Contributions of the working groups

Bratislava 2014

European Nuclear Energy Forum

Bratislava - Prague

TABLE OF CONTENT

Document 1:
ENEF Answer (endorsed WG OPP June 2013) to the EC consultation on the Green Paper 2030 Framework for Climate and Energy Policies..**1**

Document 2:
ENEF Answer (endorsed WG OPP April 2014) to the EC consultation (DG COMP) on the Hinckley Point C case……………………………………………………………….**16**

Document 3:
Severe Nuclear Accident and Assumptions for Third Party Liability Costs (endorsed WG RISKS January 2014)……………………………………………………………….**39**

Document 4:
Elements for a possible EC Recommendation on harmonised conditions for safe long-term operation of NPPs in the EU (endorsed WG RISKS April 2014)...............**56**

Document 5:
Feeding the European debate on energy-mix for the electricity supply system (endorsed WG OPP and RISKS May 2014)……………………………………………....**65**

Document 6:
Multicriteria Assessment of energy mixes - Working Paper of WG OPP and RISKS, serving as annex to the previous document 5…………………………………………..**68**

Document 7:
Society and Energy – Deciding the Future – The need for analysis, transparency and dialogue in determining the energy mix – a proposal from the ENEF – Working Paper of WG TRANSPARENCY...**80**

Document 1:

ENEF Answer (endorsed WG OPP June 2013) to the EC consultation on the Green Paper 2030 Framework for Climate and Energy Policies

WG Opportunities

Sub Working Group "Competitiveness"

ENEF ANSWER TO

EUROPEAN COMMISSION GREEN PAPER

A 2030 FRAMEWORK FOR CLIMATE AND ENERGY POLICIES

Introducing Statement

The contribution of nuclear power to EU 2030 energy and climate strategy

With around 15% (122 GWe) of the total installed capacity, nuclear energy currently produces around 30% of the EU electricity. Nuclear energy is a clean, affordable and reliable source of energy. The current fleet of nuclear reactors operating across Europe is a strong asset base supporting EU competitiveness:

- Through cost effectiveness
  - Nuclear electricity is competitive with electricity from fossil fuels.
  - The cost of nuclear electricity is stable and predictable due i.a. to a low proportion of the cost of fuel in the overall cost of nuclear electricity
  - And for Europe's energy intensive industries, stable, predictable and affordable energy prices provide a strong foundation for economic growth and jobs creation in the EU.
- As a basis of industrial development
  - The global growth of nuclear power in the years to come has strong potential.
  - European Union must maintain its industrial and technological leadership in nuclear operations and new build
  - EU and Member States must encourage a positive investment climate for the energy sector to compete successfully in the world's economy.
  - The Nuclear industry embeds a wide range of high technology skills requiring high skilled engineers and R&D. The skills developed in the frame of nuclear industry also provide benefit to other sectors

The nuclear fleet supports 250,000 direct jobs and around 800,000 jobs in total, in the EU (**Reference 1**).

For many power producers, when they are considering future generation capacity needs, the first choice is the long term operation of the existing nuclear power plants. Lifetime can be extended beyond 40 years, at least up to 60 years whilst continuing to meet the highest safety standards. Lifetime extension to 60 years is a fact already for many plants worldwide and within the EU. That means that in 2030 a significant share of the existing plants will still be operating: e.g. about 90 GWe if the average lifetime is 50 years. Moreover, new nuclear plants are under construction or planned, so that more than 100 GWe of nuclear capacity is expected in 2030. That means in 2030 the EU can still benefit from a balanced, cost efficient and low carbon energy mix.

Which energy strategy for 2030?

European energy policy is founded upon the three pillars of sustainable development and is implemented in the power sector through the internal electricity market. Very significant milestones will be reached: the completion of the internal market in 2015 and the 3x20 targets in 2020. It is now time to look beyond 2020 and to propose subsequent possible paths towards a decarbonised energy system, following the approach of Energy Roadmap 2050. On the path from 2020 to 2050, we now need to define the energy system we want by 2030 and beyond since investments decided now will determine the system for a long time.

As the most compelling priority, Europe should target **a balanced achievement of the three objectives**: security of supply, competitiveness and decarbonised energy.

Decarbonising: possible but not at any cost

The objective of decarbonised energy looks achievable in the scenarios described by the EC Communication on Energy Roadmap 2050. The common features of all those scenarios are the strong increase of electricity share in total energy consumption and the strong decrease of oil and coal consumption. In the electricity sector, that means the energy mix would mainly include renewables, nuclear and gas. However, important questions are raised also.

First, it is assumed in all the decarbonisation scenarios that global fossil fuel prices will be lower than in the more recent "Reference scenario" (reflecting current trends): e.g. an oil price of 79 USD/bbl is assumed in 2030 whereas in the last IEA/WEO (2012) the trend towards higher prices is confirmed, at 125 USD/bbl in 2035. The lower prices in those scenarios are derived from the assumption of a global commitment on climate change mitigation policy, driving a reduction of global fossil fuel consumption. Clearly, the EU would embark on thorough decarbonisation only if the other regions were also committed to strong reductions of GHG emissions. That means that as long as the commitment of the other regions is not warranted, the EU had better follow "no regret" pathways, i.e. the EU should not put at risk its competitiveness through a singular and extravagant climate policy: the extra costs induced by the deployment of low carbon generation should be kept moderate**.**

Second, the different decarbonisation scenarios should be analysed carefully, since they are likely to display varying performances with respect to the system reliability, total electricity generation capacity requirements and **the total cost of electricity supply**. They rely on different shares of renewables, nuclear, CCS and gas, require different transmission and distribution network solutions (and costs), and require different storage solutions/capacities and costs (which are very high when the share of intermittent renewables reaches 80% or more). Those issues are analysed in **Reference 2** and it is clear that scenarios with a significant share of nuclear (20% to 30%) are less costly and more robust (that is, less sensitive to the assumed input values in the long term) than those relying on a very high share of renewables.

Third, CO_2 emission price is a key driver in the decarbonisation scenarios, reaching values well above 50 €/t. Currently, the CO_2 price remains well below10 €/t. A prerequisite of decarbonisation is the proper functioning of the European Trading System (ETS). A more ambitious annual reduction of the cap has to be planned and imposed, but also protections against carbon leakage will have to be implemented. Moreover, since the vehicle of decarbonisation is the investment into low carbon technologies, it has to be driven by a compelling long term target. **Setting a target for GHG emissions in 2030 (e.g. -30% or -40% vs 1990) is essential to drive the electricity market towards the decarbonising path.**

The value of secure electricity supply

In the power sector, security of supply means satisfying two conditions together.

First, the long term security of supply will be ensured through a lower dependence on imported oil and gas; lower dependence is required to decrease the vulnerability to fossil fuel price volatility, to minimise the consequences of any disruption of supply, to improve the negotiating position of the EU when confronted by a limited number of producing countries/suppliers and to improve the trade balance of EU. Decarbonising scenarios in the Energy Roadmap 2050 would achieve a level of import dependency limited to 55% in 2030 and lower than 40% in 2050.

Second, in the short term and on a permanent basis, the reliability of electricity supply through the grid is a paramount condition for all households and all sectors of the economy. The current electricity supply system in the EU Member States was built to comply with a high level of quality (frequency and voltage stability) and a very low risk of disruption. All the components of the system: energy mix, generation technologies, transport and distribution networks contribute to this objective.

Clearly on the latter point, the increasing share of intermittent energies in power generation raises new issues. The rest of the supply system is requested to adapt to their expansion, implying more extensive grid connections, added dispatchable back-up capacities, storage capacities, demand side flexibilities, and a wider variation range of frequency and voltage. As a result, significantly higher system costs are necessary to obtain the same level of reliability. The additional system costs grow with an increasing share of intermittent renewables. This issue has been quantitatively assessed in **Reference 3,** showing the added costs in several EU countries. For instance, when RES penetration reaches 30%, the extra system cost induced by onshore wind reaches more than 20 Euro/MWh, to be added to a generation cost about 80 Euro/MWh; in the case of offshore wind, it reaches more than 30 Euro/MWh, to be added to a generation cost about 130 Euro/MWh. The study shows that no averaging effect should be expected when expanding RES production and that system costs tend to diverge with RES expansion.

Assessing true competitiveness

Competitiveness should be assessed through the electricity price for the end consumer. The price will depend on many factors: total cost of supply, but also electricity market dynamics, price regulation in some countries, taxes varying from one country to another. The deployment of renewable energies also influences the prices, but in a strange way: they can depress the wholesale market price (driver: the marginal cost) while increasing the end user price at the same time (driver: RES development financed through non-energy taxes and levies). For example, in 2013 in Germany, the price on the electricity wholesale market has fallen to 45 Euro/MWh as elsewhere in Europe but the households do not benefit from this decrease, they are paying highest ever prices well above 250 because of an added “EEG” surcharge reaching 53 Euro/MWh, (and financing the investments in renewable energies). The costs have to be paid somehow by somebody. It is of prime importance to carefully assess all the system costs (as proposed in Ref 1 and 2) and to examine carefully how they are likely to evolve in the future, depending on all the relevant drivers. Learning effects will drive the investment costs downwards for offshore wind as well as for Generation 3 nuclear plants, but other drivers may counteract, such as the growing scarcity of “good sites” with favourable wind and soil conditions. The demand for underground lines in more and more areas may also increase the cost of transmission and interconnections. Since electricity prices in the EU are already higher than in other regions, it is important to select the most cost efficient paths towards decarbonisation and security.

We conclude that reaching a balanced combination of the three objectives calls for a balanced energy mix. Every component has a role to play. Targeting too high a share of intermittent renewables would be counter-effective. It would raise several uncertainties about generation adequacy, grid stability, needs of new technologies for storage and resulting system costs. Current experience in several EU countries suggests that problems become significant above a share of 40% of generation. Nuclear energy should therefore remain a key component of low carbon energy mix, supplying base load electricity at low cost and contributing to grid stability. For peak load, low investment dispatchable means of generation such as gas fired turbines would remain the favoured option. **For that reason, no new specific target on RES share in 2030 should be set: the market should find by itself the most appropriate mix to reach the decarbonisation target while ensuring highest possible competitiveness and security.**

A last important question has to be discussed. Is it sufficient to set a CO_2 target to orient the internal electricity market towards the balanced mix of policy objectives? Past experience suggests that even with a relatively high price of CO_2 the lifecycle cost of combined cycle gas turbines may remain the lowest when the cost of investment of nuclear power and renewables is penalised by high cost of capital. Low carbon technologies such as nuclear power, offshore wind, coal plants with CCS all are characterised by a high upfront cost of investment followed by low cost of operation, as opposed to gas plants. Financing such high investments is difficult on a market with many uncertainties (future regulation changes, volatile gas and electricity prices, etc…). In a short term approach the investors will rather turn towards gas plants lower investment: without dedicated policy, no decarbonisation of the mix will happen. Then public support to investment in low carbon technologies can help under different forms (loan guarantees, tax credit, EIB loan, etc…); and it is justified under a set of conditions:

- The supported investments contribute to public goods (here, climate protection and energy security).
- The support remains technology neutral = no low carbon technology is excluded.
- The support is allocated to "First Of A Kind" projects in priority since successful project return of experience by "first movers" will give confidence to others.
- The long term view is necessary to hold on the orientation and it is the role of public policy to encourage a long term approach.

From a balanced triangle of objectives, we derive the need of a balanced energy mix. And from this needed balanced energy mix we derive the recommendation of a balanced support to investments in low carbon technologies, including nuclear power.

****

Reference 1: Socio-economic benefits of the nuclear industry in the EU to 2050 (ENEF April 2013)

Reference 2: Evolution of Electricity Costs**,** KEMA Final Report to DG ENER, January 2013 http://ec.europa.eu/energy/nuclear/forum/opportunities/competitiveness_en.htm

Reference 3: Nuclear Energy and Renewables, System Effects in Low-carbon Electricity Systems, OECD/NEA 2012

ENEF ANSWERS TO EUROPEAN COMMISSION GREEN PAPER

4.1. General

Which lessons from the 2020 framework and the present state of the EU energy system are most important when designing policies for 2030?

- Contradiction between RES support instruments and electricity market is resulting in high electricity prices for the end consumer in spite of low wholesale market prices, the latter discouraging new low carbon investments such as nuclear. This has potential future negative consequences on generation adequacy and CO2 emissions.

- The EU is losing competitiveness because of high consumer energy prices while the rest of the world is emitting more CO2 (global +1.4% in 2012, record high at 31.6 Gt according to IEA)

- The EU is not insulated from the rest of the world and this has hampered the effectiveness of 2020 framework.
  - The impact of international fossil fuel market prices: no more switch from coal to gas but the reverse, more coal fired plants are being built and operated because of lower prices of coal and of CO2 emissions, with a long term negative impact even if they are supposed to be "capture ready".
  - The carbon leakage and suffering electro-intensive industry.
  - Excessive support to buyers of renewable energy technologies has created a deceiving boom, opened the way to Chinese dumping and led to the collapse of European -PV industry.
  - The lack of new nuclear power programs in the EU is impacting European industry and leading to decreasing European nuclear leadership to the benefit of Asia and Russia.

- Security of supply, meaning fuel supply, generation adequacy and reliability of electricity grid, is an important component of energy policy. But the rising share of intermittent sources, such as solar and wind, makes it more difficult to ensure adequate and reliable electricity supply. Back-up capacities such as CCGTs are supposed to be connected when solar and wind generation weaken, but investing in such back-up units is not profitable today because the expected electricity price is uncertain at best and the expected load factor too small. Reserve capacity is needed but it has to be rewarded somehow. The effective installation of more interconnections and storage will help but will take time.

- 2020 target of minus 20% for GHG emissions looks accessible. However, in the short term CO2 emission price within ETS remains very low, too low to drive the market towards decarbonised generation. Decarbonising policy cannot be effective if capital intensive technologies are not incentivized by the market design, since most of low carbon technologies, such as nuclear, offshore wind, coal + CCS, are capital intensive. Only renewable energy technologies benefitting from subsidies and priority access to the grid have been able to increase.

- From above we conclude that the internal market in electricity has to be improved. Competitiveness and security of supply will deteriorate with further growth in the share of intermittent and subsidized renewable generation as postulated in some current post-2020 scenarios. An integrated technology neutral approach is necessary, leaving the market to operate.

4.2. Targets

Which targets for 2030 would be most effective in driving the objectives of climate and energy policy? At what level should they apply (EU, Member States, or sectoral), and to what extent should they be legally binding?

One target for each of the 3 policy objectives is recommended:

GHG emissions:
An ambitious GHG emission reduction target is the most important target to be set and implemented, such as -40% in 2030 compared to 1990 at EU level, with adequate burden sharing between Member States, legally binding. Each Member State will remain sovereign to decide on its energy mix contributing to the reduction of GHG emissions. Driving the market to meet the target essentially requires an effective ETS, where the cap evolution would ensure CO2 emission price high enough to foster investment in low carbon technologies.

Security of supply:
Non compelling targets should be proposed, at EU level.

- Long term security at EU level: energy dependency on import should be decreased (both in % GDP and by increased geographic diversity) by 2030, keeping in mind future competition between big energy importing regions: China, Japan, South Korea, India and EU.
- Short term security at MS level: within a more interconnected EU, harmonising the MS criteria for power generation adequacy, such as the annual disruption expectancy.
- Grid stability should not be degraded by future developments.
- Setting a target on GHG emissions and not on renewable share will benefit to security of supply since it will encourage the deployment of all low carbon technologies; in particular, nuclear energy deployment will have a positive effect on all aspects of security of supply (less fossil fuel dependence, generation adequacy, grid stability).

Competitiveness:
The role of a well functioning market should be emphasized; relevant performance indicators such as the Lifecycle Cost of Electricity supplied (LCOE), the total electricity consumer price, the cost per avoided ton of CO2, should be monitored at EU and MS level, to help comparison with other regions.

Have there been inconsistencies in the current 2020 targets and if so how can the coherence of potential 2030 targets be better ensured?

Yes, there have been inconsistencies:
1/ Setting a binding target on the share of renewable energies has led to a high cost per ton of CO2 avoided and at the same time it has accelerated the collapse of ETS price, which in the end discourages investment in unsubsidized low carbon technologies and so hampers long term reduction of emissions.
2/ Setting a target on reduction of primary energy consumption for the sake of energy efficiency can lead in some cases (e.g. heating) to replace low carbon electricity with fossil fuel, resulting in higher GHG emissions; reciprocally adding CCS to coal fired plants results in lower efficiency.

Coherence will be better ensured if only one binding target or benchmark is proposed <u>for each of the three pillars</u>. Moreover, coherence with the internal electricity market design has to be ensured, which means no market distortion should result from the targets per se. Setting a binding share for renewables, with strong support though grid priority and feed in tariffs, has strongly distorted the market and should not be proposed again.

Are targets for sub-sectors such as transport, agriculture, industry appropriate and, if so, which ones? For example, is a renewables target necessary for transport, given the targets for CO_2 reductions for passenger cars and light commercial vehicles?

No answer

How can targets reflect better the economic viability and the changing degree of maturity of technologies in the 2030 framework?

If no technology specific target is imposed, the market will select the most viable and mature technologies. For that reason no target value should be set for the share of renewable in electricity generation.

How should progress be assessed for other aspects of EU energy policy, such as security of supply, which may not be captured by the headline targets?

See above where non binding targets are proposed for security of supply.

4.3. Instruments

Are changes necessary to other policy instruments and how they interact with one another, including between the EU and national levels?

