FORATOM

Position Paper

Nuclear power: a key contributor to a decarbonized European Union

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 and through these associations, FORATOM represents nearly 800 European companies working in the industry and supporting around 800,000 jobs.

Summary

A new situation has emerged, with the current unsustainable design of the electricity market and the lower prices of fossil fuels, where it becomes a challenge for the European Union to reach the climate policy objectives and 2030 target, putting the European economy's competitiveness at risk. Today's energy market is distorted and failing to deliver on climate objectives and long term security of supply. Among the most important things, adequate long term price signals for new energy investments are currently missing.

Nuclear energy is a key part of the European energy mix and of the global transition to a decarbonised electricity required to comply with COP21 commitments. Nuclear was identified as the main source of low carbon electricity generation in the Energy Roadmap 2050's scenarios showing the lowest total energy costs. Variable renewable production cannot satisfy all the needs alone. Nuclear power high availability, diversity from other sources, high energy density and low sensitivity to uranium price variations contributes to the EU's security of supply. It therefore contributes to the Energy Union's key energy policy objectives. In terms of economics, long term operation of nuclear power plants is one of the best options for low carbon power generation. Nuclear new build lifecycle cost is close to that of on-shore wind while the service offered is greater with firm, dispatchable and reliable capacity, and with much smaller land size use.

New electricity market options are required to deliver the EU's decarbonisation goals, including price signals for new investments. Both nuclear new build and the long-term operation of existing nuclear plants need a predictable investment framework. The EU's 2030 decarbonisation target also requires decarbonisation of the transport and heating sectors, which will only be achievable with more extended use of electricity. Fixing electricity markets is therefore an urgent priority.

FORATOM supports solutions which do not discriminate any low carbon technology. A robust EU ETS delivering a carbon price at high enough level should be the main tool of the EU's climate policy. The electricity market design should ensure that system costs (e.g. the

cost of maintaining a secure power demand/supply balance on the grid) and transmission costs are allocated equitably. Moreover, all low carbon technologies are capital intensive. Their integration into the market requires long term arrangements such as long term contracts or contracts for difference (CfD) to encourage investments.

Introduction

The European energy sector is currently facing a new set of challenges in the light of the COP21 Paris agreement[1], the Energy Union initiative and new market design projections. Nuclear energy sector understands the post COP 21 constellation as a unique opportunity for all low carbon technologies which will be basic for transition towards COP 21 commitments.

The IEA/NEA's 2015 Technology Roadmap for Nuclear Energy[2] concludes that global nuclear capacity needs to more than double by 2050 if the 2°C ceiling is to be respected. Similarly the IEA's World Energy Outlook 2015[3] "450 Scenario", again addressing the 2°C limit, says that nuclear capacity should reach globally 540 GW (392 GW currently) in 2030 and the share of nuclear energy in power generation should increase to 13% in 2030, two percentage points over today's level. This means that **demand for nuclear energy is foreseen to more than double by 2050**.

The integration of renewable energy sources into the electricity market forms part of the Energy Union strategy. Interoperability between the future smart grid, electric vehicles and storage is a key matter to achieve the integration at high share. Nuclear energy will not only accompany renewables on the way but even facilitate the task in meeting the targets of the Energy Union: providing reliable capacity and the best energy prices as baseload source in a fully-integrated internal energy market and emissions reduction. Members States expect that the electricity generation mix is able to meet the demand at all times, which intermittent renewable generation cannot achieve alone.

However, the severe economic context in which nuclear plants are currently operating has to be underlined: declining electricity demand, lower wholesale prices resulting from a market oversupplied with low variable cost technologies, lower carbon price, high nuclear tax burden, which can lead to decisions of some utilities to the early retire of some nuclear reactors.

Magnus Hall, CEO of Vattenfall declared that "…as a result of taxes, it's more expensive to produce hydro and nuclear power in Sweden than it is to produce CO_2-emitting power in Germany, which in my world is a very strange situation"[4].

A new policy outlook for Europe is needed in order to provide low carbon capacity, lead to the modernization of technical processes and contribute to the prosperity of Europeans. In its own initiative opinion on the Energy Union adopted[5] on 15 December 2015 (rapporteur M.

[1] COP21 Paris agreement

[2] IEA/NEA's 2015 Technology Roadmap for Nuclear Energy

[3] IEA World Energy Outlook 2015

[4] Platts article – 28/04/2016

[5] EP ITRE - Towards a European Energy Union INI report

Grobarczyk), the European Parliament "calls on the Commission to ensure the EU provides an enabling framework for those Member States that wish to pursue new nuclear power projects to do so, within EU internal market and competition rules". The PINC provides a golden opportunity for the EC to put forward, or at least to propose the essential components of this "enabling framework" but this issue is not addressed.

The question of today is to what extent the current market situation will favour new investments for a decarbonised economy: lack of incentive is rather favouring status quo and carbon lock-in.

The scope of the paper is to highlight the benefits of nuclear for a low carbon future and for the security of supply and recommend actions for supporting new investments.

1. A new context

1.1 Climate change

The European Commission committed to CO_2 emissions reduction targets through the Intended Nationally Determined Contribution (INDC) of the EU and its Member States, based on the figures communicated[6] to and agreed by the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions in 2014 **Based on the INDCs of all the countries, in December 2015 at COP21 in Paris a new agreement**[1] has been signed, setting ambitious objectives, beyond former expectations:

In Article 2:

Holding the increase in the global average temperature to well below 2 °C above pre-industrial levels and ***to pursue efforts to limit the temperature increase to 1.5 °C above pre-industrial levels****, recognizing that this would significantly reduce the risks and impacts of climate change;*

In Article 4:

In order to achieve the long-term temperature goal set out in Article 2, Parties aim ***to reach global peaking of greenhouse gas emissions as soon as possible****, recognizing that peaking will take longer for developing country Parties, and to undertake rapid reductions thereafter in accordance with best available science.*

The EU is much more encouraged to follow its frontline climate policy, including the 2030 target of minus 40% GHG emissions. The latter objective is more than ever a reality for the European energy sector. **That means strong pressure in favour of low carbon energies.**

Out of the countries with the biggest share in global CO_2 emissions, China, India and Japan mentioned in the INDCs the role that nuclear sector will have in the efforts to achieve the climate change targets.

Even if it was not evidently mentioned in the INDCs, strong signals regarding role of nuclear sector in achievement of the targets related to GHG emission reduction have been sent after the Paris Conference by other nations like USA, some EU countries or Canada.

