, for example, cross party agreements, are supportive of projects for a reasonable period of time in order to be able to implement them.

As well as the above market failures, nuclear investments are also vulnerable to additional regulatory risks that act to deter investment. These include:

- A lack of clarity over whether future nuclear projects (which contribute EU energy policy objectives, including combating climate change) will be approved under the current State Aid Energy and Environment Guidelines;
- Lack of harmonisation across regulatory bodies responsible for licensing and environmental consents within the EU;
- Specific tax burdens applied to existing nuclear facilities by individual member states that distort the economics of long term operation.

In view of the above market failures, FORATOM recommends that the following market design principles be incorporated into the current review of the EU's electricity market:

General

- Right of Member State choice of energy mix preserved
- Ability to deliver the most affordable decarbonisation solutions
- CO_2 climate cost internalized in electricity prices through ETS; effective carbon price driven by structural reform of the European carbon market
- Technology neutrality
- Full system costs internalized by each supplier
- Sustainable long-term price signals *or* predictable market-driven investment climate

Security of Supply

- Security of supply should be recognized and rewarded
- We need a new definition of generation adequacy (security of supply)
- Putting a value on short term security of supply: energy, flexibility and capacity need to be properly valued by the market
- Putting a value on long term security of supply: diversity means resilience to fossil fuel price volatility

Regulatory

- Regulatory stability
- EU level harmonized framework
- Harmonisation of fuel and energy taxes (no unjustified nuclear taxes!)

Market instruments

- Long term contracts supported: allowing technology neutral competitive processes (call for tender, auctioning) and bilateral agreements negotiated between consumers and generators
- End of priority dispatch for RES
- Market prices should reflect full costs of production and transport
- Nuclear backup for variable RES would need to be incentivised (capacity markets)

6. Recommendations

1. **Action on market design is needed** to restore confidence among potential investors in power generation projects of all types, but in particular in large scale low carbon generation projects. The following principles are fundamental to an efficient market:
   a. No discrimination between technologies that deliver low carbon energy
   b. Full transparency of system costs, and market arrangements designed to ensure that system costs (e.g. cost of maintaining a secure system) and transmission costs are allocated equitably.

2. **European financial institutions** including the European Investment Bank **should ensure that funds are made available** for high quality projects, including technology demonstration projects, and that Government and EU support is offered via Euratom loans (assuming an increased ceiling), loan guarantees and credit lines. All applications for funding should be considered on a non-discriminatory basis.

3. **The Commission should make clear the importance of nuclear power to achieving climate action goals**, in order to build confidence among equity investors in nuclear power projects. The EU should facilitate projects by providing a stable regulatory framework and should not impose more constraints beyond those that individual MS already add (e.g. specific taxation)

4. **The EU Guidelines on State Aid for Environmental Protection and Energy should be revised** to include nuclear generation projects as well as low carbon renewable energy projects.

5. **The process for obtaining clearance for State Aid from DG Competition must be clear and completed to a strict timetable**.

6. **The Commission should ask the nuclear regulatory bodies** (ENSREG and WENRA) **to carry out a review of the scope for harmonisation of regulatory requirements** in order to reduce the barriers to deployment and costs of nuclear technology technologies in EU Member States.

Appendix 1

List of nuclear reactors currently operating in the EU by country

BELGIUM	Facility	Process	Net Electrical Capacity (MWe)	Commercial Operation start date	Age	Owner	Shut down date (if any)
	Doel-1	PWR	433	1975	40	Indivision Doel (EBES, INTERCOM, UNERG)	2025
	Doel-2	PWR	433	1975	40	Indivision Doel (EBES, INTERCOM, UNERG)	2025
	Doel-3	PWR	1006	1982	33	Indivision Doel (EBES, INTERCOM, UNERG)	2022
	Doel-4	PWR	1033	1985	30	Indivision Doel (EBES, INTERCOM, UNERG)	2025
	Tihange-1	PWR	962	1975	40	Electrabel + EDF	2025
	Tihange-2	PWR	1008	1983	32	Electrabel + SPE	2025
	Tihange-3	PWR	1038	1985	30	Electrabel + SPE	2025