ETS needs structural improvement to effectively drive the market towards low carbon production.

Participants in the market should be allowed to use long term contracts.

Electricity market design should be adapted to better accommodate long term energy investments; low carbon technologies, such as nuclear power, coal power stations with CCS and offshore wind, are capital intensive; with the current market design price signals are based on fossil fuel prices and do not integrate long term objectives; they provide no incentive to invest in capital intensive technologies, which will bring high benefits in the long term.

How should specific measures at the EU and national level best be defined to optimise cost-efficiency of meeting climate and energy objectives?

Limit the number of policy targets, set them as stable and long term enough, do not impose the instruments to reach the targets, but rather ensure proper market functioning. The competitive market will ensure cost-efficiency.

Stability of decisions at EU level – no change every year

How can fragmentation of the internal energy market best be avoided particularly in relation to the need to encourage and mobilise investment?

Competitiveness/affordability and security of supply/reliability of low carbon energy should be the benchmark to judge the balance of investments in the EU. Noting the importance of nuclear in meeting the EU energy policy goals, MS should have the power to encourage investment in nuclear power.

Which measures could be envisaged to make further energy savings most cost effectively?

No answer

How can EU research and innovation policies best support the achievement of the 2030 framework?

In the long term, public funding of R&D is the most efficient instrument for public aid to new technologies. Shared R&D programs at EU level are an appropriate means to limit the total cost of development and should include nuclear energy.

4.4. Competitiveness and security of supply

Which elements of the framework for climate and energy policies could be strengthened to better promote job creation, growth and competitiveness?

Job creation and growth still rely on competitive industrial capacities in our modern economies. Climate and energy policies should not only drive the internal demand towards more efficiency and less carbon emitting services, but also drive the internal offer so that it can contribute at least partially to the new demand. Otherwise the EU will depend more and more on foreign technologies and industries. Lessons should be drawn from the current evolution of photovoltaic industry in the EU. That means a real industrial policy has to be developed, with priority for high technologies to maximise domestic added value and create more high level jobs.

The following objectives should be more strongly addressed in the framework:
- Minimising the total cost of electricity supply, which is a requirement to keep competitive industry in the EU - for a target of CO_2 emission reduction it means minimising the average cost per ton of CO_2 avoided;
- Supporting EU energy sector trump cards, such as the European nuclear industry;
- Negotiating balanced free trade arrangements with other regions to avoid the EU market is open to foreign actors much more than their own domestic markets.

What evidence is there for carbon leakage under the current framework and can this be quantified? How could this problem be addressed in the 2030 framework?

No answer

What are the specific drivers in observed trends in energy costs and to what extent can the EU influence them?

The first driver is the <u>international oil price</u> which is bound to remain high according to IEA. The EU needs to decrease dependence on oil, e.g. in transport sector. That means both more energy efficiency and a higher share of electricity in energy consumption.

The second driver is the <u>price of imported gas</u>. The EU will be in better position to negotiate with gas suppliers if competing alternative sources of energy such as nuclear energy are kept at sufficient level in the mix. Access to diversified sources of gas is also helping as already currently developed, but it remains difficult for a number of Member States.

The third driver is the <u>cost of new renewable</u> energies; it is an increasing burden as long as their share increases more quickly than their “unit cost” is decreasing through learning effect. Unit cost should be understood here as not only the cost of generation but also the impact on total system cost (need of back-up capacity, added grid costs, etc…). To foster the deployment of renewable energies, the use of Feed In Tariffs and free grid connection should be phased out in the long run. Technology neutrality should prevail in mean time. Other support schemes can help controlling the total costs: contracts for difference, premium tariffs, long term power purchase agreements, co-funding of demonstrators, etc…

The fourth driver is the cost of capital. The cost of capital is sensitive to risk perception by the investors. The EU policy can influence risk perception through more stable regulatory framework, through loan guarantees, through co-funding by financial institutions such as the European Investment Bank (cf ENEF Opportunities WG Report on Financing, Prague, May 2013)

How should uncertainty about efforts and the level of commitments that other developed countries and economically important developing nations will make in the on-going international negotiations be taken into account?

EU can pursue climate policy as a world leader but it should be at reasonable cost to remain competitive: a real "no regret" option should prioritise lower cost solutions as long as other regions are not really embarking in the same constraining climate policy. That means minimising the cost of low carbon energy, by keeping a sufficiently high share of nuclear energy, through Long Term Operation and new build.

How to increase regulatory certainty for business while building in flexibility to adapt to changing circumstances (e.g. progress in international climate negotiations and changes in energy markets)?

Regulatory certainty and flexibility can best be ensured together if market regulation is focused on top level priorities without a priori specific technology picking: it should remain technology neutral. In the electricity market, value has to be clearly assigned to two top priorities:

- Reduction of GHG emissions, through the 2030 emission target and supported by a more robust ETS;
- Reliable and secure power supply, best ensured if the share of dispatchable power generation means remain sufficient.

The framework should orient the market towards the technologies offering the double value, being both low carbon and dispatchable. The market will select the most competitive among them. Nuclear power is one of them.

How can the EU increase the innovation capacity of manufacturing industry? Is there a role for the revenues from the auctioning of allowances?

NER 300 type tools should be open to all low carbon technologies including nuclear energy.

How can the EU best exploit the development of indigenous conventional and unconventional energy sources within the EU to contribute to reduced energy prices and import dependency?

No answer

How can the EU best improve security of energy supply internally by ensuring the full and effective functioning of the internal energy market (e.g. through the development of necessary interconnections), and externally by diversifying energy supply routes?

Diversity of energy sources and origins, diversity of technologies and domestic industrial know-how and capacity are the main contributors to security of supply.

Limit the share of intermittent sources, which are inducing instability of the grid, calling for costly counter-measures (e.g. back up capacity and storage).

As concerns grid infrastructure, give priority to interconnections rather than to RES specific expensive connections.

Foster peak shaving by interconnection, storage, and demand side management (smart metering)

Keep nuclear power as base load.

4.5. Capacity and distributional aspects

How should the new framework ensure an equitable distribution of effort among Member States? What concrete steps can be taken to reflect their different abilities to implement climate and energy measures?

The new framework should ensure that the right for a MS to select its mix is not hindered by other MS.
Incentives as regards achieving the targets could be set up.

What mechanisms can be envisaged to promote cooperation and a fair effort sharing between Member States whilst seeking the most cost-effective delivery of new climate and energy objectives?

No answer

Are new financing instruments or arrangements required to support the new 2030 framework?

Since the market has not delivered till now (ETS price low and the wholesale electricity prices low) and will not in the near future, <u>specific long term financing mechanisms</u> tailored to reaching the new targets and related developments of the 2030 framework have to be defined. They should be common to all Member States. National grants and subsidies should be progressively phased out in order to leave room for long-term financing sources priced on commercial terms. A clear long-term vision strongly expressed by the EU as a whole would support the mobilization of the large funding requirements attached to transition to low carbon energy. A set of clear milestones and long-term goals and a stable regulatory framework would help. This is all the more important that a substantial proportion of such funding needs will have to come from the private sectors.

Document 2:

ENEF Answer (endorsed WG OPP April 2014) to the EC consultation (DG COMP) on the Hinckley Point C case

WG Opportunities

Sub Working Group "Competitiveness"

ENEF ANSWER TO

EUROPEAN COMMISSION

PROCEDURES RELATING TO THE IMPLEMENTATION OF COMPETITION POLICY
STATE AID — UK

(Document approved by the Chairs of the ENEF WG Opportunities and Risks)

State aid SA.34947 (2013/C) (ex 2013/N) — Investment Contract (early Contract for Difference) for the Hinkley Point C New Nuclear Power Station
Invitation to submit comments pursuant to Article 108(2) of the Treaty on the Functioning of the European Union
(Text with EEA relevance)
(2014/C 69/06)

State aid SA.34947 (2013/C) (ex 2013/N) — Investment Contract (early Contract for Difference) for the Hinkley Point C New Nuclear Power Station

Introducing Statement

The comments submitted here by ENEF are addressing the following aspects of the Commission summary document, referring to the 3 major objectives of the European energy policy, to be considered as objectives of "common interest":

- Decarbonise power generation
- Ensure security of supply
- Diversify the electricity mix and provide affordable energy for the consumers

According to ENEF, the positive and significant contribution of nuclear energy to each of those policy objectives means that the notified measure of the UK towards nuclear energy aims at the three common EU objectives. Moreover, there is sufficient evidence of a market failure: the electricity markets in the UK and more widely in the EU do not favour the low carbon technologies (renewables, CCS, nuclear) because the upfront investments are too high and the foreseeable electricity prices too volatile to encourage such investments.

The comments hereafter are derived from the documents produced by the ENEF Opportunities Working Group and from reference studies which could be discussed during ENEF working meetings.

Reference documents produced by ENEF which will be quoted:
[1]. ENEF SWOT-Part 1, April 2010
http://ec.europa.eu/energy/nuclear/forum/opportunities/competitiveness_en.htm
[2]. ENEF SWOT-Part 2, May 2012
http://ec.europa.eu/energy/nuclear/forum/opportunities/competitiveness_en.htm
[3] ENEF Financing Final Report
http://ec.europa.eu/energy/nuclear/forum/meetings/doc/2013_05_30/related_docs/enef_nuclear_financing_final_report_2013.pdf
[4] ENEF The contribution of nuclear power to EU 2030 energy and climate strategy
http://ec.europa.eu/energy/nuclear/forum/meetings/2013_may_en.htm, "Related Documents"

Comments added to the extracts in this answer are in italics.

COMMENTS WITH REFERENCE TO SPECIFIC PARAGRAPHS OF THE COMMISSION SUMMARY DOCUMENT

1/ ENVIRONMENTAL PERFORMANCE

(240)
The Commission notes that while Art 191 TFEU establishes that the preservation, improvement and protection of the environment must be regarded as objectives of EU policy, it is unclear whether such objective can be immediately applicable to low-carbon generation as defined by the UK. In particular, <u>while certain generation technologies emit less carbon emissions, their impact on the environment might nonetheless be considered substantial.</u> This seems to be particularly true of nuclear generation, due to the need to manage and store radioactive waste for very long periods of time, and the potential for accidents.
(241)
In this case, it is difficult to assess the trade-off between two potential common EU objectives, namely preserving the environment through the pursuit of low-carbon electricity generation while potentially increasing risks to the environment through the use of nuclear technology.
(246)
The Commission therefore is not clear at this stage on whether the notified measure can be argued to be aimed at a common EU objective in terms of environmental protection in general, and decarbonisation in particular.

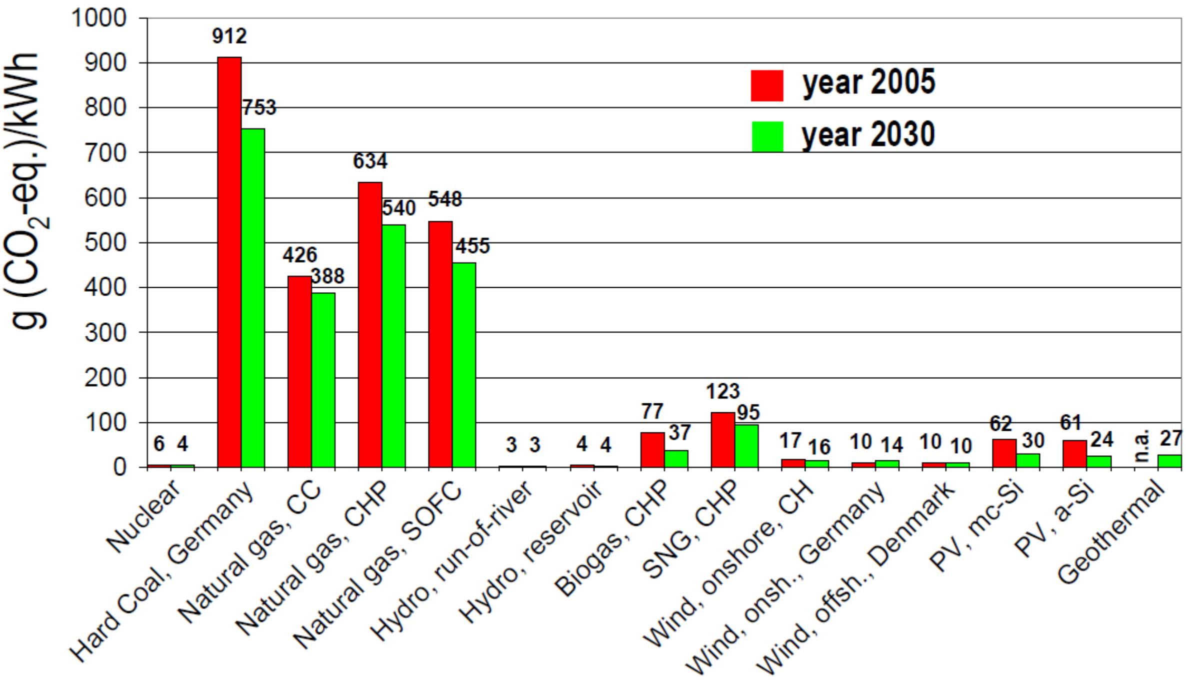
The Commission statement above is questionable. First, the radioactive discharges from nuclear facilities to environment are minimised, monitored, declared and controlled; their impact on populations and ecosystems is assessed and negligible under normal circumstances. The risk of accidental discharge exists but again is minimised through the implementation of strict safety measures. ***But also, assessing the total environmental impact of power generating technologies needs to take into account many more aspects than radioactive waste****.*

In ENEF SWOT report Part1 [1], the Competitiveness SWG investigated the environmental dimension of nuclear power on the basis of Life Cycle Analysis (LCA) studies, including life cycle GHG emissions data, life cycle environmental impact assessment, non pollutant effects (power densities in generation, power densities in consumption, land requirement for different generation technologies), severe accidents (fatalities and frequency-consequence curves), amount of wastes.

CO2 emissions

As can be seen from the figure, in terms of CO2-equivalents, fossil systems generate by far the highest burdens for global warming. GHG emissions from nuclear, hydro and wind systems remain about two orders of magnitude below GHG emissions of fossil systems. Net GHG from PV and wood and biogas cogeneration are about one order of magnitude lower than fossil. However, for these technologies substantial reductions are envisioned until 2030. Although quite substantial reductions of GHG emissions from fossil power generation can be foreseen, natural gas and especially coal systems will remain the most emitting technologies by far in 2030 (unless Carbon Capture and Storage (CCS) systems will be implemented).

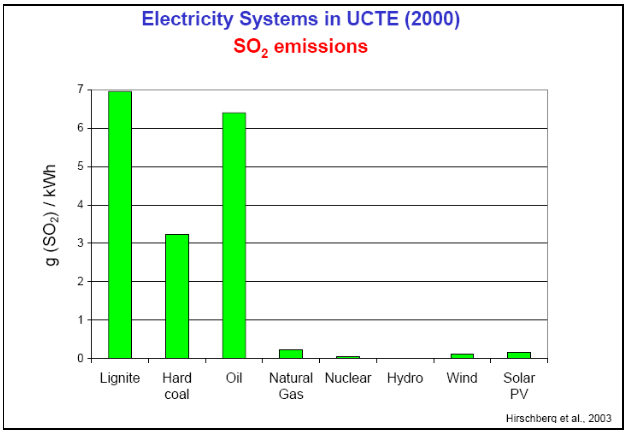
Figure 1 Extracted from SWOT report Part1 (p 56)

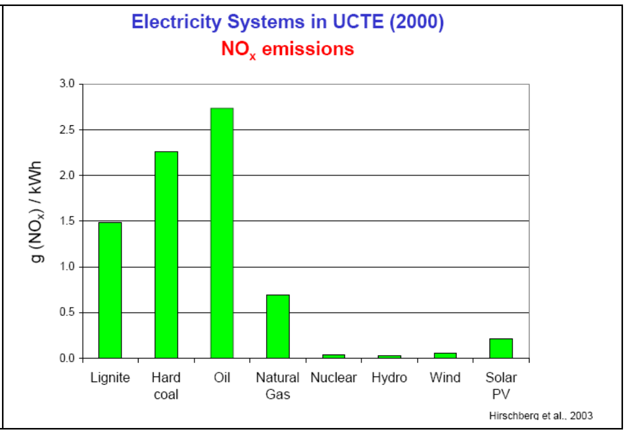


Source: Paul Scherrer Institute, [Bauer et al., 2008].

Regional environmental impact (SO2 and NOx - SWOT Part 1 extract from page 61)

Regional environmental impact from the use of different power generation technologies is mainly connected to emissions harmful to the environment in addition to GHG emissions. For example, the two charts hereafter show the emissions of SO2 and NOX to the atmosphere generated by different power generation technologies in 2000 in Europe. They are extracted from a study of Paul Scherrer Institut (PSI, Hirschberg et al., 2004) for UCTE (Union for the Coordination of Transmission of Electricity) gathering continental European transmission system operators).





More widely, the regional environmental impacts include:

- Acidification – pollution cause by airbone deposition of sulphur
- Eutrophication – pollution of ecosystems caused by nitrogen compounds
- Ecotoxicity – impact of chemicals on environment and living organisms
- Ionising radiation – naturally (radon gas and its decay products) and nuclear power

More comprehensive data can be found in the publications by PSI, showing that based on those criteria, nuclear has a very limited environmental impact.

Land requirement (Extract from SWOT Part 1 page 64)

Power/surface density ratios show that nuclear power is a highly dense energy requiring much less surface than renewables.