[6] A policy framework for climate and energy in the period from 2020 to 2030 - COM(2014) 15 final

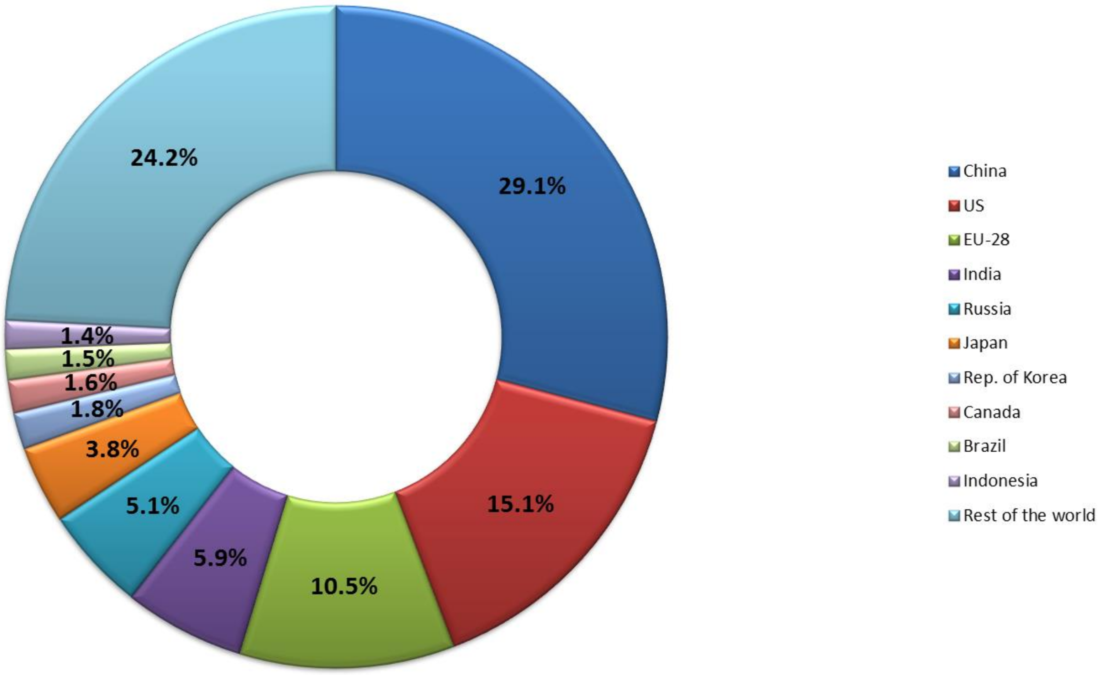

Fig.1 Share in global CO_2 emissions (2013) – Friends of Europe infographic

Electricity remains the easiest energy vector to be decarbonized. The EU objectives for 2050 are to have a 100% CO_2 free electricity generation sector and to cut the emissions by 80-95% for the rest of energy sector. That means electricity share of energy consumption should be increased and large investments have to be decided early enough.

The question is to what extent the current market situation will favour such investments: lack of incentive is rather favouring status quo and carbon lock-in.

1.2 Current electricity market status

European electricity wholesale market is experiencing a severe overcapacity with price collapse down to less than 30 Euro/MWh in some regions. This situation results from the combination of 3 factors:

- Demand stagnation, projected to last under energy efficiency progress, until new applications of electricity are deployed;
- Fossil fuel prices collapse; coal plants being the marginal units the electricity market price is determined by coal price;
- Expanding capacity of subsidised installations promoted by the Renewables policy.

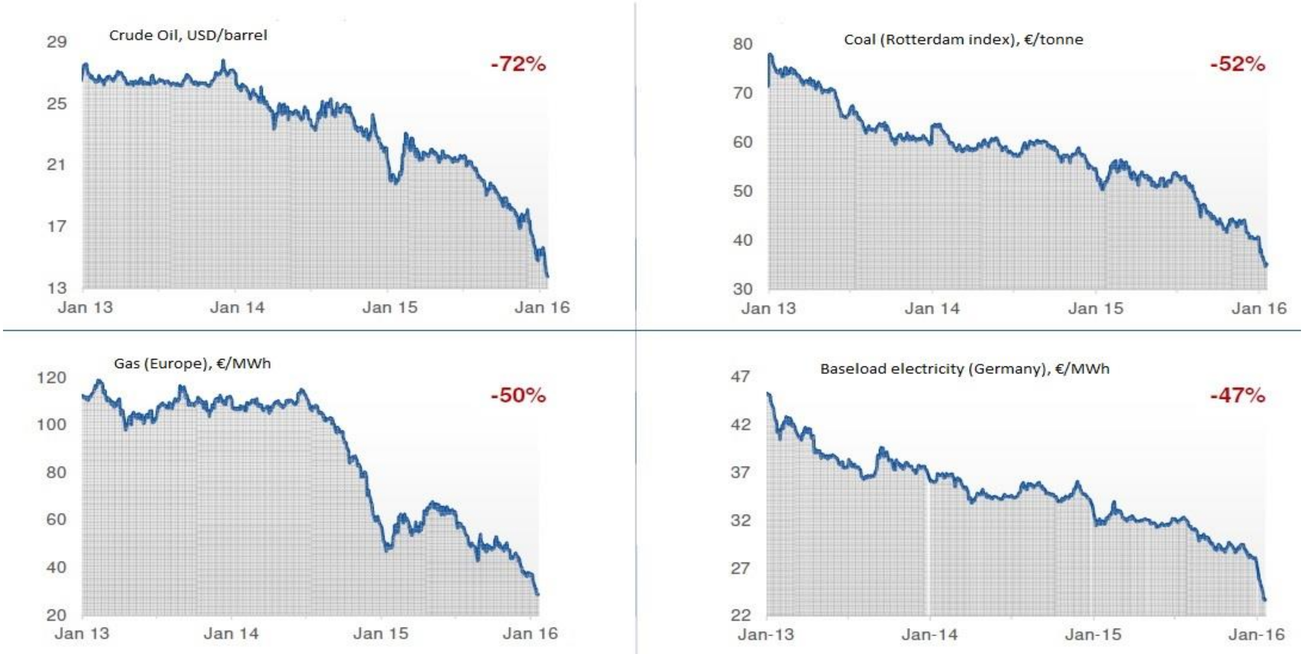

Fig.2 Evolution of the fossil fuel prices - Dr. Markus Krebber, CEO RWE Supply & Trading presentation during public during RWE Talks (15th March 2016 – Bruxelles)

From the above chart it can be seen that the wholesale price of the baseload electricity production (in Germany) is directly linked with the fossil fuel prices evolution.

In spite of that, generation adequacy is not guaranteed in the middle term:

- Variable capacities of RES are generating in excess in some periods but well under the load in others. Back-up is supposed to come from thermal plants but many CCGTs have been shut down and mothballed since they can no longer cover their operating costs, so back-up is increasingly being provided by coal.
- A growing number of aging plants (coal and nuclear) will have to be shut down soon; they have to be replaced to maintain the adequate level of firm, dispatchable capacities.

In the current situation, the baseload electricity production prices are not providing any incentives for investments in new capacities, being a risk also for the capacities under operation which are becoming uneconomical.

Consequently, the European industrial competitiveness is at risk. Energy demand is stagnating, including electricity, and low wholesale prices do not facilitate investment decisions. Taxes and subsidies are the main factor driving this divergence between end user price and wholesale price. **That means cost efficiency must be taken into account in the climate policy.**
Such a situation, if it were to be prolonged, would in the middle term result in severe damages both on the producers' and consumers' side. It would force to shut down competitive but non subsidized facilities, such as CCGTs and nuclear power plants, leaving only a combination of old coal fired plants and costly intermittent supply systems. It could even lead to serious, irreversible losses of expertise and know-how.