BULGARIA	Facility	Process	Net Electrical Capacity (MWe)	Commercial Operation start date	Age	Owner	Shut down date (if any)
	Kozloduy-5	VVER	963	1988	27	Kozloduy NPP PLC (Subsidiary company of the Bulgarian Energy Holding EAD)	2017
	Kozloduy-6	VVER	963	1993	22	Kozloduy NPP PLC (Subsidiary company of the Bulgarian Energy Holding EAD)	2019

CZECH REPUBLIC

Facility	Process	Net Electrical Capacity (MWe)	Commercial Operation start date	Age	Owner	Shut down date (if any)
Dukovany-1	PWR	468	1985	30	CEZ	
Dukovany-2	PWR	471	1986	29	CEZ	
Dukovany-3	PWR	468	1986	29	CEZ	
Dukovany-4	PWR	471	1987	28	CEZ	
Temelin-1	PWR	1023	2002	13	CEZ	
Temelin-2	PWR	1003	2003	12	CEZ	

FINLAND

Facility	Process	Net Electrical Capacity (MWe)	Commercial Operation start date	Age	Owner	Shut down date (if any)
Loviisa-1	PWR/VVER	496	1977	38	Fortum Power and Heat Oy	
Loviisa-2	PWR/VVER	496	1981	34	Fortum Power and Heat Oy	
Olkiluoto-1	BWR	880	1979	36	TVO	
Olkiluoto-2	BWR	880	1982	33	TVO	

FRANCE

Facility	Process	Net Electrical Capacity (MWe)	Commercial Operation start date	Age	Owner	Shut down date (if any)
Belleville-1	PWR	1310	1988	27	EDF	
Belleville-2	PWR	1310	1989	26	EDF	
Blayais-1	PWR	910	1981	34	EDF	
Blayais-2	PWR	910	1983	32	EDF	
Blayais-3	PWR	910	1983	32	EDF	
Blayais-4	PWR	910	1983	32	EDF	
Bugey-2	PWR	910	1979	36	EDF	
Bugey-3	PWR	910	1979	36	EDF	
Bugey-4	PWR	880	1979	36	EDF	
Bugey-5	PWR	880	1980	35	EDF	
Cattenom-1	PWR	1300	1987	28	EDF	
Cattenom-2	PWR	1300	1988	27	EDF	
Cattenom-3	PWR	1300	1991	24	EDF	
Cattenom-4	PWR	1300	1992	23	EDF	
Chinon-B1	PWR	905	1984	31	EDF	
Chinon-B2	PWR	905	1984	31	EDF	
Chinon-B3	PWR	905	1987	28	EDF	
Chinon-B4	PWR	905	1988	27	EDF	
Chooz-B1	PWR	1500	2000	15	EDF	
Chooz-B2	PWR	1500	2000	15	EDF	
Civaux-1	PWR	1495	2002	13	EDF	
Civaux-2	PWR	1495	2002	13	EDF	
Cruas-1	PWR	915	1984	31	EDF	
Cruas-2	PWR	915	1985	30	EDF	
Cruas-3	PWR	915	1984	31	EDF	
Cruas-4	PWR	915	1985	30	EDF	
Dampierre-1	PWR	890	1980	35	EDF	
Dampierre-2	PWR	890	1981	34	EDF	
Dampierre-3	PWR	890	1981	34	EDF	
Dampierre-4	PWR	890	1981	34	EDF	
Fessenheim-1	PWR	880	1978	37	EDF	
Fessenheim-2	PWR	880	1978	37	EDF	
Flamanville-1	PWR	1330	1986	29	EDF	
Flamanville-2	PWR	1330	1987	28	EDF	
Golfech-1	PWR	1310	1991	24	EDF	
Golfech-2	PWR	1310	1994	21	EDF	
Gravelines-1	PWR	910	1980	35	EDF	
Gravelines-2	PWR	910	1980	35	EDF	
Gravelines-3	PWR	910	1981	34	EDF	
Gravelines-4	PWR	910	1981	34	EDF	
Gravelines-5	PWR	910	1985	30	EDF	
Gravelines-6	PWR	910	1985	30	EDF	
Nogent-1	PWR	1310	1988	27	EDF	
Nogent-2	PWR	1310	1989	26	EDF	
Paluel-1	PWR	1330	1985	30	EDF	
Paluel-2	PWR	1330	1985	30	EDF	