Power = 1,000MWe	**Land requirements**
Fossil and nuclear power plants	= 1-4 km2
Solar thermal or PV parks	= 20-50 km2 (= a small city)
Wind fields	= 50-150 km2
Biomass plantation	= 4,000-6,000 km2 (= a province)

Waste ((*Extract from SWOT Part 1 page 69-70)*

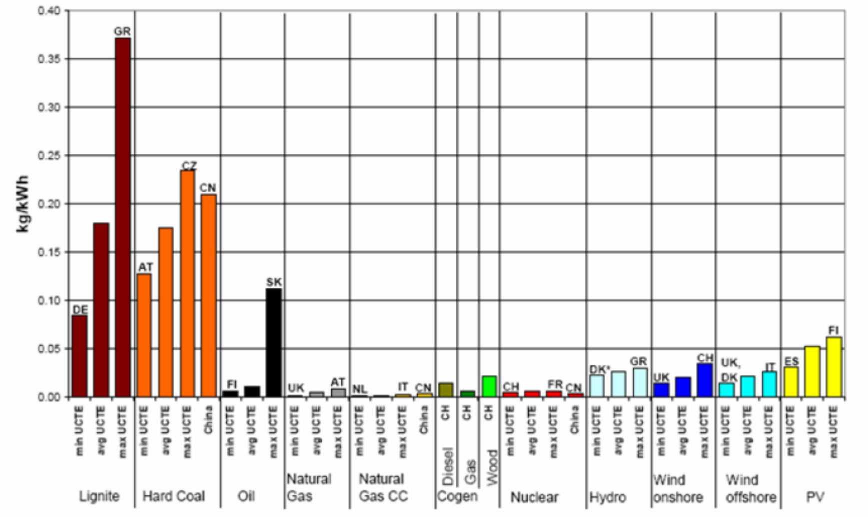
Nuclear wastes

Well known is the production of nuclear wastes by power generation technology and this aspect is a social issue. Per kWh the total volume for nuclear is quite low (about 60m3/TWh, life cycle Assessment, source PSI). Other fossil fuels as well as photovoltaics produce also nuclear wastes along their life cycle that cannot be ignored, even in very low quantity (less than 1m3/TWh). To better assess the annual quantity a power plant of 1,000MWe operating full time produces about 7-8 TWh per year.

Non nuclear wastes

Nuclear performs best together with natural gas as concerns non-radioactive toxic wastes. Particularly the fossil fuel technologies, but also the renewables show worse performance.

Non-radioactive toxic waste produced by nuclear, fossil and renewables



Source: Paul Scherrer Institute, [16; see also 13].

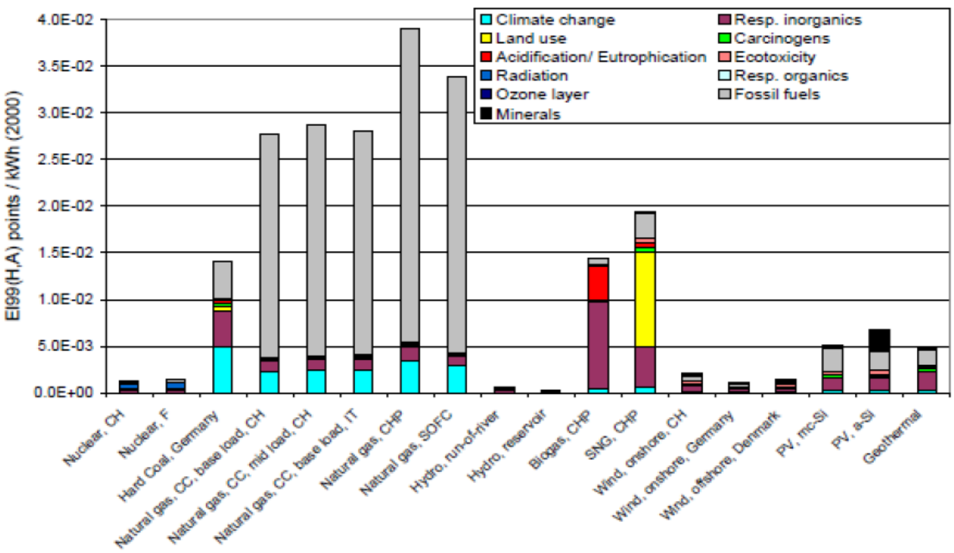
Note the relative high amounts of toxic wastes produced by Solar PV.

Aggregation of environmental effects (*Extract from SWOT Part 1 page 71*)

The following example from a PSI study [Bauer et al., 2007] compares current electricity systems across their respective lifecycles in terms of environmental impact, with the method of "Ecoindicator 99" which covers the following aspects:

- resources consumption (land use, but also fossil fuels and minerals consumption such as mentioned in chapter 3.2.4 of this report)
- human health (radiation, ozone layer, respiratory organics, carcinogens)
- ecosystem quality (climate change, acidification/eutrophication, ecotoxicity

Life Cycle Impact Assessment results for reference technologies in year 2000, using Ecoindicator 99 (H,A)



Source: Paul Scherrer Institute, [Bauer et al., 2007].

Nuclear follows hydro as top performer based on Eco-indicator 99 (H, A). Fossil systems score worst and biomass shows worse performance than other renewables.
Note that the figure also shows that nuclear performs better than Solar PV.

Water warming
SWOT Part 2 report [2] / N19-Water warming, water availability or water scarcity (impact in some areas for operation of nuclear plant)
Impact of water warming and water scarcity in some areas for operation of a nuclear plant can be managed. There is no real threat. First, there is flexibility in designing power plants allowing for dry cooling. Second, the lessons learned from recent heat waves in Europe led the nuclear operators to take measures avoiding repetition of issues due to high temperatures and lack of water resources (preventive maintenance on ventilation of industrial buildings, disposal of portable means of additional refrigeration in protected rooms for electronics, realisation of design modifications to raise the capability of some important heat exchangers, usage of procedures to be applied during hot periods, similar to those already in place to protect the plants against freezing situations).

Comparison of water consumption between different electricity generation technologies (l/MWh)

Nuclear Open Loop (remind)	**1,500 + 100 due to uranium extraction**
Coal without CCS	1,500 + 150 due to coal extraction & washing
Coal with CCS	3,000 + 150 due to coal extraction & washing
CCGT without CCS	600
CCGT with CCS	1,300
Solar with parabolic capture and solar tower	3,000 – 7,000
Oil (part due to oil extraction)	1,000 – 100,000

References: US Depart of Energy - Energy demands on Water resources and US Depart of Energy – CCS water demands

The extracts of SWOT report above show that nuclear power performs better than fossil fuels, but also than photovoltaïcs and bioenergy with respect to several environmental impacts. Focusing only on radioactive discharges and waste would provide a biased image of nuclear power relative environmental performance.

All these results and conclusions are consistent with the 2011 conclusions of IPCC on the environmental performances of energy technologies [IPCC, Special Report on Renewable Energy Sources and Climate Change Mitigation, SRREN 2011].

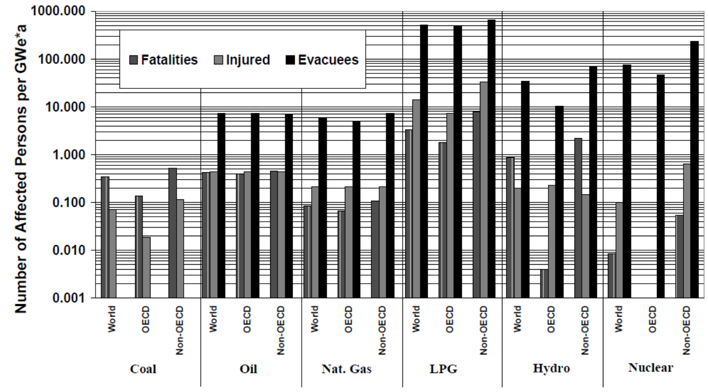
About Severe Accidents (SWOT Part1 and Part2-Appendix)

Attempts have been made to quantify nuclear risks and to put them into perspective.

Extract from SWOT Part1 (2010), pp66-68

The “classical” indicator regarding actual or potential damage from technologies is their fatal impact on human beings. The PSI’s GaBE project (Paul Scherrer Institut –PSI- 2004), quoted in the SWOT report Part1, gives results for different energy sources covering full energy chains in terms of immediate fatalities, injured and evacuated persons. These rates summarize accidents data from the period 1969-96 and distinguish between the results obtained for OECD and non-OECD countries: immediate fatality rates are much higher for the fossil fuels than what one would expect if only operation of power plants were considered. For OECD countries, the highest rates apply to liquefied petroleum gas (LPG), followed by oil, hydro, natural gas, coal and nuclear.

Comparison of energy-related human impact damage rates covering full energy chains

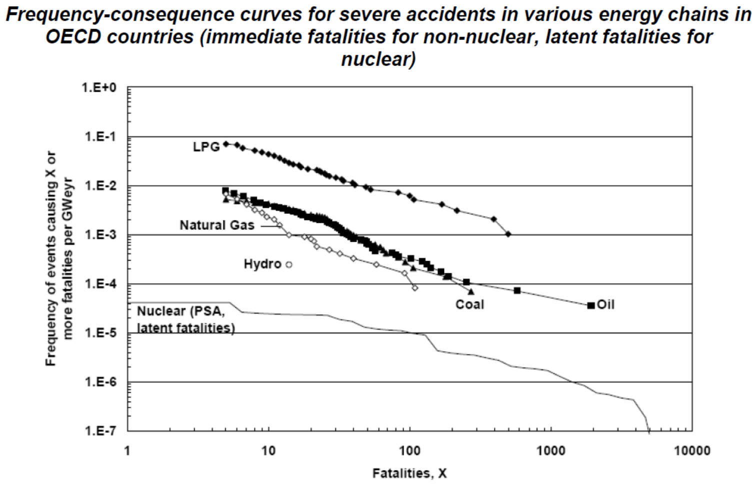


Source: Paul Scherrer Institute, 2004 [34].

To describe the societal aspect of risk related to the use of the different energy sources in OECD countries only. The next figure shows the overall frequency-consequence curves for full energy chains with partial reallocation for the period 1969-2000, as resulting from the EU-funded ExternE project.

The curves for coal, oil, natural gas, LPG and hydro are based on historical accidents and show immediate fatalities. Among the fossil chains, natural gas has the lowest frequency of severe accidents involving fatalities. Apart from LPG, coal and oil exhibit the highest frequencies of accidents up to the level of several hundred or, in the case of oil, even more than thousand fatalities, while hydro has the lowest.

For the nuclear chain, the result is derived from the plant-specific probabilistic safety assessment (PSA) for a Swiss nuclear power.



Source: ExternE [35].

Extract from SWOT Part2-Appendix (2012)

The level of safety of installed base in Europe will be increased since Fukushima Accident in 2011

Nuclear reactors in Europe have been submitted to stress tests and existing generation will take measures to improve safety and to limit consequences of accident.
Lessons learned from Fukushima will help enhancing safety of the installed base to get closer to the GEN3 reference level.
Specifically, measures taken for operating reactors concern containment venting, placing hydrogen recombiners and filtering the releases in case of a beyond design basis accident. Besides, all measures are taken to avoid cooling water shortage and continued energy supply to the power plant in order to avoid core melt down and environmental releases.

Target values for existing NPPs have been established and are as follows (for new plants lowered by a factor of 10):
• Total Core Damage Frequency (CDF) less than 10-4/reactor·year
• Adequate precautions against accidents for CDF between 10-4 and 10-5/reactor·year
• Large Early Release Frequency (LERF) of radioactive substances, significantly less than CDF
• Proof of sufficient protection against natural events for hazards ≥ 10-4/year, e.g. earthquakes
• Protection against aircraft crash for planes in operation when applying for a construction license

Table 2: Advanced Nuclear Safety Concept[1)]

Safety Level	Category	Frequency H per year	Verification	Goal	Dose limit Environment	Dose limit workers
Design Base Accidents	1	$10^{-2} < H < 10^{-1}$	Deterministic accident analysis, safety systems are available as required	Prevention of damage to - Safety relevant components - Fuel cladding	Q-DRW	50 mSv 250 mSv
	2	$10^{-4} < H < 10^{-2}$		Limitation of damage to - Safety relevant components - Fuel cladding	1 mSv	50 mSv 250 mSv
	3	$10^{-5} < H < 10^{-4}$		Assuring the - Coolability of the reactor core - Integrity of the containment	100 mSv	50 mSv 250 mSv
Beyond Design Base Accidents		$H < 10^{-5}$	PSA	Limitation of the consequences by confining the radioactivity or the controlled release of radioactivity into the environment [Internal accident management]	-	50 mSv 250 mSv
			Emergency preparedness	Mitigation of radiological consequences in the environment [External accident management]	-	50 mSv 250 mSv

[1)] Acc. to Swiss HSK-R-100, 12/2004, replaced by SR 732.112.2 and ENSI-A01

Taking into account the high level of safety in European nuclear plants and the recorded environmental performance under normal operation, It can be argued that nuclear energy not only contributes to climate protection but more generally to clean power generation in Europe. This is a key objective of common interest.

2/ SECURITY OF SUPPLY

(249)
Diversity of supply can be seen as one of the facets of security of supply, as it contributes to the ability on the part of a Member States to withstand external shocks, and essentially to the resilience of its energy system. According to this logic, in the absence of a public intervention, the market may over-rely on a single primary fuel exposing the Member State to a strategic/systemic risk.

This is a very important consideration. Diversity of technologies and energy sources is the most effective factor of security of supply. It is well established that the UK electricity market privileges the use of gas energy, eventually over-relying on it. This is due to the combination of 2 factors:

i. *initial investment is low compared with all other options (coal, nuclear, renewables);*
ii. *self-hedging is ensured by the electricity price mechanism based on gas price.*

The value of supply security is not reflected by the market spontaneous decisions. The contribution of nuclear energy to security of supply is not rewarded by the market and counteraction is needed against this market failure.

<u>SWOT Part 2 extract/ N6: Security of supply</u>

The prospect of an increased electricity demand for the coming decades in Europe will face a decrease in fossil fuel production and reserves/resources at the same time as rapidly increasing energy demand from the developing countries, mainly China and India. Political instability in some Middle East countries will add uncertainties over the security of supply for oil and gas. There may be a dash for gas worldwide and in Europe for climate policy purposes with an increasing and volatile gas price. Intermittency of local wind and solar, and the questions raised by an extended spread of renewable production centres outside the EU, mean that long term commercial and political stability, grid investments and management have to be carefully assessed. **Such a context creates for nuclear more of an opportunity rather than a threat for its contribution to the long term security of supply for Europe. The threat would be a non reliability of nuclear power for safety reasons.**

• It is important to diversify the energy mix in Europe for security of supply and not to rely only on one single type of technology and one single type of primary resource. A balanced energy mix is the best option to ensure security of supply in Europe, taking into account all aspects of the supply:

- Quantitative assessment of primary resources,
- Technological access to primary resources,
- Cost of resources,
- Geopolitical context of resource accessibility,
- Reliability of the resource (quantity, quality, etc…),
- Competition for resources worldwide with giant consumers like China and the USA

• From the perspective of the security of supply of primary energy in Europe, nuclear energy based on widespread uranium resources and light water reactors can continue to contribute securely for the coming decades. For the longer term, the development of new Generation 4 reactors would ensure the full independency of the EU for centuries.

3/ COMPETITIVENESS AND AFFORDABILITY

(251)
In particular, the UK is including in its forecasts on generation adequacy complementary policy routes including additional generation, energy efficiency and interconnection. From this perspective, the <u>UK considers that most renewables are generally only able to generate intermittently (e.g. when the wind blows or the sun shines) and new technologies such as CCS and wave and tidal stream technologies are not sufficiently proven.</u> While such technologies have a major role to play in a diverse low carbon energy mix, they cannot be directly substituted to baseload electricity generation such as the one provided through nuclear generation.

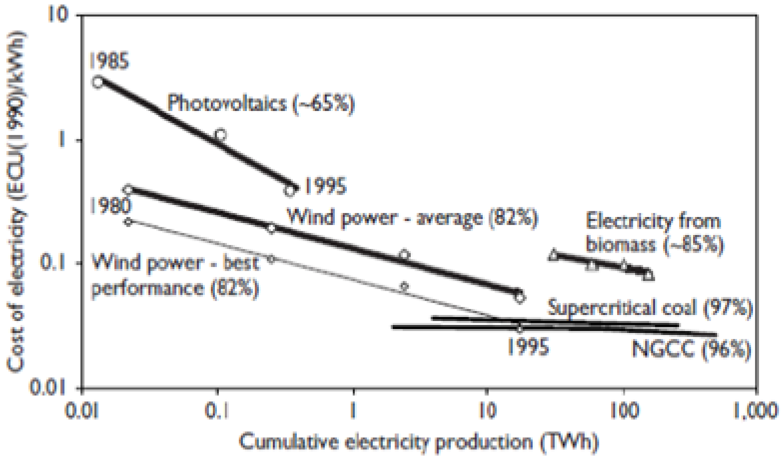
ENEF SWOT Part2 [2] report addresses the long term maturity and competitiveness of low carbon technologies (N21) and supports the UK statement here above.

Extract from ENEF SWOT Part2 [2] /pages 82-87
Conclusion: In conclusion to this overview of technology evolutions, nuclear competitiveness will remain in the next decades, at least up to 2030 because:
- Nuclear is already competitive on the electricity markets.
- There is possible progress for nuclear technology mainly from implementation in series of Gen 3 reactors and the studies assume a slightly decreasing trend in investment cost per kWe.
- With at least a load factor of 80% and an investment cost of 3,000-5,000 USD/kWe, nuclear competes with renewable technologies with load factors of about 40% at 1,500-2,500 USD/kWe like offshore wind power in the future and other full time technologies with greater investment costs, like solar photovoltaic (grid parity by 2030 with achievements of big envisioned progress) and CSP (4,200-8,000 USD2008/kWe, achieving grid parity by 2030).
- CCS will be mature only beyond 2030 with additional cost for fossil power plants.