However a return to more reasonable wholesale prices may be expected if the electricity demand is boosted by new applications such as heat pumps and electric cars, if the growth rate of renewable capacities is slowing down and if ETS market price rises up to a sufficient level to discourage coal fired generation.

1.3 Creation of the Energy Union

After the announcement made in 2014 by EC President Jean-Claude Juncker about the 'European Energy Union' as one of the Commission's main priorities for the coming five years, the communication "A Framework Strategy for a Resilient Energy Union with a Forward-Looking Climate Change Policy" was released in February 2015.

The Energy Union strategy proposed comprises five dimensions considered to be the solution to bringing greater energy security, sustainability and competitiveness to the EU:

- Energy security, solidarity and trust;
    - Nuclear energy generates electricity in 14 of the 28 Member States, producing almost 30% of the EU's electricity. Hence it contributes significantly to reducing dependence upon imported fossil fuels. As a mature technology, nuclear is well positioned to strengthen Europe's energy security[7].
- A fully integrated European energy market;
    - That means a technology neutral market where nuclear power plants operating in 14 Member States contribute to maintain European grid balance and stability[8].
- Energy efficiency contributing to moderation of demand;
- Decarbonising the economy,
    - Nuclear energy is a reliable source of electricity in the EU counting for more than 50% of the low carbon electricity produced. Therefore, nuclear energy should play an important role in meeting EU energy and climate targets.
- Research, Innovation and Competitiveness.
    - It should be highlighted the European Strategic Energy Technology Plan (SET-Plan) which aim is to accelerate the development and deployment of low-carbon technologies. SET-Plan seeks to improve new technologies and bring down costs by co-ordinating research and helping to finance projects.
    - In the communication on "Nuclear Illustrative Programme"[9], the EC states that*: "The EU must maintain its technological leadership in the nuclear domain…so as not to increase energy and technology dependence, and to give business opportunities for European companies. This will in turn support EU growth, jobs and competitiveness"*.

After the Communication's publication, EC Vice-President Maroš Šefčovič started a tour of the EU countries to present the opportunities that the Energy Union offers for Europe. Based on the conclusions of the tour, the EC released, in November 2015, the first State of Energy Union package, which was a good opportunity to take stock of the progress already made towards building the Energy Union and to highlight the issues where further attention was needed. In the Member States facts sheets, part of the Energy Union package, 14 countries

[7] Ensuring Europe's security of energy supply: the role of nuclear, FORATOM position paper

[8] FORATOM's response to EC Energy Market Design consultations

[9] COM(2016) 177 final - Nuclear Illustrative Programme

emphasized the existence of nuclear in the energy mix, some of them like UK adding also "the share of nuclear energy in the UK's energy mix is set to increase, as industry is planning to develop approximately 16GW of new nuclear power. This will replace the current generation of nuclear reactors which produce around 18% of the UK's electricity and are set to be decommissioned by 2030".

EURATOM Treaty: a possible model for the Energy Union.

Since the very beginning of the European Community, energy has always been at the centre. It is enough to say that in 1951, six countries established the European Coal and Steel Community to be followed in 1957 by the European Economic Community and the European Atomic Energy Community (EURATOM). EURATOM Supply Agency monitors and controls nuclear fuel security of supply and common rules are edicted across the Union.

1.4 ETS reform – the possible solution

ETS should be the main tool to reduce industrial greenhouse gas emissions, leaving to market players to select and develop the most efficient low carbon technologies. Power plants, air lines and other companies can buy or sell emission allowances, which are permits to pollute at a price that is meant to encourage them to pursue energy savings and carry out emissions reducing measures. ETS market is functioning and the current low prices reflect the excess of granted allowances, due to policy weaknesses: overestimated evolution of emissions and depressing effect of out of market renewables support. ETS driving role should be reinforced with the reform initiated, and also extended to more sectors.

Currently these permits are very cheap, because demand for them dropped due to the economic crisis while the supply has remained constant. By 2013, there was a surplus of around two billion allowances compared to actual emissions, which if nothing changes could increase to more than 2.6 billion by 2020. Having a large surplus discourages companies from investing in green technology, thereby hampering the scheme's efficiency in combatting climate change.

The current ETS fails to create incentives for investment in low carbon technologies. With a minimum targeted price of 30 Euros/t CO_2, the current price reached an historic minimum of 5 Euros/t CO_2. That means CO_2 price has to soar up quickly to prevent fossil fuel power plant lock-in.

Fig.3 Evolution of the ETS carbon price - Damien Morris (Sandbag) presentation during public hearing on "Emissions Trading System - ETS" in EP-ENVI Committee (18th February 2016 – Bruxelles)

The EC is proposing to reform the EU-ETS for its fourth phase (2021-2030).
In order to achieve the target of reducing EU emissions by at least 40% by 2030, the sectors covered by the EU ETS will need to reduce their emissions by 43% compared to 2005. This means that the overall number of emission allowances will decline at a faster pace than before: by 2.2% annually from 2021 onwards, instead of 1.74%. This is equivalent to an additional emissions reduction of around 556 million tonnes between 2020 and 2030.
EC proposal includes, among others the following changes:

- a revision of the system of free allocation, focusing on the sectors at highest risk of relocating their production outside the EU (this covers around 50 sectors);
- a considerable number of free allowances set aside for new and growing installations;
- more flexible rules to better align the amount of free allowances with production figures;
- an update of 52 benchmarks used for measuring emissions performance - to reflect technological advances since 2008.

A high enough carbon price to attract new investment in low carbon generation is an efficient way to internalise the climate change externality. However, governments must recognize that this is likely to take time and that price uncertainty induces increased investors' perception of market risk.
Under current coal and CO_2 market price conditions, lignite and coal fired plants are the most competitive. A price of at least 30 €/tCO_2 is required to switch from coal to gas; even higher to encourage new capital intensive projects under market uncertainty. The ETS reform underway is unlikely to achieve such level before 2030. A recent French initiative to accelerate carbon price uplift by setting a price corridor in volunteering MS could help accelerate the upside shift leading to 30 €/tCO_2 by 2030. According to the PINC[9] "beyond that horizon (2025), the minimum carbon price from which new nuclear capacity would be deployed by means of private financing ranges from 43 to 72 EUR/tCO_2. The 2013 EU Reference scenario projects ETS prices of between 35 EUR/tCO_2 in 2030 and 100 EUR/tCO_2 in 2050".

1.5 The need for a new energy market design

The Juncker Commission made the development of a resilient Energy Union with a forward-looking climate policy one of its strategic objectives. But also the threat of too high energy costs in Europe when compared to other regions of the world was realized. Achieving the goals of climate policy, security of supply and competitiveness together requires the redesign of the European electricity market.

The EC launched, in July 2015, a public consultation on a new market design, which objective is to seek stakeholder's views on the issues that may need to be addressed, such as:

- **improvements to market functioning and investment signals**;
- market integration of renewables;
- linking retail and wholesale markets;
- reinforcing regional coordination of policy making, between system operators and of infrastructure investments;
- the governance of the internal electricity market; and,
- a European dimension to security of supply.