	Paluel-3	PWR	1330	1986	29	EDF
	Paluel-4	PWR	1330	1986	29	EDF
	Penly-1	PWR	1330	1990	25	EDF
	Penly-2	PWR	1330	1992	23	EDF
	St. Alban-1	PWR	1335	1986	29	EDF
	St. Alban-2	PWR	1335	1987	28	EDF
	St. Laurent-B1	PWR	915	1983	32	EDF
	St. Laurent-B2	PWR	915	1983	32	EDF
	Tricastin-1	PWR	915	1980	35	EDF
	Tricastin-2	PWR	915	1980	35	EDF
	Tricastin-3	PWR	880	1981	34	EDF
	Tricastin-4	PWR	880	1981	34	EDF

GERMANY

Facility	Process	Net Electrical Capacity (MWe)	Commercial Operation start date	Age	Owner	Shut down date (if any)
Brokdorf	PWR	1410	1986	29	E.ON Kernkraft GmbH	end 2021
Emslqnd	PWR	1335	1988	27	Kernkraftwerk Lippe-Ems GmbH	end 2022
Grafenrheinfeld	PWR	1275	1982	33	E.ON Kernkraft GmbH	end 2015
Grohnde	PWR	1360	1985	30	E.ON Kernkraft GmbH	end 2021
Gundremmingen-B	BWR	1284	1984	31	Kernkraftwerk Gundremmingen GmbH	end 2017
Gundremmingen-C	BWR	1288	1985	30	Kernkraftwerk Gundremmingen GmbH	end 2021
Isar-2	PWR	1410	1988	27	E.ON Kernkraft GmbH	end 2022
Neckarwestheim-2	PWR	1310	1989	26	EnBW Kernkraft GmbH	end 2022
Philippsburg-2	PWR	1402	1985	30	EnBW Kernkraft GmbH	end 2019

HUNGARY

Facility	Process	Net Electrical Capacity (MWe)	Commercial Operation start date	Age	Owner	Shut down date (if any)
Paks-1	PWR	470	1983	32	MVM	2032
Paks-2	PWR	473	1984	31	MVM	2034
Paks-3	PWR	473	1986	29	MVM	
Paks-4	PWR	473	1987	28	MVM	

NETHERLANDS

Facility	Process	Net Electrical Capacity (MWe)	Commercial Operation start date	Age	Owner	Shut down date (if any)
Borssele	PWR	482	1973	42	EPZ	2034

ROMANIA	Facility	Process	Net Electrical Capacity (MWe)	Commercial Operation start date	Age	Owner	Shut down date (if any)
	Cernavoda-1	PHWR/CANDU	650	1996	19	SN Nuclearelectrica SA	2049
	Cernavoda-2	PHWR/CANDU	650	2007	8	SN Nuclearelectrica SA	2060

SLOVAK REPUBLIC	Facility	Process	Net Electrical Capacity (MWe)	Commercial Operation start date	Age	Owner	Shut down date (if any)
	Bohunice-3	PWR/VVER	471	1985	30	Slovenske Elektrarne a.s.	
	Bohunice-4	PWR/VVER	471	1985	30	Slovenske elektrarne a.s.	
	Mohovce-1	PWR/VVER	436	1998	17	Slovenske elektrarne a.s.	
	Mohovce-2	PWR/VVER	436	2000	15	Slovenske elektrarne a.s.	