<u>**Development**</u>
Power Generation costs include investment, fuel and O&M (Operating and Maintenance) of the installations. Nuclear power generation full life cycle cost includes the cost of waste management and dismantling. Similarly, fossil power generation costs should include the cost of their emissions, in particular CO2-certificate costs. Even for fossil fuel power plants equipped with CCS (carbon capture and storage), as the capture efficiency is not 100%, about 100g/kWh remain to be emitted and carbon cost should be added.

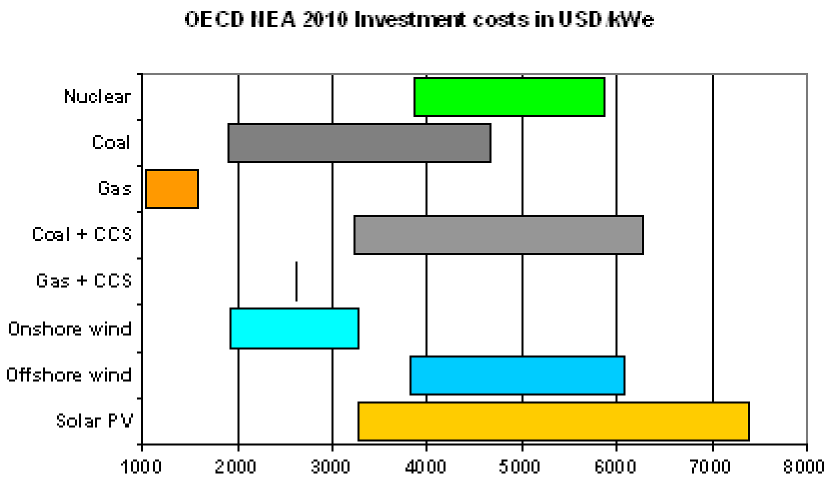
For technologies still under development or at early deployment phase, learning rates can significantly decrease the investment costs over the coming decades. This applies well to renewable technologies such as wind and solar. The Energy Technology Policy, OECD 2000 provides a broad vision on past progress rates (in brackets) of power technologies, showing a great improvement potential for wind power and solar photovoltaic.

Experience curves for capacities installed in the EU over 1980-1995 vs. conventional technologies



For more mature technologies such as traditional thermal power plants like fossil fuels and nuclear, the expectations in costs decreases are less and for fossil fuel specifically carbon capture and storage will lead to over costs.

In the OECD-NEA study on "Projected Costs of Generating Electricity" (2010 Edition), nuclear's ability to deliver significant amounts of very low carbon baseload electricity at cost stable over time is confirmed. Here are presented the investment costs ranges for the EU 27 countries.



Cost evolution in the long term for low CO2 technologies

From the Prognos AG report we can extract the following ranges of investment cost, in USD2008/kWe for low coal technology:

-for coal +CCS: currently 2,900-3,800, decreasing to 2,200-3,100 by 2030 and 1,800-2,700 by 2050

-for gas + CCS: currently 1,600-1,900, and then down by 2050 in the range 900-1,400 .

Investment costs for renewable power plants from the Prognos AG report have a larger range and show bigger differences between the studies than for fossil and nuclear power plants. Most renewable technologies show a large decline with rising total installed power capacity and inclusion of learning rates. This tends to enhance the difference in the results of scenarios that do not set a normative constraint on renewables. Wind onshore, hydro and biomass can be considered as well established renewables and show less decrease of investment costs than others. In Europe the potential of hydropower is limited and climate change constraints could add pressure for the availability of this resource for food and agriculture. Tide, waves and geothermal have limited potential as well and biomass has to consider availability and cost of fuel as well as full life cycle emissions.

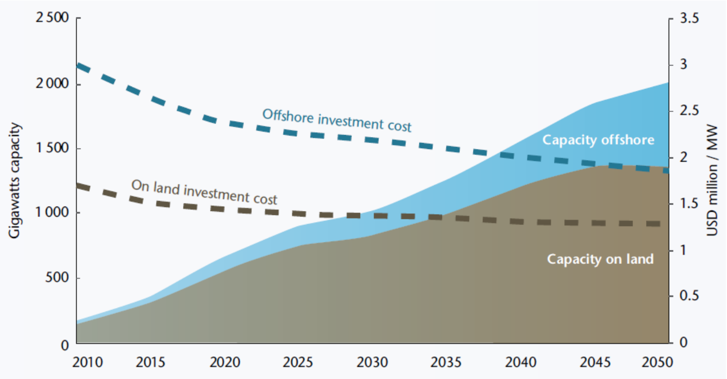
Investment costs for onshore wind power plants are among the lowest of the renewables and vary only little between studies (1,200 to about 2,000 USD2008/kW).

Offshore wind power plants are more expensive (around 3000 USD/kW- between 2,000 and 4,000 depending on site) and show a higher decline of costs.

Source: IEA Wind Roadmap 2010

Onshore/Offshore wind

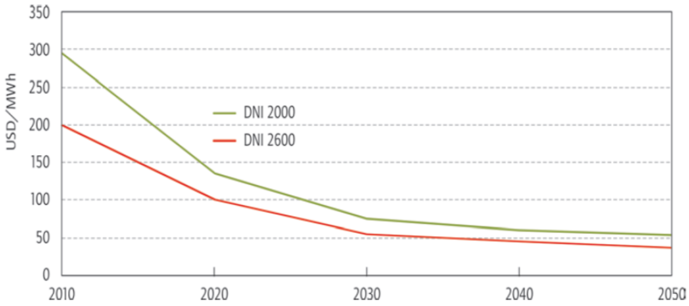
Wind power capacity development and investment cost reduction offshore and on land in the BLUE Map scenario, to 2050



By 2050, 32% of wind capacity would be located at sea.

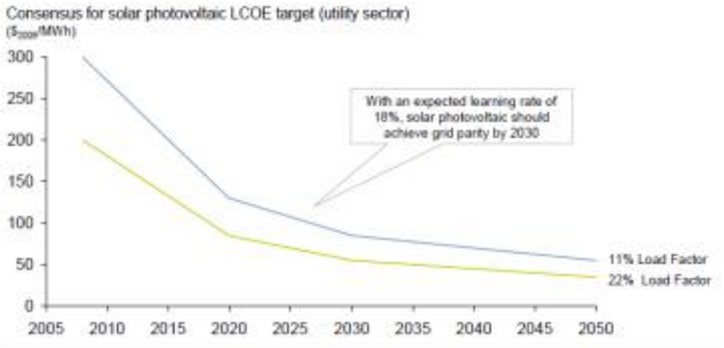
Solar breakthrough: not before 2030

Projected evolution of the levelised electricity cost from CSP plants, in USD/MWh, under two different DNI levels in kWh/m2/y (a 10% learning rate is assumed)

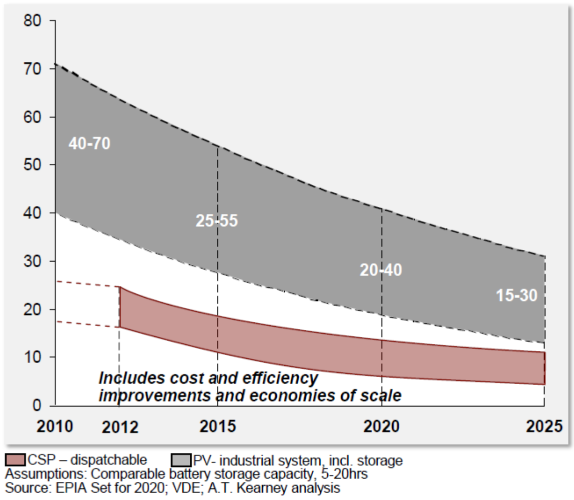


To mitigate intermittency, all CSP plants must be equipped with storage capacities. Installations can be designed for peak load (large storage and large turbine), intermediate load (small and medium storage + medium size turbine) or almost baseload (large storage and small turbine).
Current investment costs are from USD 4,200/kWe to USD 8,400/kWe. For 50 MWe units without storage the SET Plan (2011 Technology Map EUR24979) indicates a value of 4,800€/kWe ranging from 2,100€/kWe to 6,000€/kWe.

Solar Photovoltaic shows same current range of costs as CSP (currently 2,500-7,000 USD2008/kW)



Levelised costs for solar technologies including battery storage cost for PV (Spain, in €c/kWh)



4/ NEED AND ACCEPTABILITY OF PUBLIC ACTION

(245)
The Commission notes in this regard that <u>a support mechanism which is specific to nuclear energy generation might crowd out alternative investments</u> in technologies or combinations of technologies, including renewable energy sources, which may have occurred in the absence of the notified measure.

The above comment by the Commission would rather apply to the existing national support mechanisms for renewables (Feed in Tariffs and priority of dispatch) which are crowding out investments in the other technologies (including nuclear).

(271)
In this context, it is unclear how the intended measure <u>can remedy potential failures such as carbon emission externalities, beyond sectoral regulation, mandatory pollution standards, pricing mechanisms such as the ETS and the carbon price floor</u>. It is also unclear how the intended measure interacts with other policies and measures in place that aim at remedying the same market failure. The notification does not provide information on alternative, potentially less distortive, technology combinations which would allow the UK to achieve its objectives.

The UK has set up a mechanism of carbon floor price which increases steadily over time. Up to now, the announced value in 2017-18 is about £25/t. This would drive the technology switch from coal to gas but won't necessarily be sufficient to drive the deployment of low carbon technologies which are capital intensive. Such investments require more long term view on carbon prices.
Nota: *The UK Government has announced final details about the carbon price floor (CPF), which has come into effect on 1 April 2013. First, this measure confirms the carbon price support (CPS) rates for 2015-16 and announced indicative rates for the following two years. The rates from 1 April 2015 will be equivalent to £18.08 per tonne of carbon dioxide (tCO2). The indicative rates for 2016-17 and 2017-18 are equivalent to £21.20 and £24.62 per tCO2 respectively.*

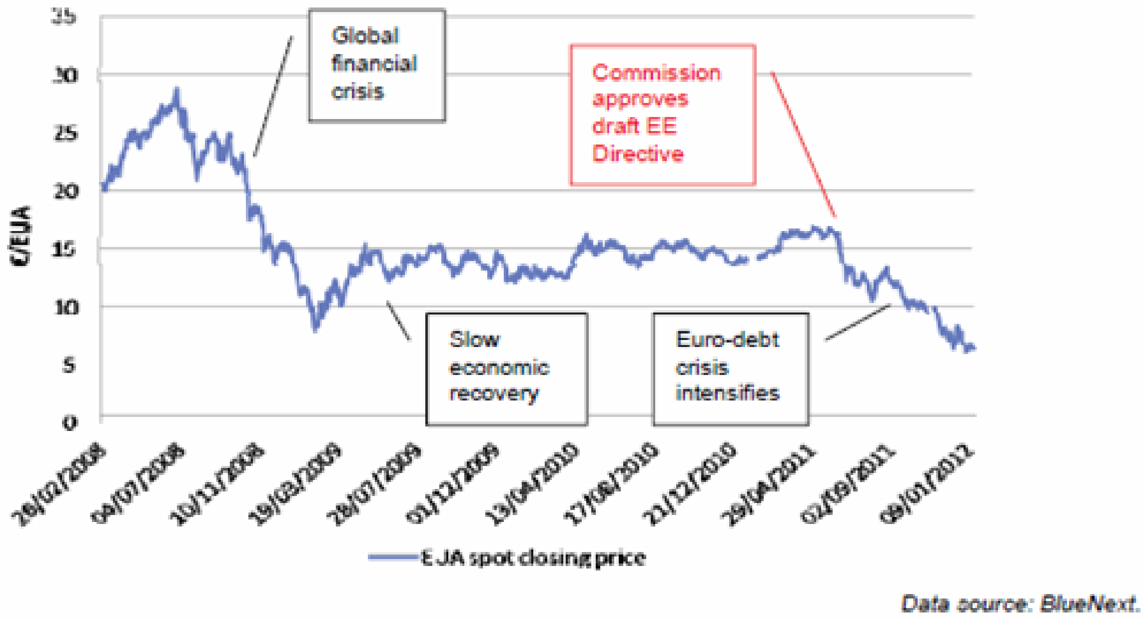
The SWOT Part 2 report (N5) addresses the necessity of a strong and stable carbon price to favour nuclear investment. Extract:

The European carbon market has not delivered the right signal for investment in non-CO2 but highly capitalistic power generation technologies.
"A significant carbon price has to be maintained to trigger non emitting investments. In the short term, the current EU ETS oversupply should be restrained in order to maintain the credibility of this policy instrument."

Development: extract from N5

The price of carbon in the EU has collapsed since the establishment of the EU-ETS. It had a value in the pre-ETS period from 2005 to 2007 and then continued to be valued in the first part of Kyoto period which lasted from 2008 to 2012. It collapsed when the economy was driven down in 2008 and never recovered.

The EUA price (Fev2008-Jan 2012)



Generally, it is assumed that a cap and trade system, by limiting the emissions, allows the mastering of quantities better than a tax or simply fixing a carbon price, both of which give rise to great uncertainties on the amount of reduction achieved. Of course, the abatement costs of technologies will play a role in the carbon price formation on markets.

The carbon price can be an efficient signal for new investments only if the current oversupply of permits in the EU ETS is checked, for example by setting aside some allowances during 2013-2020. In the UK, the government has taken a national decision to implement a carbon floor price.

The level of carbon price would reflect the over costs of cleaner power technologies (more efficient fossil technologies, Carbon Capture and Storage-CCS) expressed in long range marginal costs (LRMC), integrating capital costs.

If strict climate policy is implemented, the carbon price should normally increase steadily and play its role.

By 2050, several models value CO2 in the range of 40 to 60€/tCO2 if the current structure of the market is maintained, with full inclusion of the power sector. This range is significantly high to favour nuclear competitiveness. The impact of 50€/tonCO2 on generation costs without CCS is around 40€/MWh for a supercritical coal plant (800gCO2/kWh) and 20€/MWh for a CCGT plant, to be added to generation costs in the range of 50 to 70€/MWh:

i.e. a very sharp increase driving new build investments towards low carbon options including nuclear.

(276)
Nuclear energy is characterised by extremely high fixed, sunk costs, and by very long time periods during which such costs need to be amortised. This implies that investors considering entry into nuclear energy generation will find themselves exposed to considerable levels of financing risks. Indeed, funding for the type of investment size and duration that characterise nuclear power plants might well be considered unparalleled.

ENEF considers the lack of investment in low carbon technologies as a market failure. The market failure is still more acute in the specific case of nuclear energy, because of the high fixed cost and financing risk mentioned above by the Commission. The issue of financing was qualified in SWOT-Part 2 as the most important threat to the future deployment of nuclear energy in Europe.

SWOT Part2/ N18 on financing issue

According to a bank analysis (Citibank 13 September 2011) the whole EU power sector has become "un-investable" with too many political and regulatory uncertainties in some EU Member States. With huge investments needing to be implemented in the EU power sector - 1 trillion Euros by 2020 and 2.5 trillion by 2050 - this concern has to be taken into account for investments in all energy sources and in all infrastructure investments. In the Fukushima aftermath, it is particularly challenging for the nuclear sector as some Member States have made far reaching decisions on phasing out nuclear and thus creating additional need for new capacity. After Fukushima, public opinion on nuclear power has slightly worsened in many countries.

However, some Member States have clearly stated that they will continue their nuclear programmes as planned. The bankability of new power plant projects is going to be the key to the implementation of these programmes.

Future energy needs - especially electricity needs - have not changed after Fukushima. According to the scenario analysis, approximately 180 GWe of new "Generation 3" nuclear power plants would have to be built between now and 2050, to compensate for the shutdown of the existing "Generation 2" plants. By 2030, about 70 GWe of additional nuclear capacity would be needed. Depending on the power output of these plants, between 120 and 180 new plants (of respectively 1,700 and 1,100 MWe output) would have to be built. Considering the electricity industry’s hypothesis on the average cost of nuclear capacity over this period , this would represent an investment need of 180 billion € by 2030 and 470 billion € by 2050 (or about 13b€ per year).

External financing of nuclear projects is particularly challenging due to

- High capital cost and long term pay back times
- Uncertainties related to the planning and construction period including supply chain constraints, possible delays, costs overruns and changing regulation
- The fact that the economics of nuclear are sensitive to regulation related to safety and market conditions (volatility in the price of carbon credits)
- The specific nature of nuclear projects (political uncertainties, public acceptance)
- Nuclear spent fuel and waste management as well as decommissioning and their financing schemes

Predictable market conditions are necessary for investors to be able to evaluate the investment. Economically viable nuclear power plant projects should not be jeopardized by allowing arrangements that limit proper and sufficient financing resources (e.g. specific taxation for nuclear energy).
If the EU seriously considers the long term objectives of climate protection, energy security and competitiveness, it should take into account in its policy the value of nuclear energy's competitiveness in the long term.