FORATOM responded[10] to the consultation, promoting some basic principles that should be taken into account in the future improved market design. Similar principles for the low carbon generation investments (including carbon prices targets) have been drawn by IEA[11] and Oxford Institute for Energy Studies[12] in their recent reports.

It is agreed that sustainable long-term electricity price signals or predictable market-driven investment climate are needed. Also, CO_2 climate cost should be internalized in electricity prices through the ETS effective carbon price driven by a structural and predictable step-by-step reform of the European carbon market.

The new electricity market design should be founded on the following key considerations.

- Central objectives
  - Price in the externalities: climate change damages, security of supply benefits;
  - Enable return on capital-intensive technologies: revenue certainty;
  - Overcome the lock-in of high-carbon generation: public action required to foster the transition in the absence of an adequate carbon price.
- An adequate market design depends on the technologies available
  - Supply exclusively based on variable renewable energy sources can become feasible only when demand and storage flexibility are marketable;
  - Today still and for the foreseeable future a more diversified supply is required including firm capacities (nuclear, CCS, biomass…).
- Current low prices of fossil fuels and CO_2 hinder investment in low carbon technologies. The market risk is high for such capital intensive power generation means, inducing the vicious circle: high risk premium request by the investors, which results in higher investment cost and less competitiveness. During the transition until higher CO_2 prices are established, policy intervention supporting low carbon investment is needed.
- The role of instruments needed to support investments in low carbon is changing: no longer bridging a large cost gap for some non mature technologies, but providing revenue predictability and visibility during the energy transition. They should be embedded in the electricity wholesale market. Among the possibilities:
  - Modulated MWh price premium: the premium would decrease when CO_2 market price increases and vice-versa, which would mitigate the electricity market price risk;
  - Auctions for new capacities (competition for entry into the market)
  - Contracts for Difference;
  - Other kinds of long term arrangements based on average lifecycle costs.

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[10] FORATOM response to the EC public consultation on a new energy market design

[11] Re-powering Markets: Market design and regulation during the transition to low-carbon power systems

[12] Electricity markets are broken – can they be fixed?

The key mission of policy makers and regulators in the market design is to strike a balance between providing certainty for capital intensive projects and maintaining market feedback and competition. Financing at low cost of capital requires confidence in future revenue, which implies limited exposure to market price volatility. But Feed-in-Tariffs providing revenue certainty to selected technologies should be avoided since they are distorting competition. More technology neutral processes should replace them. And they should expose investors to some but not all market risks.

2. Nuclear energy as an important part of the solution

In this new climate change context, EU policy objectives will be achieved only if nuclear energy's important contribution is sustained and even increased. Nuclear energy makes it easier to combine security of supply, competitive electricity prices and lower GHG emissions within the next two decades with the 2030 target in view. **A share of 25% of electricity supply, from an installed capacity of around 120 GWe, should be the reference target for 2050[13].** A lower share of nuclear would make decarbonisation harder to achieve, could waste valuable capital assets and would reduce supply diversity, leading to increased use of fossil fuels as is currently happening for example in Germany.

The first urgency is to keep operating all the nuclear power plants when they are safe, authorized by the Safety Authorities for Long Term Operation and considered as competitive by the operators. Shutting down NPPs can only lead to higher generation costs and higher CO_2 emissions. Clearly, imposing heavy taxes on nuclear capacities will only lead to premature closure of otherwise economic power stations.

The second urgency is to set up a more favourable legal and regulatory framework that would encourage investments in new nuclear build, since the fleet will have to be nearly 100% renewed between now and 2050.

2.1 Maintaining the Security of Supply

Nuclear energy contributes significantly to reducing dependence upon imported fossil fuels. One tiny uranium fuel pellet can produce as much energy in today's reactors as 3 barrels of oil, 1 tonne of coal or 500 cubic meters of gas.

Both the transportation and storage of uranium is relatively straightforward and takes up little space. For oil and gas, new transport routes, improved port facilities and increased storage capacity within the EU will require enormous financing and long lead times.

Many years of uranium supply can be stored in a relatively small area. It is common practice for nuclear operators to store sufficient fuel assemblies on-site for a number of years of operation, making it relatively impervious to supply constraints. Whilst the EU's gas storage inventories are satisfactory high at the moment without consistent supply, and in the face of potential physical interruption, they could just as easily be depleted over a short period of increased demand. Likewise, any physical interruption of gas flow to the EU will have

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[13] Energy Roadmap 2050 - COM(2011) 885 final

immediate impact on supply, and potentially serious consequences for the economy. In the face of geopolitical supply risks, nuclear energy also holds advantages that other fuels such as oil, coal and gas do not enjoy. For comparison, fossil fuel independence from fuel supply is of the order of weeks or a few months whereas for nuclear fuel it is of the order of years.

The EU uranium production industry, thanks to adequate and sustained investments, has been able to keep pace with global prospecting, developing, financing and mining operations. This strategy put a European company at the very top of the list of world producers.

The world-wide and long-term availability of uranium resources is assured by having a variety of producers. The majority of producing countries are politically stable. Australia (which has 29 % of the world's known recoverable resources as well as the majority of 'reasonably assured resources') and Canada remain reliable suppliers of uranium, in addition to which there has been recent development of mining projects elsewhere, particularly in Kazakhstan, Namibia, and Niger.

Because uranium enrichment technology is strategically sensitive and capital intensive, only a limited number of facilities worldwide are able to achieve commercial operation. The biggest and most effective enrichment capacity is located in Europe, combining the joint output of two major players, one single technology – gas centrifugation –, and plant location in four countries – France, Germany, the Netherlands and the UK.

The nuclear fuel market has become increasingly competitive. A handful of fabricators, who are also reactor vendors, share a world capacity significantly in excess of demand. The market remains primarily regionally driven, with the majority of the supply coming from the same continent. In Europe, the fuel market is shared between a few manufacturing plants in France, in Germany, in Sweden and in Spain. The EU share in the main steps of conversion, pelletizing and fuel rod manufacturing – i.e. 31 % – is quite in line with the global fuel requirements of EU's reactors.

Moreover, a singularity of the European nuclear market lies in the large-scale development of spent nuclear fuel industrial reprocessing. Plutonium and uranium retrieved from this process can be used as MOX fuel in water reactors, extending the autonomy of utilities versus new uranium supply. The only commercial MOX fabrication facilities are operated in Europe. So far, no equivalent capacity exists anywhere else in the world.

2.2 Long term operation – lifetime extension

Long term operation (LTO) of the NPPs represents one of the best economical options when they are proved to be safe and authorized by the Safety Authorities.

According to the EC study "Synthesis on the Economics of Nuclear Energy"[14] for Europe and referenced by the more recent OECD EIA-NEA report "Projected Costs of Generating Electricity"[15], the levelized costs of electricity (LCOE) for LTO (20 years) of a nuclear reactor are ranging between $€_{2012}$23/MWh to $€_{2012}$30/MWh (with discount rate assumption of 10%), that is 32 to 40 USD/MWh in OECD report, considering an overnight refurbishment cost (ORC) ranging between 400 to 850 million €. As can be seen from figure no.5 hereafter, the

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[14] Synthesis on the Economics of Nuclear Energy, William D'haeseleer, November 2013.