SLOVENIA	Facility	Process	Net Electrical Capacity (MWe)	Commercial Operation start date	Age	Owner	Shut down date (if any)
	Krsko	PWR	676	1983	32	Nuklearna Elektrarna Krsko (NEK)	

	Facility	Process	Net Electrical Capacity (MWe)	Commercial Operation start date	Age	Owner	Shut down date (if any)
SPAIN	Almaraz-1	PWR	1011	1983	32	Iberdrola Generación (53%) Endesa Generación (36%) Gas Natural SDG (11%)	
	Almaraz-2	PWR	1006	1984	31	Iberdrola Generación (53%) Endesa Generación (36%) Gas Natural SDG (11%)	
	Ascó-1	PWR	995	1984	31	Endesa Generación	
	Ascó-2	PWR	997	1986	29	Endesa Generación (85%) Iberdrola Generación (15%)	
	Cofrentes	BWR	1064	1985	30	Iberdrola	
	Sta. María de Garoña (*)	BWR	446	1971	44	Nuclenor S.A. (Iberdrola 50% + Endesa 50%)	Long-term shutdown
	Trillo-1	PWR	1003	1988	27	Iberdrola Generación (48%) Gas Natural SDG (34,5%) Hidroeléctrica del Cantábrico (15,5%) Nuclenor (2%)	
	Vandellós-2	PWR	1045	1988	27	Endesa Generación (72%) Iberdrola Generación (28%)	

(*) Operating license expired on 6 July 2013. On 27 May 2014, Nuclenor applied for the renewal of the operating license until 2 March 2031.

SWEDEN	Facility	Process	Net Electrical Capacity (MWe)	Commercial Operation start date	Age	Owner	Shut down date (if any)
	Forsmark-1	BWR	1120	1980	35	Forsmark Kraftgrupp AB	
	Forsmark-2	BWR	996	1981	34	Forsmark Kraftgrupp AB	
	Forsmark-3	BWR	1170	1985	35	Forsmark Kraftgrupp AB	
	Oskarshamn-1	BWR	473	1972	43	OKG Aktiebolag	
	Oskarshamn-2	BWR	638	1975	40	OKG Aktiebolag	
	Oskarshamn-3	BWR	1400	1985	30	OKG Aktiebolag	
	Ringhals-1	BWR	881	1976	39	Ringhals AB	2020
	Ringhals-2	PWR	807	1975	40	Ringhals AB	2020
	Ringhals-3	PWR	1063	1981	34	Ringhals AB	
	Ringhals-4	PWR	1115	1983	32	Ringhals AG	

UNITED KINGDOM	Facility	Process	Net Electrical Capacity (MWe)	Commercial Operation start date	Age	Owner	Shut down date (if any)
	Dungeness-B1	AGR	520	1985	30	EDF	
	Dungeness-B2	AGR	520	1989	26	EDF	
	Hartlepool-A1	AGR	595	1989	26	EDF	
	Hartlepool-B1	AGR	585	1989	26	EDF	
	Heysham-A1	AGR	580	1989	26	EDF	
	Heysham-A2	AGR	575	1989	26	EDF	
	Heysham-B1	AGR	610	1989	26	EDF	
	Heysham-B2	AGR	610	1989	26	EDF	
	Hinkley Point – B1	AGR	475	1978	37	EDF	
	Hinkley Point – B2	AGR	470	1976	39	EDF	
	Hunterston-B1	AGR	475	1976	39	EDF	
	Hunterston-B2	AGR	485	1977	38	EDF	
	Sizewell-B	PWR	1198	1995	20	EDF	
	Torness-1	AGR	590	1988	27	EDF	
	Torness-2	AGR	595	1989	26	EDF	
	Wylfa-1	GCR (Magnox)	490	1971	44	Nuclear Decommissioning Authority (NDA)	

Source: IAEA PRIS Database Last update 10/09/2015