Solutions to the financing issue were proposed by ENEF Opportunities WG in [3] ENEF Financing Final Report:
http://ec.europa.eu/energy/nuclear/forum/meetings/doc/2013_05_30/related_docs/enef_nuclear_financing_final_report_2013.pdf

Extracts from Financial Final Report/Part 4 proposing solutions:

(4.1) Policy and regulatory framework

- Decarbonising policy
- Security of supply
- Competitiveness

(4.2) Market models supporting investments in a low carbon future

- partnerships facilitating investments (Mankala-model, Exelsium-model)
- Electricity Market reform: Carbon price floor, Capacity mechanisms, Contracts for Difference, Emissions Performance Standard

(4.3) Societal development

Society needs to be able to understand the advantages and disadvantages of different energy options and these should be presented clearly in an informed manner.

- There is a need for more information on the energy mix in the low carbon economy and advantages and disadvantages of different technologies.
- Information of cost composition of the electricity system
- The public preference for discussion and debate, on the decisions on energy policy and the use of nuclear energy
- There is a need for more information on the importance of security of electricity supply
- There is a need for more information on what is the role of nuclear power in maintaining an affordable and stable electricity price and in creating growth and jobs in the EU
- There is a need for more transparency

(4.4) Existing EU financing tools and set up adequate instruments

ENEF SWG Financing recommends not only to make best-use of existing EU financing tools (4.4.1) but also to set up adequate and temporary financing tools (4.4.2) which will have a signaling and catalytic effect for private investments in nuclear new build projects.

(283)
There are three costs which are particularly uncertain, and are caused by the production of radioactive material and the possibility of nuclear accidents: costs related to the decommissioning of the nuclear plant, costs related to the management and disposal of spent fuel and nuclear waste, and costs related to liability insurance.
(284)
The production of radioactive material implies the need to decommission the nuclear plant, i.e. to 'close it down' permanently, by decontaminating the site and ensure that the area can remain viable in the future. It also implies the need to manage, and dispose of, spent fuel and nuclear waste, which is a by-product of the production process.
(285)
Commission Recommendation 2006/851/Euratom of 24 October 2006 on the management of financial resources for the decommissioning of nuclear installations, spent fuel and radioactive waste states (61) that "[t]he polluter pays principle should be fully applied In this regard, the primary concern of nuclear operators should be to ensure the availability of adequate financial resources for safe decommissioning by the time the respective nuclear installation is permanently shut down." (62)
(286)
The 'polluter pays principle' is therefore clearly envisaged for the decommissioning of nuclear power plants. The costs involved can be quantified to a large degree. They might however be subject to some uncertainty, in particular in relation to new technologies, such as the one which will be used in the HPC plant.
(287)
Costs related to the management and disposal of spent fuel and nuclear waste are subject to a substantially larger degree of uncertainty. Storage of waste is typically temporary and on site (i.e. where the nuclear plant operates) for a certain length of time, but it then needs to be carried out on a larger scale and in specific sites which are devoted to this objective. The costs of this activity depend on choices which might be taken far ahead in the future compared to when the plant operates. Spent fuel and nuclear waste stay radioactive for thousands of years, and no country in the world has yet built permanent facilities to store them. There is therefore a disconnect between the costs which need to be borne by the operator, and the actual costs of the activity.

The financial risk perceived does not lie only in the high initial investment.
In the 283-287 paragraphs above, the Commission underlines financial risks that are specific to nuclear energy, either related to the uncertainties on end of life costs: decommissioning, waste disposal, or to the residual risk of severe accident. Clearly, one factor of the reluctance to invest in nuclear power plants may be found in the perception that such risks might be too high. Misperception of risks effectively induces a bias against nuclear energy. Public intervention against such market failure should in priority focus

- on appropriate regulated funding mechanisms ensuring end of life expenses: this is the case in most European countries including the UK;

- on the implementation of international civil nuclear liability conventions;

- on better clarification and communication to the public and the investors about the level of those risks, ***which in the end amount to a small percentage of total generation cost****: cf the recent comprehensive review by* William D. D'haeseleer, Synthesis on the Economics of Nuclear Energy, Final Report, ENER/2012/NUCL/SI2.643067 (November 2013), http://ec.europa.eu/energy/nuclear/forum/forum_en.htm.

The latter reference provides comprehensive information on all the cost components of nuclear electricity and the resulting figures suggest that nuclear energy lifecycle cost of generation is competitive, especially when compared to other low carbon technologies.

According to ENEF, the total value of nuclear energy consists of environmental performance, security of supply and low lifecycle cost with low risk of cost volatility. For such a technology contributing to three major EU policy objectives, specific public action to counteract market failure (here: misperception of risks and lack of adequate financing schemes) seems justified.

Document 3:

Severe Nuclear Accident and Assumptions for Third Party Liability Costs (endorsed WG RISKS January 2014)

Severe nuclear accident and assumptions for third party liability costs

In recent months, studies about the costs of a severe nuclear accident have been reported in the media. Most of these studies show the cost of accidents to be very high but with large disparities. They assume a worst case catastrophic scenario without consideration of the probability of the accident occurring. Furthermore, most of these studies do not take into consideration the safety improvements that have been or are being made from lessons learnt, analyses and R&D regarding severe accidents (such as Three Mile Island and Fukushima) which have significantly reduced the accident probability and the potential radiological consequences. Also, the economic consequences estimated in these studies are extensive, covering not only direct economic consequences but also some subjective and psychological ones such as image costs.

The purpose of this paper is to discuss qualitatively the main assumptions used to assess the economic consequences of a severe nuclear accident, and primarily those which are covered by **third party nuclear liability,** being understood that the third party liability regime is not limited to such severe nuclear accidents but covers all nuclear accidents as defined in the Paris Convention[1]. This paper complements the ENEF contribution to the Commission's public consultation on nuclear civil liability[2].

In order to determine the economic consequences of a nuclear accident, the following issues have to be examined: the radiological releases, the effects on people and environment, the costs for the operators, the costs for society, and the costs of nuclear damages covered by the revised third party liability Paris and Vienna Conventions.

ooo

Safety level of Nuclear Power Plants in the European Union

All nuclear operators in the European Union share the same commitment that nuclear safety is the overriding priority for sustainable use of nuclear energy. Nuclear Safety corresponds to the various provisions made to protect people and their environment against the harmful effects of ionizing radiation under all circumstances, or in other words to prevent incidents and accidents as far as reasonably achievable and mitigate their effects, should they occur.

Nuclear plants in the European Union are designed and licensed according to the defense-in-depth safety approach. The first element is that multiple physical barriers exist preventing or mitigating unintended release of radioactivity under all circumstances, including accidents. All barriers have to be breached for a significant release of radioactive substances into the environment to occur.

The second element in this approach is the use of independent levels of protection comprising redundant and/or diverse plant systems designed to ensure that nuclear reactivity is under control, radioactive materials are cooled and radioactivity is confined. These systems are

[1] According to the Paris Convention, a nuclear accident is any occurrence which causes damage, provided that such occurrence or any of the damage caused results either from the radioactive properties or a combination of radioactive properties with toxic, explosive or other hazardous properties of nuclear fuel or radioactive products or waste, or from ionizing radiations emitted by any source of radiation inside a nuclear installation.

[2] Letter Marc Beyens, Chair ENEF Legal Roadmap Group to Commissionner Oettinger and DG Lowe dated 21st October 2013.

designed and constructed to the highest quality standards and are periodically tested and inspected to ensure that they perform their safety functions reliably.

With these design features, the probability of occurrence of accidents is very low. Nevertheless, the defense-in-depth approach includes several levels of protection which aims to prevent the accident evolution or to mitigate the accident consequences, should the levels of protection and the physical barriers fail.

Each nuclear operator in the European Union has effective accident response procedures linked with the on-site emergency response plan. There are measures which aim to prevent core or fuel element damage, so that the radiological impact of such an accident is minor. Another set of measures are aimed at mitigating the possible accident consequences if, for example, all cooling possibilities fail and core or fuel element damage occur (called a severe accident). These measures aim at limiting or reducing the radiological impact of the accident by focusing on the integrity of the reactor vessel and on the protection of the last physical barrier, the containment. The on-site emergency response plan is set up in close cooperation with the national Nuclear Safety Authority as well as other civil protection authorities.

The last level of the defense-in-depth is the off-site emergency plan which exists for the protection of the general public. This plan aims to limit the harmful effects of a possible release of radioactivity by specifying relevant protection measures, such as iodine prophylaxis, sheltering, and if necessary, temporary public evacuation. Exercises of the emergency response plan (on- and off-site) are performed on a regular basis with participation of all involved parties.

Continuous safety improvement, as already required by the existing EU Nuclear Safety Directive through periodic safety reassessments, is a key element for the nuclear industry which is committed to learning from the full range of operating experience reported globally. Improvements on plant designs, operation, organization, accident management, and training have been implemented since the beginning and especially after accidents, such as Three Mile Island in 1979 or Chernobyl in 1986. After the Fukushima Daiichi accident, safety assessments were performed by the European Union's nuclear operators under the supervision of the independent national authorities and through peer review. Improvements were agreed by each operator to reinforce existing safety margins in order to ensure that nuclear power plants are even safer and more robust against unexpected events. These improvements are now being implemented on the nuclear power plants according to the national actions plans.

The whole process, its requirements, its documents, its planning are under the control of the national safety authorities. These authorities are members of ENSREG (European Nuclear Safety Regulators Group) where they work together to establish the harmonized conditions for continuous improvement and enhancing the transparency of nuclear safety in the European Union.

All these improvements (organizational, design and emergency preparedness) make a severe nuclear accident a low probability event, with significant off-site consequences even more unlikely.

However, should a severe nuclear accident occur, what would be the consequences?

ooo

Radiological releases and source terms

First, it is important to state that not all accidents have consequences outside the plant. Only a severe accident with a core melt, and potentially threatening containment integrity, as the last barrier, could lead to significant radiological releases into the environment. In terms of radiological consequences, releases are classified according to the source term and its kinetics. The source term is the magnitude of the release as defined by the radionuclide mix and its radioactivity and is characteristic of a type of accident, a type of reactor, and a type of fuel. Each source term covers, by definition, a number of possible accident scenarios.

There are three main categories of severe accident source term, listed below in decreasing order of severity. One has to consider on one hand the quantity of radioactivity and on the other hand the time frame (e.g. time after shut down) of the releases.

1. Large Early Releases “ST1” corresponding to early containment failure a few hours after onset of the accident. Releases represent a significant part of the radioactive fuel inventory. The Chernobyl accident on a RBMK reactor is an extreme example of a ST1 type (immediate destruction of the reactor, due to intrinsic instability, with no efficient containment building).

2. Large Late Releases “ST2”corresponding to a release to the environment following loss of containment integrity one or several days after accident initiation (practically 24 hours). Releases represent a few percent of the radioactive fuel inventory. The Fukushima accident can be considered as being in this category.

3. Late Indirect or Filtered Releases “ST3” corresponding to indirect or filtered, and delayed release to the atmosphere. Releases represent a few thousandths of the radioactive fuel inventory, except for noble gases which are partly released in the environment.

In each Member State, nuclear installations must be designed, constructed and operated with the objective of preventing accidents and, should an accident occur, mitigating its effects and avoiding large as well as long term off-site contamination. This applies to new reactors at the design stage and also to existing reactors in the framework of the periodic safety reviews for implementing reasonably practicable safety improvements.

As the ENSREG report on the stress test process has shown, most nuclear plants in the European Union have provisions to protect containment integrity, (e.g. systems allowing to terminate severe accidents and to remove the heat from the containment without having to open the containment, or by the provision of a filtered venting system), so that any significant release with off-site consequences would be delayed and filtered. The few that are not yet fitted with these provisions have committed to considering implementing them according to their national action plans and under the supervision of the national safety regulators. The implementation of these national action plans will be peer reviewed by ENSREG. Accordingly, scenarios leading to source terms “ST1” or “ST2” can be practically eliminated[3], which makes them very different from the severe accidents which happened so far in the world (Chernobyl and Fukushima). An accident with fuel melt may occur but the releases would be less than ST3 (such as in the case of the Three Mile Island accident).

As the revised Nuclear Safety Directive (even if the final wording is not yet finalized) precludes large off-site contamination, [in accordance the WENRA (Western European

[3] A possible occurrence is practically eliminated if it is physically impossible for the conditions to occur or if the conditions can be considered with a high level of confidence to be extremely unlikely to arise

Nuclear Regulators Association) safety objectives], the "ST3" source term is therefore the relevant source term to be considered in this discussion.

The ST3 source term is first characterized by a certain delay after core melt and then by scrubbing or filtering effectively the containment aerosols (and some also iodine) prior to release. The releases of fission products which can cause long term contamination due to their long half-life period are thus limited and thereby the countermeasures to be implemented after such an accident are significantly reduced compared to ST1 or ST2 scenarios.

With regard to the countermeasures (depending on the underlying scenario), such ST3 release could lead to:

- A limited evacuation of the population within a few km radius;
- A limited long-term contamination of the environment within a radius of a few km;
- Use of stable iodine prophylaxis within a radius of about ten km (even less if the venting system filters methyl iodine).
- A return of the population at the end of approximately one week. A temporary displacement of the population longer than a year is however possible closer than 2 km to the plant.

Appendix 2 provides some examples of preventing and mitigating measures, existing or decided after Fukushima which support the limitation of the consequences of a possible severe accident to ST3 level for European Union typical reactor technology. More detailed information is available in the post-Fukushima national report and the respective actions plans available on the ENSREG website.

°°°

Economic consequences

The economic consequences of the nuclear accidents are identified in two parts; those that fall **under the third party liability regime**, and those that do not. The economic consequences that fall **under the third party liability regime** are the following:

- **Costs of health effects or medical monitoring due to the radiological releases**
  "*Loss of life or personal injury*"[4]

The radioactive releases in the environment represent a risk for the public and the environment. Countermeasures such as stable iodine prophylaxis, sheltering or evacuation up to a few km ensure that the dose incurred by the public will be limited (as already confirmed by the Fukushima case). There are neither short term health effects on the public because doses are below the deterministic effects threshold nor immediate deaths.

[4] The subtitles in italics and in brackets refer to the definition of nuclear damage in the revised Paris Convention.

In the case of high doses, the effects are deterministic. For lower doses the effects are stochastic; i.e. there is a small probability of deleterious effects occurring, in the long term, cancer for example. Medical monitoring of all people likely to have been exposed to radiation has to be implemented.

As a conservative approach, the evaluation of the medical consequences on the population exposed to radiological doses from a nuclear accident is generally carried out by using a linear relation without threshold between the dose and its stochastic effects.

It is obvious that the costs of health effects do not depend only on the accident itself, but also on how its consequences are managed: the extension of countermeasures will increase costs but will decrease those related to the health impacts.

In addition, the costs associated with loss of life or personal injuries due to effects other than radiological ones are included in the costs.

- **Costs of countermeasures**
  "Preventive measures"

Implementation of countermeasures depends on the country's own legislation and its execution during a severe accident. To assess the extent of the required evacuation zone and of the stable iodine prophylaxis zone, the dispersion of the activity release needs to be taken into account.

The weather (wind and rain conditions …) has a significant influence on the dispersion of radioactive particles and therefore on the radiological consequences of an accident. The evaluation of potential consequences must be done over a range of realistic weather conditions for a specific site, since the main wind direction, for example, differs significantly between sites.

Also other site specifics need to be taken into account for the assessment of landscape consequences, as some sites are situated at an ocean while others are surrounded by areas with high population density and intensive agricultural land use.

- **Costs of decontamination**
  "Loss of or damage to property" and "Reinstatement of impaired environment"

Iodine contamination disappears after about 10 weeks and does not have long term effects. Caesium and strontium contamination, only, have a longer half life (the more common cesium 137 has a half-life of 30 years and strontium-90 has a half-life of 29 years). A filtered containment venting reduces the releases of this kind of radionuclide by a factor of 1000. For these reasons, nuclear accidents with ST3 source term don't lead to a large and long term contaminated area. These costs are also site-specific depending on the nature and the use of the surrounding land.
After contamination decrease or removal, some reinstatement may be necessary. However, due to the source term and the respective properties of the isotopes released, impairment of the environment would be limited.

- **Compensation for loss of property, relocation, salaries**
  "Loss of or damage to property", "Preventive measures" and "Economic loss"

The people affected by evacuations have to be compensated for food, relocation and wages. The period to be considered depends on the level of contamination. The most important contributor to the contamination is iodine which disappears within a few weeks. Most of the people will be able to return home within a month, fewer within a year. There may be also a no return area in the very close vicinity of the plant. However, the number of people concerned and the duration of compensations are site-specific due to the population density and use of the surrounding land, and in any case moderate.

- **Associated costs with the food restrictions**
  "Loss of or damage to property" and "Economic loss"

European Union legislation determines the maximum thresholds for food commercialization and consumption. With contamination caused by a ST3 accident, food restriction on farm products will be implemented on a small area around the plant: crops up to a few tens of km, milk up to a hundred km. Contamination will only last for some weeks and will not affect future crops due to the short half-life of the nuclides emitted. However these costs are site-specific depending on the type and use of the surrounding land.

- **Costs of business losses**
  "Loss of income" and "Economic loss"

Losses of business activity are to be considered due to the contaminated or evacuated zone. They can be evaluated as a fraction of GDP proportional to the number of individuals and business assets concerned. However, the restriction of business activity in the contaminated area may result in a transfer into neighboring areas of the country, which can reduce its impact on the economy. These costs are also site-specific due to the population density and use of the surrounding land.