[15] Projected Costs of Generating Electricity, OECD IEA-NEA, October 2015

LTO LCOE remain the lowest out of all the energy sources new build projects, when they are not submitted to specific, undue taxes.

After the stress tests, safety upgrades have been decided and they are included in the LTO generation costs. Including all those costs, LTO option still remains very competitive[16].

Phasing out the nuclear power plants leads to higher costs and higher CO_2 emissions.
For example, in 2013 in Germany, if nuclear wouldn't be available and the capacity would be allocated proportionally to other energy sources (see figure 4), would increase CO_2 emissions by around 50 million tonnes/year, representing 15% of Germany's GHG emissions. But currently the phased-out nuclear capacity is not allocated proportionally with the other sources, being noticed an intensive switch to coal, making the CO_2 emissions increase even more severe.

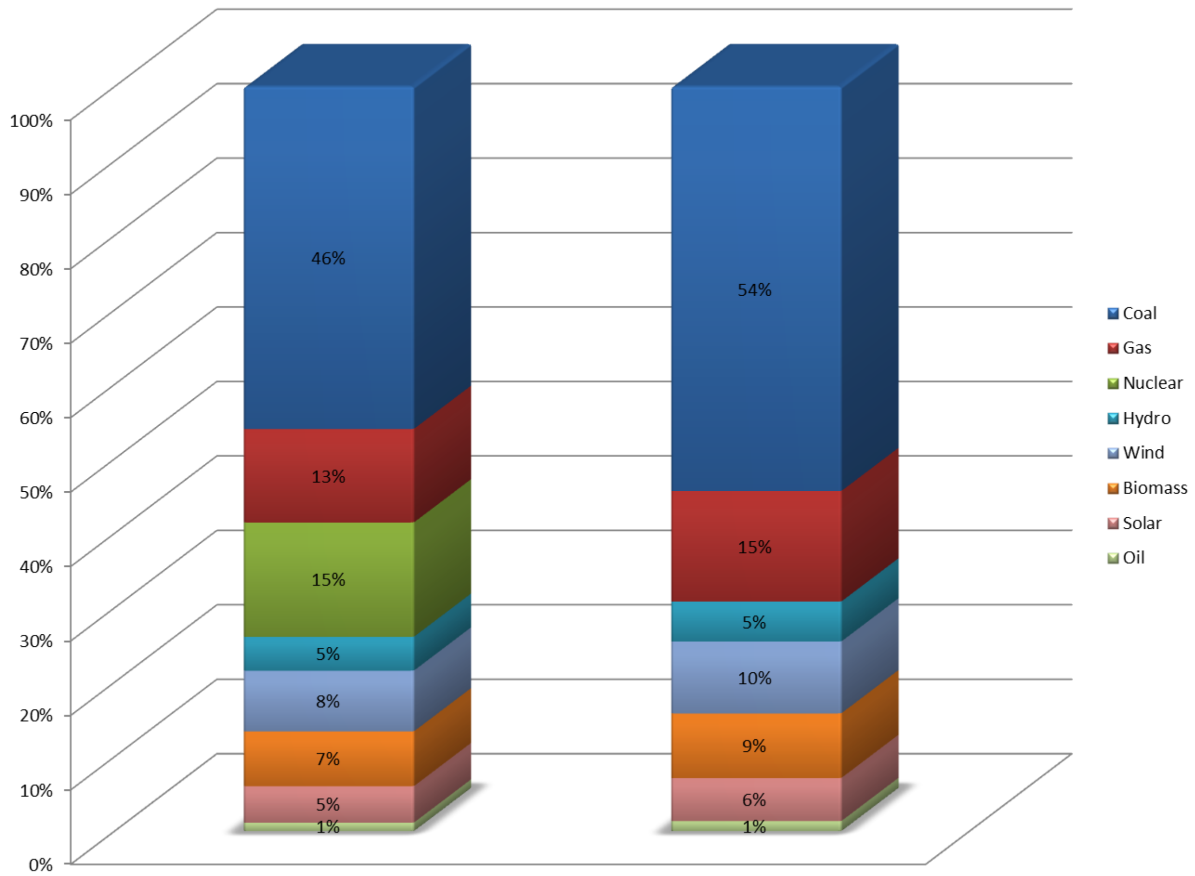

Fig.4 Comparison of electricity mixes in Germany in 2013 with and without nuclear – FORATOM own calculations

RES with gas back-up can easily result in a system with greater emissions than coal when the impact of methane leaks and life cycle analysis are taken into account, depending on the state of the gas infrastructure.

Operating NPPs are proven to be reliable and competitive with LTO through lifetime extension and investments for safety upgrades. For the 2030-2040 timeframe, LTO is expected to have been applied to more than 50% of the entire nuclear fleet in operation.

[16] Les coûts de la filière électronucléaire - Repport de Cour de Compte Français, 2012

Several EU countries are deciding LTO after refurbishment/safety upgrades of nuclear reactors that reached or are close to reach the operation lifetime:

- Belgium decided to extend the operation lifetime of Doel 1&2[17] and Tihange 1 reactors, remaining to further decide for the rest of operating reactors (Doel 3&4 and Tihange 2&3) as the designed lifetime not being reached yet. Belgium's current policy to close all nuclear power plants between 2022 and 2025 should be relaxed to let the NPPs run as long as the regulator considers them safe, IEA said in a review of the country's energy policy[18]. IEA also said shutting the reactors would seriously challenge Belgium's efforts to ensure electricity security and provide affordable low-carbon electricity.
- Finland performed refurbishment at Loviisa 1&2[19] and secured generation for the duration of the operating licences – until 2027 (Loviisa-1) and 2030 (Loviisa-2).
- Bulgaria signed a lifetime extension contract with Russia for Kozloduy 6[20].
- In Hungary, the lifetime of Paks 1 and 2 reactors was extended with 20 years[21].
- In France, EDF forecasted the lifetime extension costs of all 58 French reactors by ten years at 55 billion €.
- The Czech Republic decided to extend the operation lifetime of Dukovany NPP.
- UK is planning to perform life extension of AGR reactors to keep them on operation up to 2030 latest[22].
- Slovenia and Croatia decided to extend the operation lifetime of Krsko NPP with 20 years (until 2043)[23].

2.3 Nuclear New Build

According to EC-PINC, 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. 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.

The capacity replacement up to 2050 will most likely be achieved with the most advanced Generation 3 reactors.

According to this scenario, more than 80 GWe of new nuclear capacity would have to be commissioned until 2050. That should be regarded as the low scenario, while the reference scenario in line with EU climate and energy policy objectives would target 120 GWe in 2050 and 100 GWe new build to be commissioned until 2050.

One condition for such a scenario to be realised is the competitiveness of nuclear new build. In table 1 are presented, according to OECD IEA-NEA study[15], the LCOE for the projects to

[17] NucNet article – 29/12/2015

[18] NucNet article – 19/05/2016

[19] NucNet article – 04/01/2016

[20] NucNet article – 29/01/2016

[21] NucNet article – 28/11/2014

[22] NucNet article – 18/04/2016

[23] NucNet article – 11/05/2016

be commissioned in 2020 that is likely to happen when cost of capital is moderate (discount rate =7%).

USD/MWh	France	Germany	United Kingdom
CCGT	97	103	103
Coal	-	**76**	-
Nuclear	**83**	-	**101**
Onshore Wind	91	93	124
Offshore Wind	183	183	158 (Round 2)
Solar PV-large	134	127	168

Table 1 LCOE (USD/MWh) at Discount Rate = 7% and CO_2 = 30 USD/t

However, the discount rate value reflects the cost of capital, which will vary with the technologies, depending on the level of risks each one is exposed to. A value of 10% will be more representative for risky projects. As shown in Figure 5, for a value of discount rate of 10%, coal and gas plants are the cheapest but nuclear and on-shore wind are still near them, as the most competitive low carbon technologies.

In those estimates, overnight construction costs in the range 3700-4500 Euro/kWe have been projected in Europe, anticipating cost reduction of 15-25%[14] with respect to the First Of A Kind projects now under construction. Such cost reduction integrates several factors: overall return of experience, already qualified subcontractors and supply chain, design fine tuning and also less licensing costs. For example, the EPR has now been licensed in 3 European countries and it might be expected that licensing in a fourth country would rely on the cumulated sum of safety assessments available.

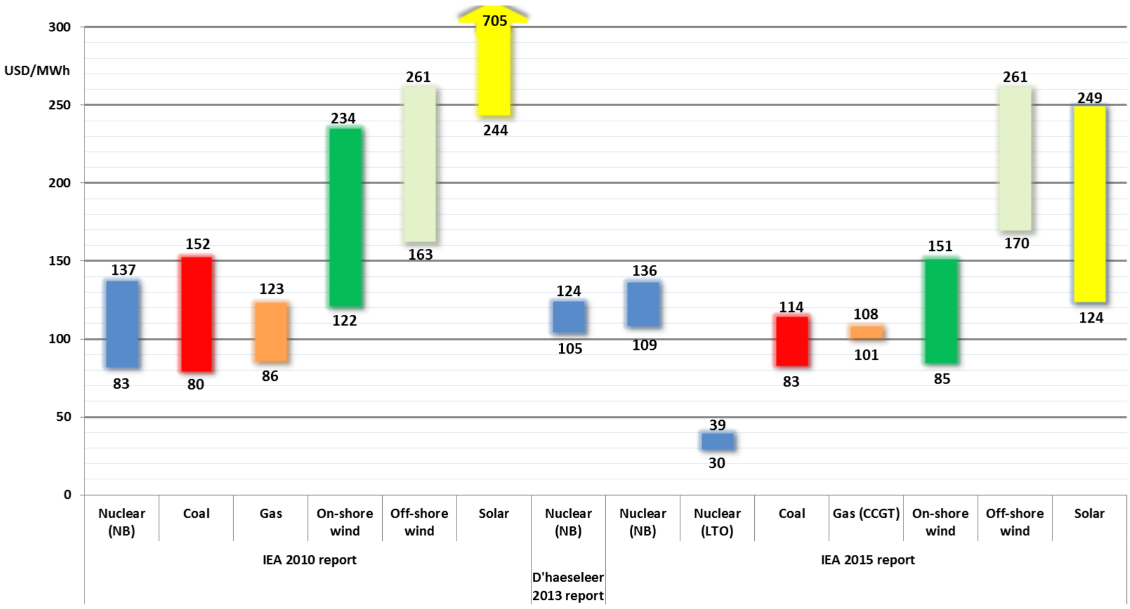

Fig.5. Comparison of LCOE (Levelized Cost of Electricity) for different technologies in Europe - 10 % discount rate scenarios – CO_2 = 30 USD/t (20 Euro/t)

LCOE is a useful tool for comparing the unit costs of different technologies over power plants' operating lives, and it was used by IEA to estimate the cost ranges for generating electricity from various low-carbon sources and fossil fuels.

The latter induce more costs in the electricity supply system than at bus-bar outlet to the grid. The so-called system costs include profile costs (autocorrelations which do not fit the load variations, requiring back-ups), balancing forecast errors, and dedicated transport and distribution networks extensions. This is illustrated in figure 6. The system costs increase when the share of intermittent energies increases; and those costs should be carried by the intermittent generators. Simultaneously the average price on the wholesale market decreases, and more acutely the price when wind and solar are producing a lot at near zero marginal cost. That means a high share of intermittent energies generates negative impacts on the profitability of all facilities.

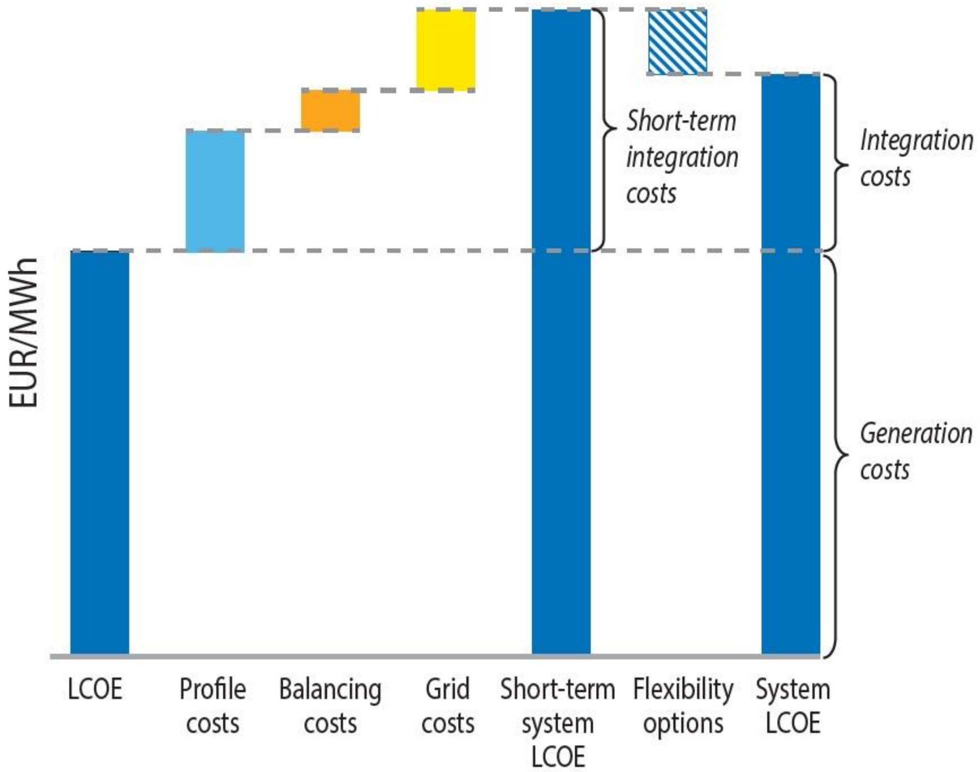

Fig.6 System cost approach – IEA report on Projected Costs of Generating Electricity – 2015 edition