- **Damage to the economy**
  "Loss of income" and "Economic loss"

This covers damage to the economy caused by the perception of the public but not directly caused by the physical consequences of the accident. They concern in particular tourism and food industry, which might be affected on a wider scale and also depending on the anxiety and wealth of the population. They can be considered as psychological or media-induced effects (non-consumption of products coming from an area close to an area being under restrictions or to an area having been under restrictions). Some of these costs could be covered by a third party liability regime (as it is the case in the Paris Convention). However the plaintiffs will have to prove a direct relation between the accident and their claimed losses.
These costs are the most difficult to apprehend and hard to assess.
No model for such insurance exists in other industries (chemical, airlines, bio-engineering, food industry…).

The internal costs (**entrepreneur risks**), which are **not under third party liability regime,** are:

- **Cost of immediate on-site counter measures**

This includes remedies for the employees taking part in accident mitigation, contractual costs for a support during accident conditions, etc.

- **Cost of long term measures including dismantling**

The costs on site relate to the damage caused to the installation by the accident: on-site decontamination, loss of the reactor and anticipation of dismantling. The costs of dismantling can possibly be burdened by a radioactive environment. Additional manpower may be necessary to perform the task.

- **Loss of income from the energy no longer produced/cost of energy replacement**

The cost of the loss of the unit is generally estimated on an energy replacement cost basis.

°°°

Conclusion

The economic cost of a nuclear accident is intrinsically linked to the source term released and to the size of the resulting long-term contamination. The density of the population and the use of land in the area surrounding the plant are also important parameters. Multiple layers of defense-in-depth are implemented to prevent and mitigate these consequences even for very low probability events: protection against the effects of natural hazards, systems and procedures dealing with loss of cooling or electricity, confinement and ways to control it, emergency planning and ways to restore safety functions in due time to prevent, delay and mitigate large releases. As there is no significant long-term off-site contamination, the impact is considerably limited and the costs of accidents to be considered under the third party liability regime are much lower than the overall costs reported in the studies so far.

All nuclear operators in the European Union performed a comprehensive safety and risk assessment for their nuclear reactors after the Fukushima accident, resulting in consolidating the current safety margins and in decisions for modifications to improve further the safety features for prevention or mitigation of severe accidents in compliance with the WENRA safety objectives and the on-coming revision of the Nuclear Safety Directive. This leads to the conclusion that solely accidents characterized by controlled, delayed and filtered releases (ST3), without significant long-term contamination, should be used for cost evaluation of nuclear damages as defined in the international Third Party liability regime.

The paper identifies the third party liability costs and provides elements that show that they would be limited and are expected to remain in the range of the amounts established by the revised international Conventions. The other costs are internal costs related to entrepreneur risk.

In order to go further and have reliable and comparable costing, it would be necessary to have an evaluation methodology shared at European level.

Appendix 1

An overview of the existing studies on nuclear accident cost evaluations

The objective of this overview is to identify and compare the costs of a nuclear accident, as presented in recent international studies:

- ExternE (2002) : « Externalities of Energy », Vol. 5 Nuclear, 1995
- USA / NRC (1997) : « Regulatory Analysis Technical Evaluation Handbook, Nureg / BR -0184, January 1997 »
- Canada / COG (2002): Candu Owners Group, COG 01-002, « Benefit-Cost Analysis: Principles and Process », August 2002.
- France / IRSN (2007) : Institut de Radioprotection et de Sûreté Nucléaire : It was declared cancelled by IRSN
- UK / COCO (2008): COCO-2: A Model to assess the economic impact of an accident, November 2008.
- France / IRSN (2013 – press release, study to be published in 2014): L. Pascucci-Cahen, P. Momal.

This overview focuses on two types of severe accident scenarios: "ST1 type" scenario characterized by early and large releases and "ST3 type" scenario with delayed and filtered releases. When such scenarios are not described in the studies, the nearest scenario in terms of consequences has been chosen. Among the various cost items, we selected the costs under the third party liability regime.

Regarding the costs of a nuclear accident, this overview reveals the following:

- On ST3 type accidents, costs are between €400 million (European ExternE study) and €26b (according to IRSN 2013 press release, study to be published in 2014). The differences are partly due to variation of accident scenarios (quantity of radioactivity, time frame of the releases)

- On ST1 type accidents, costs are within a range of € 17b (Canadian study COG) to b€ 171 (2013 IRSN press release, study to be published in 2014). A higher amount (€504b) was put forward in 2007 by IRSN study but it has since been invalidated by IRSN itself.

No clear homogeneity is observed in any costs subcategories, except for the monetary value of the unit of radiation exposure, for which a common value around € 160 / man.mSv is found.

Appendix 2: Safety improvements at EU plants supporting a "ST3" source term and limited protective measures

General context

TMI accident in 1979 and Chernobyl accident in 1986 led the nuclear operators to implement major improvements of the design of their installations and also to their organisations to increase the level of prevention and mitigation of severe accidents and to limit the radiological consequences of such accidents.
In the European Union, the Council Directive 2009/71 Euratom of 25 June 2009 establishing a community framework for the nuclear safety of nuclear installations, requires that the licence holders, under the supervision of their competent regulatory authority, regularly assess and verify, and continuously improve, as far as reasonably achievable, the nuclear safety of their nuclear installations in a systematic and verifiable manner. In this frame, the nuclear operators in the EU, perform Periodic Safety Reviews of their installations taking into account the feedback of operating experience and the new knowledge accumulated so far.
After the Fukushima accident in 2011, complementary safety assessments (also called "stress tests") were carried out in the EU to assess the safety margins against extreme natural events resulting in total loss of the heat sink and of the electrical supplies of all the units on a site. The conclusions of these complementary assessments were peer-reviewed under the supervision of ENSREG at the EU level. The details of these measures are available in the country reports and in the main ENSREG report on the ENSREG website. The "stress tests" resulted in national action plans with measures to increase the robustness of the plants..
Nowadays,, the nuclear installations in the EU, regardless of their type of technology (PWR, BWR, AGR, CANDU) benefit already from significant safety improvements (plus others under implementation or being considered to be implemented) "practically eliminating" the risk of large or early releases, limiting the source term and therefore also long term contamination in case of a severe accident. Consequently, the relevant protective measures of the population in the vicinity of the plant can also be considered as limited in area and time
This appendix gives some examples of typical safety features implemented on the nuclear plants in the EU to prevent and mitigate a severe accident and it evaluates the maximum source term as a ST3 type source term.

Typical safety features to "practically eliminate" large or early releases

After TMI accident and Chernobyl accident, measures were taken to reinforce the defence in depth aimed at preventing and mitigating severe accidents including core melt.

In the area of prevention, typical measures were implemented for coping with beyond-design basis events such as loss of ultimate heat sink or station blackout through additional and diversified means including mobile equipment and adequate emergency guidelines. After Fukushima, specific measures were taken in addition to increase the protection and the autonomy of the plants against severe natural events and total loss of heat sink and of electrical supplies affecting all plant units e.g. reinforced site protections, hardware equipment, alternate heat sink, increased water storage capacities and additional mobile means.

With respect to mitigation, the main improvements aimed at protecting the containment against the different potential modes of degradation challenging the confinement function in case of a severe accident. For many plants they were implemented before the Fukushima accident and improved after the accident along with an enhanced severe accident management and staff training. Off-site emergency response organisation was also in place and has been significantly reinforced in several countries. On-site Emergency Control Centres are also being built now at many plants in the EU to support severe accident emergency response.

LWRs

The following table shows for the different modes of degradations of the containment examples for light water reactors (LWRs) of safety features to "practically eliminate" the risk of large or early releases to the environment.

Mode of degradation of containment [5]	**Examples of dispositions for light water reactors already in place or decided after Fukushima**
High energetic hydrogen combustion (global detonation, fast deflagration and local detonation)	for PWRs, passive recombiners or igniters inside the containment, For BWRs, containment inertisation by nitrogen atmosphere prevents conditions for hydrogen combustion. In case of containment leakage, ignitors in the reactor building to avoid hydrogen concentration (Nordic BWRs)
High energetic in-vessel steam explosion	Reactor pressure vessel is robust enough to resist to a steam explosion
High energetic ex-vessel steam explosion	For PWRs, the reactor pit is kept either dry, cancelling risks of steam explosion or in case of fuel coolant interaction due to water in the cavity pit, the internal structures can withstand the mechanical loads. For BWRs, strengthened hatch in the lower drywell and the internal structures can withstand the mechanical loads.
High pressure core melt and Direct Containment Heating	For PWRs, pressurizer valves and discharge line, robust enough and power-secured that eliminates the risk of high pressure core melt in the vessel For BWRs, automatic depressurization of primary circuit initiated with highly reliable relief valves
Containment over-pressurization	To prevent containment over-pressurization (by steam and non-condensable gas production) different means such as spray system and/or filtered containment venting can be used.
Basemat meltthrough	In some PWRs, in-vessel retention by ex-vessel wall cooling In other PWRs, after the vessel failure, molten core stabilization by ex-vessel corium reflooding and stop of

[5] **The scenarios in bold have the potential for large early releases with significant consequences.**

	concrete ablation or implementation of specific devices such as "core catcher". For BWRs, automatic flooding of lower drywell before the reactor pressure vessel melt-through.
Containment isolation failure	Fail safe and emergency power supplied containment isolation valves
Fuel degradation in SFP	Prevention of fuel uncovering (e.g. by bunkered emergency power source and water make-up withstanding extreme hazards)

AGRs

The AGR use enriched uranium dioxide fuel with stainless steel cladding, carbon dioxide as the primary coolant and have pre-stressed concrete reactor pressure vessels. They have some fundamental differences to the PWR/BWR reactors which are significant in terms of safety:

- the power density of the reactor core is much lower and its thermal capacity is significantly larger, giving more time for operators to respond to loss of cooling accidents,
- under loss of cooling conditions, significant quantities of hydrogen are not generated as water is not the primary coolant and the cladding is stainless steel and not zircalloy,
- in conditions of overheating, the coolant does not go through a phase change (liquid to gaseous state) as in a water reactor thus maintaining its thermal properties,
- the use of carbon dioxide for coolant reduces the likelihood of steam explosion.

The safety functions are provided by a number of diverse and redundant systems:

- Reactivity Control: The primary means are control rods that fall under gravity into the reactor core. The diverse shutdown system is based on rapid injection of nitrogen into the reactor core or based on control rods that are actively lowered into the core and backed up by manually initiated nitrogen injection. A tertiary shutdown (boron beads or water) is provided for the longer term if required.
- Post-Trip Cooling: Post-trip fuel cooling is provided by gas circulators pumping the CO2 coolant through the reactor core and boilers, or by natural circulation provided the containment is pressurised.The heat is removed from the boilers by the post-trip feed water systems.There are at least two diverse post-trip feed water systems with redundancy and diversity in their electrical supplies.
- Containment: AGRs do not have a containment building around the pressure vessel. None of the design basis Loss of Coolant Accidents (LOCA) for AGRs result in large scale fuel failure and the plant is designed to be capable of retaining the bulk of any radioactive material that might be released from the fuel.The AGRs concrete pressure vessel together with the large mass of graphite in the core provide hours of heat sink in case of total loss of cooling.
- Post Fukushima back-up arrangements: Back-up equipment for power generation and water injection into the boilers is provided at a location off-site and can be mobilised and installed on site should it be required.

Based on the overall AGR safety provisions together with the AGR inherent characteristics, large and early releases can be effectively discounted.

PWHR CANDU 6

The PHWR CANDU 6 reactors use natural uranium as fuel and heavy water as moderator and coolant.

This type of reactor is equipped with safety systems, multiple and diverse heat sinks available to cater for severe core damage accidents, and each systems uses a combination of passive and active features to ensure maximum reliability of the heat sinks during accident conditions.

The PHWR CANDU 6 reactor has inherent design robustness against core damage (i.e, no severe core damage occurs at high pressure, high pressure melt and direct containment heating are precluded, reactivity induced accidents are precluded by two fast, highly reliable and redundant shutdown systems).

Severe accident progression in CANDU reactors is strongly influenced by the unique aspects of the reactor design. In particular, the low pressure heavy water moderator in the calandria vessel surrounding the pressure tubes and the large volume of light water in the calandria vault which surrounds the calandria vessel, provide a heat sink capability which, in many event sequences, will delay the progression sequence significantly. The approximate inventory of heavy and light water, available for heat removal, is as follows: ~ 120Mg heavy water in heat transport system (HTS), ~ 230Mg heavy water in calandria and ~500 Mg of light water in calandria vault. The existing multiple sources of cooling water and power supplies have been supplemented by the provision of the capability to connect mobile external power and water sources.

The main design and operating provisions that ensure that the containment integrity in the event of a severe accident is maintained to an extent that significantly reduces the risks of early or large releases to the environment are summarized in the table below:

Mode of degradation of Containment	Measures to prevent loss of containment integrity in place or planned to be installed as part of the Fukushima Action Plan(FAP)
Containment over-pressurization	- Multiple provisions are available to avoid steaming in the containment: - Highly reliable, active, post-accident heat sinks are provided for the primary coolant circuit, the calandria vessel, and the shield cooling system; - Local Air Coolers dedicated to cooling the containment atmosphere - Dousing sprays used for containment pressure suppression - Containment Filtered Venting (FAP)
Hydrogen control	- Igniters

	- Passive Autocatalytic Recombiners(FAP) - Local Air Coolers fans promote forced air circulation for hydrogen mixing
In-Vessel Retention	In PHWR in-vessel retention of the corium is ensured by make-up and recovery circulation of the moderator (in-vessel cooling) or by make up to the calandria vault (ex-vessel cooling). In-vessel retention means that there is no contact between corium and the basemat.
Containment isolation failure	Redundant isolation valves designed to fail closed on loss of instrument air or loss of control power supply, thereby creating a fail-safe condition.
Scenarios For Large Or Early Release From Out Of Core	**Prevention measures in place or planned to be installed as part of the Fukushima Action Plan (FAP)**
Fuel degradation in the Spent Fuel Bay (SFB)	- The relatively low decay heat level of CANDU spent fuel means that it would take many days to expose spent fuel as a result of pool heatup to boiling and loss of inventory. This gives ample time to establish makeup sources. - Design changes and emergency operating procedures provide for the use of multiple means of water make-up in the SFB (seismically qualified pipe installation to provide water to the spent fuel bay with connection to fire trucks, or to diesel driven pump)(FAP); - The characteristics of natural uranium used in CANDU plants preclude possibility of re-criticality of the spent fuel whether in air or in light water

Maximum source term released in the environment in case of a severe accident

LWRs

Due to the safety features listed above, in case of a severe accident the containment integrity will remain over a long period of time (e.g. for PWRs longer than 24 hours) and will not be challenged by phenomena resulting in an early containment failure. For LWRs equipped with containment filtered venting system, the performance of these filters with a high decontamination factor for aerosols (typically in the order of 1000) reduces drastically the contamination outside of the containment.

Therefore, it is justified to consider “ST3” source term corresponding to indirect or filtered and delayed releases with the magnitude in the table below.

Fission products	**Core activity released to the environment LWR (fraction of the core inventory)**
Noble gases	≈ 1 (100%)
Iodine	≈ 1,5 10^{-3} (0,15%), and less with filters with iodine filtering capability.
Aerosols (Cs, Rb, Ag, Cd, Br, Mo, Sb, Te)	Some 10^{-5} (some 0,001%)
Other aerosols	Less than some 10^{-6} (some 0, 0001%)

AGRs

The design basis for AGR includes consideration of a maximum credible depressurisation within the pre-stressed concrete pressure vessel (PCPV) and its penetrations. The AGR design includes fourfold redundancy of the boiler loops as well as redundancy and diversity for all essential safety functions and the safety analysis allows for independent random failures in the post trip cooling systems. Radiological consequences are calculated based on a conservative prediction of fuel damage and taking due account of allowances for uncertainties. Thus, AGRs have been subject to progressive programmes of backfitting of safety enhancements since the early 1990s.
More recently, following the events at Fukushima, provisions have been established to transport back up equipment to the AGR sites from remote locations. This equipment is intended to restore essential cooling to a site following an unforeseen, site-wide event in which all power and post trip cooling systems fail. The long timescales available for AGRs referred to earlier permits this approach whilst ensuring that large scale radiological release would be prevented.

The reasonably foreseeable release for AGRs is defined to be:

Fission products	**Core activity released to the environment AGR (fraction of the core inventory)**
Iodine	≈ 3 x 10^{-5} (0,003%)
Caesium	≈ 2 x 10^{-5} (some 0,002%)

PHWR CANDU 6

The design and operating provisions adopted for the CANDU 6 NPPs ensure that containment integrity is maintained such that the risks associated with early or large release are significantly reduced following severe accidents. The containment filtered venting system ensures that potential releases of radioactivity products to the environment are reduced by a factor of up to 1000.

For a generic CANDU 6 that experiences a representative severe accident case (station blackout, which corresponds to a “Fukushima-type” scenario), the estimated releases in the table below correspond to indirect or filtered and delayed releases (i.e. “ST3” source term):

Fission products	**Core activity released to the environment (fraction of the core inventory)**
Noble gases	15.4%
Iodine	0.0012%
Aerosols (Cs, Rb, Ag, Cd, Br, Mo, Sb, Te)	Sb: 0.0019% Cs: 0.001% others: 0.0001% max
Other aerosols	0.00004% max

Document 4:

Elements for a possible EC Recommendation on harmonised conditions for safe long-term operation of NPPs in the EU (endorsed WG RISKS April 2014)

Elements for a possible Commission Recommendation on harmonised conditions for safe long-term operation of Nuclear Power Plants in the EU

Endorsed by the ENEF WG Risks on 17 April 2014

The Roadmap for long-term operation (LTO) of nuclear power plants in the EU as endorsed by the ENEF Working Group Risks on 27 April 2010 proposed a set of harmonised conditions for LTO on the basis of Directive 2009/71/EURATOM establishing a Community framework for the nuclear safety of nuclear installations adopted by the Council in 2009. For substantive and legal reasons, outlined in the roadmap, a Commission Recommendation on this issue appears to be the preferable instrument.