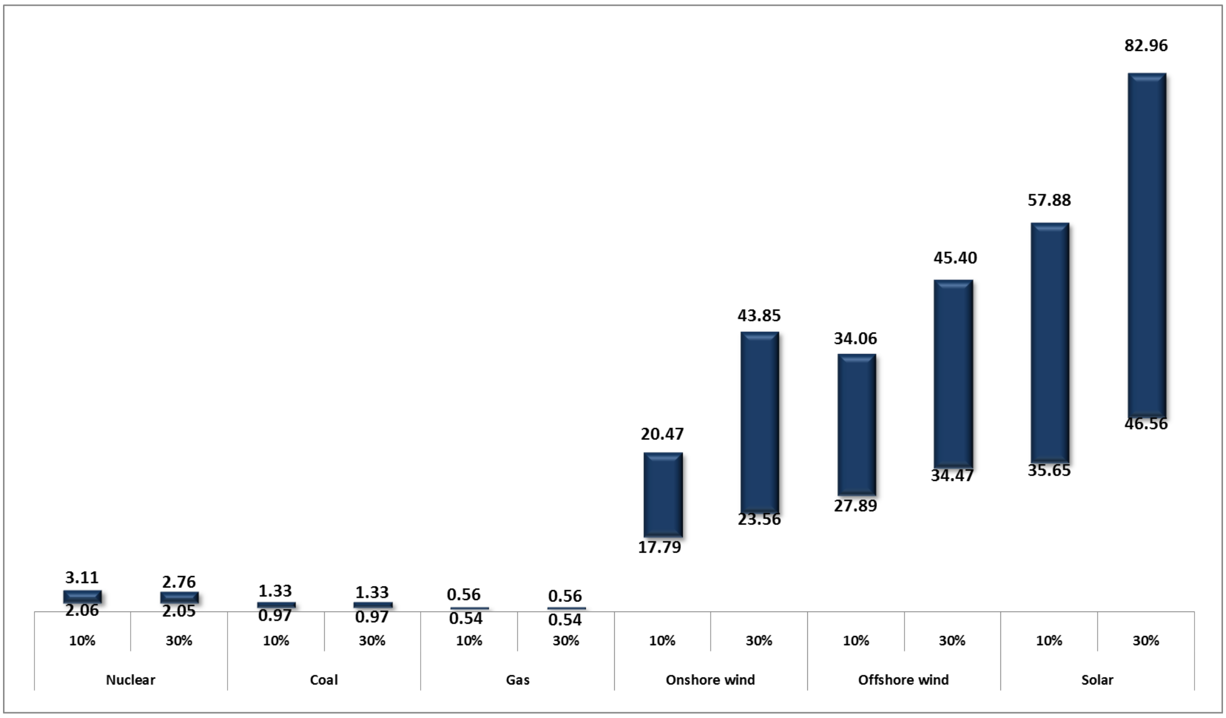

Fig.7 Grid-level system costs in different European countries (minimum and maximum prices for aggregated data for Finland, France, Germany and UK) (USD/MWh) – OECD-NEA report on Nuclear Energy and Renewables – System Effects in Low-carbon Electricity Systems (2012).

Note: System costs were calculated at 10% and 30% penetration levels of the main generating sources

2.4 Financing issue

The cost of capital (WACC) determines the investment cost and nuclear power competitiveness. For example, decreasing WACC from 10% down to 5% would reduce a new project LCOE value by 40%. WACC high value for nuclear projects reflects the perception of risks attached to the project, since a nuclear new build is subject to political risks (change of legislation), market risks (price volatility) and project risks (construction delays and overcosts). While nuclear industry has to reduce nuclear specific construction risks, it is also necessary to reduce market risk down to a level compatible with low carbon technologies which all are capital intensive projects; that means long term arrangements should be allowed such as long term contracts or CfDs, protecting against electricity price volatility on the wholesale market.

Currently, the wholesale electricity prices in the Europe are in the range of USD 30-50 per megawatt hour (MWh). These are far too low to recoup investment costs and could remain low for most of the transition period if the current wave of subsidized low-carbon investment leads to prolonged excess capacity.

During the transition, government intervention is necessary to promote long-term arrangements. Low-carbon investments are capital intensive and this cost structure does not fit well with short-term marginal costs due to carbon price risk and fossil fuel price risk. Long term arrangements can provide visibility and mitigate risks for investors and keep financing costs low.

Market-driven instruments including long-term contracts can offer revenue stability and are needed if Europe is to meet its goals to decarbonise its power system at an affordable cost while ensuring security of supply. The challenge now for policy makers is to reintroduce long range marginal costs in the market mechanisms driving investment decisions.

	Germany	United Kingdom
Coal fired	6.9%	--
CCGT	6.9%	7.5%
Large hydro	6.7%	5.8%
Solar PV large ground	5%	5.3%
Onshore Wind	5%	7.1%
Offshore Wind	7.5%	10.1%
Nuclear	--	9.5%

Table 2 - WACC values in European power plant projects – IEA report on Projected Costs of Generating Electricity – 2015 edition

As concerns the policy and regulatory risk, it will vary from one Member State to another, depending on national consensus or controversies with respect to nuclear energy. At EU level however and under EURATOM Treaty, some general in principle support to nuclear energy should remain the rule. That would extend to the a priori explicit openness to financial support (loans, loan guarantee etc.) from the European institutions. When explicit, such in principle support would reduce the risk perceived by investors.

2.5 European technology leadership

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.

2.5.1 Supply of nuclear fuel

The European nuclear industry is leading on fuel cycle technologies and maintains strategic assets in the EU. Ongoing investments to maintain and modernize the European fuel cycle facilities and to retain the current level of security of nuclear fuel supply include upgraded conversion facilities and increased capacities of enrichment by ultra-centrifugation. Mining assets are also secured through investments outside Europe (e.g. participation to Cigar Lake new mine started in 2014 in Canada).

2.5.2 Reactors

The EPR reactor is, for the time being, the only Generation III reactor currently licensed for new build in European Union (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 Hitachi-GE ABWR). The EU is also a worldwide leader in products and services for nuclear reactors currently in operation. 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.

2.5.3 Used Fuel and Waste

The EU is a world leader in the reprocessing and recycling of used fuel, radioactive waste management and final disposal.
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. 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.
EU is a world leader on final geological waste disposal where countries such as Finland, Sweden and France are at the forefront in the preparation for final deep geological disposal.
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.

2.5.4 R&D and Innovation

Research is ongoing to develop the next generations of fission reactor – both thermal and fast reactors – as well as small modular reactors. In addition, research into technologies for decommissioning of nuclear facilities, waste minimization, management and disposal remains central for maintaining the long term role of nuclear power.

Nuclear R&D is an integral part of the EU priorities as part of the Strategic Energy Technology (SET) Plan and is supported by the industry through the Sustainable Nuclear Energy Technology Platform (SNETP).European R&D in nuclear energy on operating and currently constructed reactors, as defined within the SNETP by NUGENIA, is supported to a limited extent in the EU research programmes. Beyond existing reactor technologies, the EU also supports the European Sustainable Nuclear Industrial Initiatives (ESNIIs) which addresses the need for demonstration of Gen-IV fast neutron reactor technologies, together with the supporting research infrastructures, fuel facilities and R&D work.

Examples of the potential benefits of nuclear R&D and innovation for the overall EU energy strategy are numerous. For instance, R&D in instrumentation and control can further improve the flexibility of existing nuclear power plants that could support the integration of renewables in Europe. R&D is also paramount in the process of continuous improvement of safety features on new and existing reactors. Regarding Gen-IV reactors and advanced nuclear fuel cycles, a number of projects are taking place and being supported by the European Commission for building demonstrators in the 2030 timeframe. The goals of Gen-IV reactors, as defined by the Gen-IV International Forum, on sustainability, economics, safety and reliability and proliferation resistance and physical protection are ambitious, and can only be achieved through a strong commitment on R&D on all these domains.

The importance of nuclear R&D for the EU is reflected in the 2016 PINC document that underlines in its conclusion that “continuous investment in nuclear R&D activities will be essential” if the EU is to maintain this leadership.

Consequently, EU fission research funding should be increased to a level commensurate with the potential of nuclear to make a major sustainable contribution to future low carbon energy supplies and keep Europe’s leadership in nuclear technology. This importance of increasing public R&D expenditures in nuclear fission is consistent with the view held by the International Energy Agency (IEA) which recommends to triple existing funding if we want to meet out climate change objectives and recognizes that nuclear will be an important and necessary contributor to meet these climate objectives.

Beyond existing EU R&D funding available primarily through the H2020 programme and EURATOM loans, the low carbon contribution of nuclear should also be fully recognized to allow nuclear to access dedicated funding mechanisms for innovative low carbon technologies. For instance, this includes mechanisms based on the sales of emission allowances from the EU emissions trading system (EU ETS) and managed by the European Investment Bank. The current NER 300 restricts funding to CCS and renewable technologies and the availability of this mechanism to innovative nuclear technologies should be considered for the next phase of the programme.

3. PINC

On 4th April 2016, EC published the new "Nuclear Illustrative Programme" – PINC[9], the last such publication being dated in 2007 (updated in 2008).

Analysing the document, FORATOM drafted some comments, showing the views of the European nuclear industry on the proposed programme:

General

Article 40 EURATOM calls for the PINC "to indicate in particular nuclear energy production *targets* and all the types of investment required for their attainment". As far as we can see, the draft PINC contains **no targets**. There are numerous forecasts and projections of what the EC expects to happen and what the associated expenditure might be, but there is no EC *nuclear investment policy*.

Moreover the document takes a very "dispassionate" view of the future of EU nuclear. It's almost as though the EC is a completely passive actor. The document refers to the positive aspects of nuclear (for example that nuclear provides half of the EU's low-carbon electricity and is a major contributor to security of supply) but there is no statement that nuclear should play an important role in meeting EU energy & climate targets, that the nuclear share of electricity should be maintained, that the lives of NPPs should be extended, or that replacement plants should be built, for the common good of the Community. This passive approach is not in line with the spirit of the EURATOM Treaty.

Nuclear market

In its opinion on the Energy Union adopted[24] on 15 December 2015 (rapporteur M.Grobarczyk), the European Parliament "calls on the Commission to ensure the EU provides an enabling framework for those Member States that wish to pursue new nuclear power projects to do so, within EU internal market and competition rules". The PINC provides a golden opportunity for the Commission to put forward, or at least to propose the essential components of this '**enabling framework'** but this issue is not addressed at all.

[24] EP ITRE - Towards a European Energy Union INI report

As well as the challenges the current electricity market presents to future investments, we believe the PINC should also be addressing the **severe economic context** in which nuclear plants are currently operating (declining electricity demand, lower wholesale prices resulting from a market oversupplied with low variable cost technologies, lower carbon price, high nuclear tax burden) which has led to the early retirement of nuclear plants.

Decommissioning

The document mentions that only 3 reactors have so far been completely decommissioned, but could have added that this is not so surprising given the policy in most Member States of deferring decommissioning to allow for radioactive decay. There is also no reference to decommissioning of non-reactor facilities.

Fuel Cycle

The ‘back end’ part of the Communication focuses only on the challenges of waste management and decommissioning and makes no assessment or recommendation regarding the value of spent fuel recycle. The future deployment of commercial fast-breeder reactors, with a step change improvement in sustainability, will depend on the availability of reprocessing and an adequate supply of plutonium.

As a conclusion, in our view the PINC should set out a clear **roadmap for nuclear investment**. If nuclear energy is to remain an important contributor to low-carbon energy production, there needs to be a positive investment climate for new build and LTO. In our view, the PINC should be helping much more to create that positive climate.

4. Recommendations

a. Actions on market design are needed to restore confidence among potential investors in power generation projects of all types, but in particular in large scale low carbon generation projects:

- to be introduced long-term price signals that can lead to an adequate level of investments;
- to be implemented instruments mitigating the exposure of plant revenue to electricity price volatility risk such as:
  - bilateral long term contracts or Contracts for Difference ;
  - a modulated market premium until ETS carbon price has firmed up, as proposed by IEA.
- In the long term, since with low carbon technologies the cost of electricity supply will no longer be driven by variable costs but mainly depend on upfront investment cost, the market design will have to ensure competition **to** the market rather than competition **in** the market.

b. The following principles are fundamental to an efficient market:

- No discrimination between technologies, competition being based only on their performances: electricity supply cost, security of supply, carbon emission;
- 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 internalized and allocated equitably.
- More generally, the market will deliver the expected results if all externalities are internalized: as charges (CO_2 emissions and other environmental impacts) or as benefits to be rewarded (security of supply)

c. EU ETS as the main instrument of decarbonisation has to be reformed as soon as possible, in line with the ambitions of the COP 21 commitment and 2030 targeted emission reduction of 40%. If there are conflicts which make the current ETS ineffective, such as policy overlaps, they have to be removed by adjusting ETS allowances in order to strengthen its predictable function. CO_2 climate cost should be internalized in electricity prices through the ETS.

d. The Commission should make clear the importance of nuclear power to achieve climate action goals at reasonable cost, as it was recognized in Energy 2050 Roadmap scenarios. The EU should facilitate projects by providing a stable and harmonised regulatory framework and should not impose more constraints beyond those that individual MS have already added (e.g. specific taxation). The recent PINC Communication lies well under its mission when no clear objective is proposed to nuclear energy, and no more adapted framework proposed to make investments possible. The PINC Communication[9] should be updated in that respect.

e. The European Investment Bank, should ensure that funds are made available for high quality projects, including technology demonstration projects, and Government and EU support should be 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.

f. Technological and industrial independence. The Commission and MS should reinforce the support to nuclear fission R&D and pilot demonstrations (SNETP, SET Plan). Or the risk is to lag behind other regions (USA, China, and Russia) where nuclear technology development is strongly supported.