At its Bratislava plenary meeting in May 2010 the Forum mandated the WG Risks to prepare a detailed contribution for a Commission Recommendation on harmonised conditions for safe LTO. The ENEF Sub-Working Group Nuclear Installation Safety subsequently developed a paper but this was not published because of the change of focus to Fukushima and the stress tests.

However last year's plenary asked WG Risk to review this work and update it, as necessary, in the light of lessons learned from Fukushima and from the stress tests peer reviews. This paper sets down the elements to be considered if the Commission prepares a Recommendation addressing the issue of LTO (in the following text, it will be called the "recommendation"). The elements are structured along the lines of a Commission Recommendation.

I. Elements proposed for the Preamble

1. Art. 33 EURATOM Treaty calls on each Member State to lay down the appropriate provisions to ensure compliance with the basic standards established within the Community. This applies to all technical and organisational aspects to achieve a high level of safety, including LTO. According to Art. 33 EURATOM Treaty the Commission shall make appropriate recommendations for harmonising the provisions applicable in this field in the Member States.

2. Article 2 (b) of the Treaty calls on the Community to establish uniform safety standards to protect the health of workers and general public and ensure that they are applied.

3. Article 2 (c) of the Treaty calls on the Community to facilitate investment for the development of nuclear energy.

4. Chapter 3 of the Treaty requires that basic standards shall be laid down within the Community for the protection of the health of workers and the general public against the dangers arising from ionising radiation.

5. The Court of Justice of the European Union in its case-law C-29/99, recognised that the provisions of Chapter 3 of the Treaty, on health and safety, form a coherent whole conferring upon the Commission a wider number of competences under the EURATOM treaty in order to protect the health of workers and the general public against the dangers arising from ionizing radiations. However there are some restrictions with regard to issues of design, construction and operation of nuclear installations. It is judged that the scope of a Recommendation, regarding special technical aspects, can be more extensive than a Directive.

6. The Council Directive 2009/71/EURATOM established a Community framework for the safety of nuclear installations recognising the basic principles of national responsibility of member states and the principle of prime responsibility of the licence holder for nuclear safety of its nuclear power plants under the supervision of its national competent regulatory authority. In particular this Directive has as an objective “to maintain and promote the continuous improvement of nuclear safety and its regulation”. It requires that licence holders, under the supervision of the competent regulatory authority, should regularly assess and verify, and “continuously improve, as far as reasonably achievable, the nuclear safety of their nuclear installations in a systematic and verifiable manner”.

7. In judging reasonableness for safety improvements, both in design and operational aspects, the integrated risk informed decision making process is used in many Member States. The integration of operating and deterministic considerations, probabilistic analyses and other factors such as economics leads to more coherent and balanced decisions.

8. Directive 2003/54/EC[6] of the European Parliament and of the Council of 26 June 2003 lays down common rules for the internal market to achieve a competitive, secure and environmentally sustainable market in electricity.

9. In its Communication on “Energy 2020”[7], the Commission addresses, in Priority 3/ Action 2, the continuous improvement in safety and security and requests active pursuit of greater harmonisation of future plant designs and certification at the international level to contribute to the responsible use of nuclear energy worldwide.

10. The Commission Communication on “Investing in Low Carbon Energy”[8], March 2010, states that in the nuclear sector, to sustain its current contribution to low carbon electricity, two key challenges, identified in

[6] Directive 2003/54/EC http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2003:176:0037:0055:EN:PDF
[7] COM (2010) 639final: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2010:0639:FIN:EN:PDF
[8] Communication from the Commission (doc. 7110/10 of 5 March 2010).

the Strategic Energy Technology Plan (SET-Plan), have to be tackled – lifetime extension of facilities and solutions for nuclear waste.

11. Many operating nuclear power plants are approaching the limits of their original design basis lifetime: the EU average fleet age was 26 years (in 2010). Based upon the original 30 to 40 year plant lifetimes, about 1/3 of the installed EU nuclear net capacity would be lost from the grid over the next 10 years. This is confirmed by the Commission Communication on "Energy 2020", November 2010. In addition a number of nuclear power plants are being shutdown prematurely as a result of member states decisions following the accident at Fukushima. This puts further pressure on EU electrical capacity and low carbon generation.

12. On 22 January 2014, the European Commission tabled its proposed 2030 Framework[9], with a binding target of 40% CO_2 reduction in 2030 and an EU binding target for RES of 27%, but no national binding targets. This would leave to the Member States the full decision on their energy mix to meet the decarbonisation target. This 2030 Framework provides a rather positive environment for LTO of existing nuclear power plants, allowing Member States to take full advantage of the high competitiveness of these facilities.

13. In many Member States LTO is being envisaged or has already been implemented for reasons of economy, security of supply and the protection of the climate. It is furthermore concluded that the NPPs concerned were built to sufficiently stringent standards and, in many cases, have significant safety margins so that the design basis lifetime does not constitute a technical limit. Current engineering technology is able to assess the safety margins for physical structures of the NPP and indicate if safe LTO is technically feasible. Additionally many older nuclear power plants have gone through important modernisation programmes in order to meet new safety standards.

14. National/international practices required that NPPs be operated in a conservative manner compared to the design criteria. The combination of a sufficiently stringent design and an operational regime that follows specific conservative modes of operation is an essential basis for continuing operation beyond the original technical design basis lifetime.

15. Operating experience (OE) gained from nuclear power plants around the world is a valuable source of information which allows operators to continually improve their knowledge and the safety of their nuclear installations. Through WANO cooperation and other feedback mechanisms the nuclear operators have been increasing and sharing their operation experiences. The EU Clearinghouse has been established under the umbrella of the EC Joint Research Centre to strengthen co-operation between EU Safety Authorities, Technical

[9] COM (2014) 15 final

Support Organisations and the international OE community, in sharing NPP operational events data and apply lessons learnt.

16. The nuclear power plants currently operating in the EU have been continuously improved during their lifetime and also major upgrades have been made before and post Fukushima, thereby further reducing the likelihood of severe accidents and enhancing the mitigation capabilities of the nuclear power plants. This was acknowledged by the outcome of the EU-Stress-Tests and will continue in the future by, for instance, following the national action plans. With all these measures, the risk of severe accidents with large and long term off site contamination can be considered as being minimal, making the situation in Europe different from the severe accidents seen so far in the civil use of nuclear power outside the European Union (Chernobyl and Fukushima).

17. The safety of workers and of the general public against radiation risks is of paramount importance to the European Community. High safety standards and regulatory requirements should therefore guarantee that these risks are addressed during the service life of nuclear power plants.

18. Without prejudice to the general principle of subsidiarity, harmonisation of technical safety requirements should also be recommended to achieve a high level of safety of LTO and a stable operational requirement framework in the EU. This harmonisation of safety requirement should be done by relevant safety authorities through the work of WENRA as is already the case for existing and new NPPs.

19. This Recommendation is based on the IAEA “Fundamental Safety Principles (SF-1)”; the IAEA Safety Requirements “Management Principles for Facilities and Activities (GS-R-3); “Safety of NPPs: Commissioning and Operation (SSR 2/2)” and “Safety of NPPs: Design (SSR 2/1)”. It also takes into account the IAEA Safety Guides SSG-25 (Periodical Safety Review for NPPs), NS-G-2.12 (Ageing Management for NPPs) and the IAEA Safety Report Series No. 57 (Safe Long Term Operation of NPPs). Proposed modifications to some of these documents as a result of lessons learned from Fukushima (DS462) were also taken into account.

20. The recommendation is also based on the WENRA Reactor Safety Reference Levels issued in January 2008 together with the update, issued in November 2013 for stakeholder comment in relation to lessons learned from Fukushima. These reference levels are or will be implemented in national regulations according to an agreement amongst the regulators.

II. Elements proposed for the Sections

a. Purpose and scope

21. The recommendation describes harmonised conditions for the safe long-term operation of Nuclear Power Plants (LTO) in the European Union. The aims are to ensure:
    - A level of nuclear safety as high as reasonably achievable
    - Security of supply of low carbon energy in Europe,
    - Fair competition between European nuclear power producers,
    - A clear, transparent and predictable framework as a basis for the necessary investments to be made by the industry, based on an integrated approach with a long-term vision for at least 20 years.

22. This recommendation is addressed to Member States and covers operating NPPs

b. Terms and Definitions

23. Long-Term Operation (LTO)
LTO is the operation of the plant beyond the technical design basis lifetime that is justified by safety assessment, considering life limiting processes and features for systems, structures and components.

24. Technical design basis lifetime
Technical design basis lifetime is an assumption used during original plant design to base design calculations of specific Systems, Structures and Components (SSCs) for technical issues such as fatigue. It is not a technical limit.

25. Configuration management
Configuration management ensure that changes to the plant and its SSCs important to safety and availability are properly identified, screened, designed, evaluated, implemented and recorded.

26. ALARP
As Low As Reasonably Practicable

c. Responsibilities/Tasks of the License Holder

27. Long-term operation should be managed in an integrated manner. This integrated approach should encompass the following elements:

28. **Ageing management programme**:
The license holder should have implemented an ageing management programme which describes the technical and organisational elements of physical ageing management, covering SSCs important for safety. Mechanisms should be identified to determine the possible consequences of ageing and to determine the necessary activities for maintaining the operability and reliability of SSCs. The ageing management programme should be based on a systematic approach comprising maintenance, in-service inspection, experience feedback analysis, technical programs also covering wear-out mechanisms and

potential age related degradations. The programme should also identify the support needed by a long-term R&D strategy. A review process should provide the demonstration that SSCs are assessed during the planned period of long-term operation at regular intervals.

29. Non replaceable components

The ageing management programme should ensure that the operational safety of non-replaceable components that are part of the two main safety barriers e.g. the reactor pressure vessel (RPV) and the reactor containment building (RCB) are assessed, taking into account the ageing effects:

RPV: the integrity and the residual service life should be assessed by a combination of a deterministic approach (e.g. embrittlement surveillance program, in-service inspection, hydro test, overpressure system protection) and a probabilistic risk analysis (uncertainties and data scattering), in order to demonstrate that the probability of a pressure vessel failure remains in the safety residual risk.

RCB: the integrity and leak tightness of the concrete and steel structure should be assessed and maintained by adequate measures (e.g. leak tests for the structures, inspection, monitoring of conditions inside the containment, repairs) in order to monitor and mitigate the ageing effects, in order to demonstrate that the objectives of control of releases to the outside environment are reached.

30. SSCs obsolescence programme

Equipment should be replaced whenever the ageing management programme reveals either, its potential degradation and inability to perform its intended function until the end of operation, or because of the unavailability of spare parts or the loss of suppliers for the initial original equipment. The design of replaced SSCs should be consistent with the existing design basis. The SSCs obsolescence programme should cover not only safety related components but also those needed for power generation.

31. Knowledge management programme

This programme should cover two aspects: the ongoing continuous knowledge of the design and the human resources issue.

The license holder should ensure that throughout the lifetime of the nuclear power plant, starting from the design stage, an internal organisation is in place that has overall responsibility for the continuing integrity of the plant design.

The history of operation and of potential different configuration should be recorded in order to be able to maintain the plant correctly. This will facilitate modifications and improvements that would appear to be necessary without degrading the safety of the nuclear power plant.

The detailed knowledge and experience of operating staff that have participated in the commissioning tests of the nuclear power plant should be captured and documented for transfer to new staff, especially through coaching. This knowledge transfer needs to be planned well in advance. It becomes even more acute when considering long-term operation.

32. Continuous safety improvement

In compliance with the Directive (2009/71/EURATOM) establishing a Community framework for the nuclear safety of nuclear installations, measures should be taken to regularly assess and verify, and continuously improve, as far as reasonably achievable, the nuclear safety of their nuclear installations in a systematic and verifiable manner. The safety assessments should aim at ensuring both compliance with the original design basis and further reasonably practicable improvements of safety, by taking into account ageing issues, operational experience and most recent research results. These assessments beyond potential design aspects should also cover both managerial and operational aspects.

The potential improvements should be decided on a risk informed basis and not solely on deterministic requirements. Depending on country practices, risk informed decision making could take the form of “cost/benefit” assessment, “ALARP” analysis or comparison with quantitative safety objectives. Once the choice of a modification has been made, the detailed design should use some deterministic rules.

33. Regular Periodic Safety Review

Periodic safety reviews are part of the regulatory framework in Europe as a means of the implementing continuous improvement. The license holder should perform systematic periodic safety reviews at least every ten years. The scope should be as comprehensive as reasonably practicable with regard to significant safety aspects of an operating plant. The following areas should be covered by the review:

- Compliance of plant design with the license using configuration management method
- Actual condition of systems, structures and components including equipment qualification
- Safety analyses, including both deterministic and probabilistic safety analysis (PSA).
- Conformity assessment against current safety standards and hazard levels as well as assessment of changes in internationally recognised safety standards and good practices since the last review.
- Procedures, accident management and emergency preparedness

- Protection of workers and radiological impact on the environment.
- Operating experience during the review period, including events from NPPs worldwide, and the effectiveness of the system used for experience feed-back
- Organisational arrangements, self-assessment of the safety culture of the operating organisation
- Staffing and qualification of staff

The licence holder should report to the regulatory body in a timely manner on the review results implementing an action programme.

d. Responsibilities of the Regulatory Authority

34. The Regulatory Authorities should develop and implement harmonised safety LTO conditions for NPPs especially for the use of a risk informed decision making approach for continuous safety improvement as well as for non-replaceable components.

35. The Regulatory Authority should ensure that the license holder defines and implements the integrated approach for LTO.

36. The consent and oversight process for long-term operation should follow the established national regulatory processes for operation. Review and assessment should be performed in accordance with the lessons learned and experience gained throughout the operational stage.

e. Reporting

34. Member States should include information regarding their national approach to LTO, including any relevant LTO regulations, in the report required in the Article 9 of the Council Directive establishing a Community framework for the nuclear safety of nuclear installations.

Document 5:

Feeding the European debate on energy-mix for the electricity supply system (endorsed WG OPP and RISKS May 2014)

ENDORSED BY ENEF WG OPP AND RISKS MAY 2014

Feeding the European debate on energy-mix for the electricity supply system

In February 2014 the Berlin European Fossil Energy Forum was open for the first time to representatives of other (low carbon) energies, to initiate a horizontal dialogue on the European Energy Policy. The European Nuclear Energy Forum (ENEF) strongly supports this initiative, which is clearly needed in view of the energy challenge: striking the right balance between security of supply, competitiveness, and environment protection (ia lowering CO2 emissions).

Using the opportunity of its 2014 Plenary Meeting in Bratislava ENEF wants to propose a process for a transparent, structured and informed dialogue between the various electricity sources in Europe. To feed this debate, that should not only involve power producers but also other stakeholders such as consumers, industry, regulators, interested citizen…, we need a shared methodology,. ENEF is convinced that a level playing field is missing since long and the launch of the wide Berlin Forum might provide an opportunity to create one.

A MultiCriteria Analysis (MCA) methodology has been developed and applied by a number of organizations in Europe (such as Paul Scherrer Institute (PSI) in Switzerland or the University of Manchester in the UK (Spring project)) to help clarifying the debate on the energy-mix. Several European Research Programs such as ExternE and NEEDS have also helped to develop this methodology.

Applied to the electricity sector, the MCA methodology consists in looking at various elements of the electricity system (full energy chain, from resources to distribution) through a number of factors pertaining to **economic**, **environmental** and **societal** aspects.

To support a dialogue at wide EU level, the first step should be to agree on the list of factors (or "criteria") under each of the three aspects (economy, environment, societal). In a second step, these factors ("criteria") have to be quantified as objectively as possible. Finally, in a third step, weighting factors, affecting the three aspects (economy, environment, societal) will be added to the methodology by each stakeholder depending on their priority opinion or interest. This process making a clear distinction between the facts and the issues to be discussed can contribute to a focused debate.

Our ENEF proposal is to revisit this MCA methodology, applied to the electricity system, in the framework of the "extended Berlin Forum", under the auspices of the EC Energy Directorate. The work already achieved by ENEF working groups provides a large amount of data and analysis of nuclear power on the three aspects: economic, environmental and societal, dealing with a wide spectrum of criteria. This set of criteria could potentially be revisited and expanded to cover the views of the different stakeholders of the energy sector. We think sufficient data and analysis are available also from other energies and other organizations, to feed a multi-criteria analysis for the whole electricity supply system (including generation, transmission and distribution).

Using this kind of methodology could be useful both at national and European level.

At the national level, the results of the methodology might be different because assessments of several criteria will depend on national conditions (technical, geographical or political) and because at the end the choice of energy mix is a national responsibility. But it could bring more rationality into the discussion of these choices and it could help a better coordination between national energy policies.

At the European level the use of this methodology could help defining more pertinent energy priorities and the Berlin Forum should focus on this level.

The attached working document describes in more detail the proposed methodology with an illustrative set of criteria and could be proposed to the Berlin Forum as a starting point.

The Risks and Opportunities working groups therefore ask the Bratislava plenary meeting for approval to go forward with this approach to the next Berlin Forum.

Document 6:

Multicriteria Assessment of energy mixes - Working Paper of WG OPP and RISKS, serving as annex to the previous document 5.

ENEF Opportunities/Competitiveness
ENEF Risks/Nuclear Installations Safety May 2014

WORKING PAPER

MCA:
Feeding the European debate on energy mix for the electricity supply system

1 Introduction

Berlin Energy Forum (2014 February 11) has opened the way to a comprehensive and open debate on European energy policy:

« The following actions at EU and national level were considered essential to assure security of supply and to keep costs and prices in check:

- *Providing stable investment conditions and a long term framework 2030;*
- *Diversify energy resources (new energy suppliers, new energy routes, renegotiation of gas contracts with third countries, promotion of renewables in a cost efficient way, exploitation of (unconventional) gas);*
- *Investing in technology and innovation.*

It was broadly agreed that ***all sources of energy are needed*** *to make the transition towards a competitive low carbon economy a success. Another precondition for success is a climate of mutual trust and confidence. »*

A renewed evaluation of power system is needed as huge investments are needed in the coming two decades, to reach the European 2050 low carbon objective, to replace the retiring power plants and to follow the growth of consumption.

Developing and maintaining a diversified energy mix has always been a priority to respond to a complex combination of objectives of economics environmental and social issues.

More formally, the assessment of power generation options has been developed by institutes and utilities through European programs such as ExternE and NEEDS. A comprehensive array of criteria has been examined and assessed for each energy technology, covering the three dimensions: economy, environment and social aspects.. Every energy technology should be assessed according to a common set of performance criteria through a methodology called MultiCriteria Analysis (MCA).

2 Multicriteria assessment (MCA)

MCA (Multi Criteria Analysis) or MADA (Multi Attribute Decision Analysis) is a tool helping to take decisions on optimal choices between different solutions or options when each option exhibit pros and cons without an obvious winner.

- The first step is to determine a set of criteria or attributes that characterizes the positive and negative aspects of the different options.

- The second step is to determine how each option scores on each criterion. This step should be as objective as possible and rely on solid quantitative data. Then each option is ranked on each criterion assigning a 10 for the best result and a zero for the worst, other options being assigned a note between zero and ten according how the options rank on these criteria.

- The third step is to determine a weighting factor to be applied to each criterion since it is likely that all criteria would not represent the same importance for the decision makers. It could be through a discussion between some recognized experts trying to reach a consensus. Summing the weighted note of all criteria for every option will give a ranked listed of options. In order to check the robustness of the result, slightly different weighting factors could be used. The result of the preferred option should not be sensitive on small variations of the weighting factors.

If the decision to be made would impact several groups of people or even the public, a representative sample of the groups or the interested public could be gathered to ask them to individually choose the weighting factors. The set of weighting factors used in the methodology will be the average weighting factors from the groups.

This methodology is to make a clear distinction between objective and quantitative attributes that are not likely to be debatable and the potential different views of the various stakeholders that will be captured mostly in the weighing factors. This multi-criteria approach offers a transparent and traceable way to feed the debate on the "optimal" or suitable energy mix. .

3 Scope of assessment: list of proposed criteria

The need of a comprehensive evaluation of electricity supply systems is emphasized. To make it clear, it is useful to review all the components of the electricity supply service expected by the consumers.

3.1 Value of service

It is meaningful to compare the total cost or overall risks of different electricity generation technologies only if they provide the same ***value of service.*** For the end consumer, the electricity supply *service* involves at least four components:

- Reliable access to power (MW) on demand at any time (load): that implies access to the grid, available on line capacity, reliable supply (i.e. very low probability of failure) and flexibility. Grid stability also has to be ensured permanently. All that requires adapted infrastructure and equipments. The whole system from primary energy supply to low voltage distribution will contribute.

- Electricity supply (MWh) at lowest possible marginal cost (€/MWh): that implies low cost of primary energy consumed, high conversion efficiency, but also low pollution (emissions of CO2 and others) if pollution costs are internalized as they should be.

- Energy security: past and present events show how strong dependence on one external energy supplier may lead to conflicts; maintaining the diversity of energy sources, linked to diversity of electricity generation technologies, is crucial.

- Compliance with sustainable development objectives: that implies minimized long term impacts on environment and minimized natural resource depletion. That implies also social equity: serving all categories without discrimination.

All four components add up to the total ***value of service provided.*** The value of reliable access to power, energy security and compliance with sustainable development will drive the consumer’s willingness to pay, even though they are not easily quantified in the financial balance of a project.

3.2 The three sets of criteria

Based on the published scheme elaborated by Paul Scherrer Institute, three sets of criteria covering environment, economy and social aspects are proposed. This list is not exhaustive and other criteria and indicators could be defined. However they are supposed to cover the main elements of each domain. In addition the corresponding indicators exist in recent literatures.

Environment

- Resource consumptions : primary energies, raw materials, water,
- Green house Gas emissions (CO2, CH4, etc…)
- Discharges to environment and their impactss on ecosystems,
- Ultimate waste

Economy

- cost of electricity supply,
- security of supply : diversity of sources, availability and reliability of generation plants,

- capital intensity,
- fuel price sensitivity,
- peak load response,
- domestic added value
- grid costs
- liabilities

Social aspects

- Employment,
- Human health impacts (normal operation and accidents)
- Risk aversion,
- Proliferation,
- Terrorist threat,
- Quality of living conditions (noise, visual, …)
- Public acceptance,

Examples of indicators corresponding to some of these attributes are further detailed thereafter (Part 4).

3.3 Full energy chain approach

The analysis should cover all the mature or close to be mature electricity generation systems: coal, oil, gas, nuclear, hydro, biomass, wind and solar. The marine and geothermal energies are still at the R&D phase and could be discarded. The electricity supply system consists of a cascade of several main operations: exploration, extraction, transport, storage, power generation, electricity distribution, waste treatment and disposal. Not all operations are applicable to every power technology, but when assessing the different attributes of a technology, all operations of the energy chain should be considered.

For instance the nuclear electricity costs are mainly at the power generation stage as for gas electricity the main cost is at the fuel supply stage. Similarly, most accidents for the coal chain occur at the extraction stage, as for the oil chain, the risks are mainly at the transport stage and for nuclear chain at the power generation chain. Solar power has nearly no impact on environment at the generation stage, but some significant one during the fabrication process of solar cells.

In any case it is important to consider carefully every stage of an energy chain to make meaningful comparisons.

4 Some preliminary insights

4.1 Environment

Resources consumption

There are several definitions of fuel reserves (coal, oil, gas, uranium): proven, expected… There is also the distinction between conventional and non-conventional sources (oil sand, shale gas). A simple indicator is to use the ratio between the current level of consumption and the proven reserves.

Beside fuel, some electricity power systems used raw materials for which resources or access are limited (e.g. indium, gallium, platinum, rare earths...) for photovoltaics, (vanadium, lithium...) for electricity storage. In some cases substitution is currently not possible. The European Commission identified 14 critical raw materials for which resources should be better estimated.

Water is a crucial element for most electricity generation technologies, especially the thermal technologies. Its availability, in particular in a changing climate, will influence the choice of location, design and operation of a site. Hydroelectricity use renewable water. A comparison of the rate of water consumption (M3/MWh) for different electricity systems can be found in the IPCC report (SRREN 2011).

Greenhouse Gas emissions

All electricity generation technologies emit greenhouse gases at some point in their life cycle and all have a carbon footprint. Fossil-fuelled electricity generation has the highest carbon foot print and most emissions are produced during plant operation. CCS technologies could reduce those emissions significantly but have not yet developed at a large scale. By contrast renewables and nuclear generation have a low carbon footprint and most emissions are caused indirectly, for instance during the construction phase. Detailed comparison of carbon footprint between electricity generation technologies could be found in a recent Eurelectric report (Eurelectric 2011).

Discharges to environment

All electricity generation release some form of pollutants in their life cycle. These pollutants are dispersed into the atmosphere, into rivers or in seawater at both local and regional levels. Assessing the overall impact on the environment of all these pollutants is a difficult task. However, as a first step, the comparison of the amount of the most important of these pollutants released by GWh is accessible (SPRING 2011) and it is of interest to group them according to the kind of impact they could produce (Ozone depletion, acidification, eutrophication, radiation exposure).

Ultimate wastes

There are huge differences of waste natures and volumes between electricity generation technologies (ore barren, ashes, fission products…). Large efforts have been made and are still being made to reduce the waste and to recycle them as much as possible. However there remain some ultimate wastes that should be disposed of. A simple indicator could be the quantity (volume or mass per MWh). A sub set should be used for those waste that need long term containment from the biosphere like fission products, transuranic elements or high toxicity chemical wastes.

4.2 Economy

Cost of electricity supply

The methodology to assess lifecycle costs of electricity generation is well established, both in public, generic exercises like OECD reference costs and in private practice when power companies have to decide investments. The resulting main performance indicators are the levelised lifecycle cost of electricity (LCOE in Euro/MWh), and for investors the Return on Equity (ROE) and the Net Present Value (NPV in MEuros) of a project. The main caution is to compare options in the same perimeter. Assessments limited to the electricity output from the plant will not account for differences in the total supply system required around the plant : transmission network, back-up capacities, etc… A comprehensive review of lifecycle costs for nuclear has been recently (December 2013) published by Professor William D'haeseleer on behalf of the European Commission (DG Energy).

Security of supply

Diversifying the sources is the most effective way to ensure security of supply. A major issue with oil supply to Europe is the strong dependence on Middle-East and Russia. The concentration of resources, notably the strong dependence on Russia, is still more acute for gas. For coal and uranium, it is easier to split the supply between several important supplying countries: such as Australia, Canada, Kazakhstan, Niger and Namibia for uranium. Indicators such as percent dependence on one single source can be used to measure vulnerability. As to the economics, broader diversity would mitigate the impact of acute fuel price crisis and give room to more bargaining power on the consumer's side.

Capital intensity

Capital intensive technologies are subject to strong dependence on financial resources, that is the current price of capital . The latter is expressed through WACC (weighted average cost of capital) parameter, mixing equity and loan financing costs. Since 2008 and under the new Basel 3 bank regulatory framework, financing large investment is confronted with capital scarcity. The main issue now with most of low carbon technologies is their capital cost, calling for adequate financing shemes. Otherwise, they cannot compete with less capital intensive gas fired turbines. The key indicator here is the « overnight cost of construction » in Euro/kWe, measuring the cost of construction without introducing interests paid during the construction time. The second indicator required will be the total time of construction, driving the added cost of financing.

Fuel price sensitivity

The fuel component of total cost is significant for two reasons. First, in the electricity market, the wholesale price at any moment is supposed to be determined by the marginal cost of production, which mainly consists of the fuel cost. Second, all primary fuels (oil, gas, coal, urainum) are subject to price volatility. Low fuel price sensitivity means predictable and stable price of electricity. The relevant indicator is the ratio of relative total cost increase to the relative unit price increase of fuel.

Peak load response

Electricity supply systems include both base load technologies such as nuclear or hydropower on stream and peak load technologies such as gas fired turbines or hydro reservoirs. Base load production is best supplied by low fuel cost technologies whereas peak load is best supplied by low capital cost technologies. In all cases, the system operator needs to know what capacities will be on line, i.e. dispatchable, at any moment. Optimal energy mix assessment has to differentiate base load and peak load conditions. All technologies also have to contribute to grid frequency and voltage stability. Relevant indicators have to be defined for this item.

Domestic added value

For European economy, the trade balance is improved when a larger share of added value of a supply chain is localized. Domestic added value will involve domestic raw material including primary fuel (e.g. lignite in Germany), domestic fuel transformation and conditioning (e.g. uranium enrichment in European plants) and domestic equipment manufacturing (e.g. wind turbines). The total direct and indirect annual added value (MEuro/year) generated by a new operating power facility can be evaluated. Clearly domestic added value carries on domestic jobs.

4.3 Social aspects

Employment

The employment supported by an industry can be assessed including both direct (design, equipment manufacturing, construction and operation) and indirect (supply chain) jobs. The geography of the jobs created as well as the spectrum of skills are important aspects. Such assessments then have to be carefully used in scenario comparisons, confronted with several issues. Job creation is more important when new capacities are under construction than in the phase of stationary operation. Installing a new technology in substitution to another will create jobs in one area and kill other jobs elsewhere. That means jobs specific to a technology have to be counted on a life cycle basis, from cradle to grave, to be compared. One overall indicator can be the number of jobs created per unit of initial investment (number of jobs per MEuro). The difference between two technologies may also lie in the spectrum of skills and in the geography (domestic versus foreign jobs) more than in the total employment content

Human health impact

Impact on normal operation

Health impacts of electricity systems in normal operation have been widely assessed.
A global indicator to assess this overall impact, the concept of “Years of Life Lost” (YOLL) has been proposed. It measures the mortality primarily caused by major pollutant emissions resulting from normal operation. People may die prematurely due to acutely high concentrations of air pollutants, but the major share of years of life lost is due to chronic illness caused by less severe more or less continuous burdens over the years. The reduction in life expectancy for individuals is summed to the total YOLL for the population. Technology specific mortality expressed in YOLL per Kwh have been developed by PSI (Hirschberg S et al 2008).

Impact of accident situations (risk of accidents)

Risk is defined as the product of a probability by a consequence (in term of early or latent fatalities or in term of contaminated land). Therefore both terms of the product need to be considered to be able to associate the consequence and the probability, knowing that in general the high consequence events have low probabilities and low consequences events are more likely.

A very significant amount of work has been done by PSI on the comparison of the risks associated with severe accident situations occurring on various forms of electricity generation. It includes a data base (ENSAD, ENergy related Severe Accident Database) that records nearly every accident that had occurred worldwide on fossil and hydro chains in a consistent manner since 1970 onward. Severe accidents are defined by one of the following criteria: more than 5 early fatalities, more than 10 injured persons, more than 25 Km2 of land affected, more than 5 million US$ in economic losses. This database includes today more than 2500 events that allow statistical analysis, but also extrapolation for high severity low probability events. To be able to compare between the different energy chains, the accident frequency is normalized to the unit of electricity generated.

For nuclear generation, only two events comply with these criteria: Chernobyl and Fukushima. Therefore statistical analysis is not possible. However probabilistic assessment could be used and especially PSA level 3 which account not only for the probability of core melt but also for the probability of significant releases and the probability of impact on the public in term of early and latent fatalities. Of course the result depends on the technology used (LWR, versus other technology, vintage of the plant) and the location of the power plant (population density in the surrounding, economic activities nearby…)

For renewable (solar and wind), even though some accident had occurred none of them were recorded up to now with more than 5 fatalities. Therefore no statistical analysis is possible. However, in a Multi Criteria Analysis one should consider that, unlike all other sources of electricity generation, these energies are not permanent, and that alone they cannot provide a base load service. They always need to be supported by other source of generation. Therefore, the back-up source of electricity should be considered in the risk assessment.

The best way to present the results of these statistical and probabilistic analyses is to draw Frequency/Consequences curves.

But for a more simple comparison in the framework of a Multi Criteria Analysis we suggest the following indicators:

- The maximum number of early and latent fatalities per GWe.year based on statistical data for fossil and hydro and a large source term corresponding to an early containment failure for nuclear (ST1 type)
- The expected number of fatalities based on statistical data for fossil and hydro and the source term corresponding to a filtered release for nuclear (ST3 type)
- The maximum area of land or seashore affected with the same methodology as above.

Risk aversion

It is well known that the perception of risk by the general public is somewhat different from the reality of the risk measured by statistical data or probabilistic analyses. In general the public perception of the risk is over estimated for the very low probability events and underestimated for the high probability events. Typical of that is the respective perception of risks of car accidents and of flight accidents.

It is also well known that the benefit from the application of a technology is an important factor of the perception of its risk. The low cost of electricity linked to the share of nuclear power in France is an element of explanation of the lower perceived risk of nuclear by the French public in comparison with Germany.

Some authors have tried to quantify a risk aversion indicator. It mainly consists in affecting an exponent on the consequence of the accident by a factor greater than 1 for scaring technologies and lower than1 for the familiar ones.

Terrorist threats

Nuclear power plants, as well as other energy supply facilities, are exposed to the threat of external aggressions from human malevolence: physical terrorist attacks, including through deliberate aircraft crash, or cyber-attacks to software systems. Reinforced protection has been imposed by governments after the 2001, September 11 terrorist attack. Cybersecurity has become a major concern in all industrial sectors. Assessing the whole electricity supply system vulnerability calls for specific areas of expertise and more discussion is needed on the way it can be handled.

Public acceptance

Nuclear energy continues to be a controversial issue and a challenge from the point of view of public opinion, especially because nuclear power often is associated with risks: severe accidents, radioactive discharges, etc… Meanwhile, other sources of energy also suffer from poor public acceptance and local opposition to new installations: coal fired power plants, wind farms, carbon capture and sequestration, LNG terminals. New advanced energy technologies are not free from controversy. Plans for new High Voltage transport lines suffer from even higher opposition. About one technology, monitoring public acceptance evolution is possible through periodic polls raising the same questions. When several technologies have to be surveyed monitoring is more complex. Public perception occupies a growing importance in energy policy decision-making and it can sway policy decisions. There is a strong case for better public information and involvement. Society needs to be able to weigh the advantages and disadvantages of different energy options against each other in an informed manner.

5 Conclusions

The multi-criteria approach proposed here encompasses a wide spectrum of performance indicators. At first sight that may look challenging but in fact a considerable amount of data is available from reliable sources. Agreeing on a common database and on methodology would open the way to a more effective debate around the optimal energy mix. The debate between the different stakeholders could focus mainly on the relative weight assigned to each dimension of sustainable development and to each criterion. ENEF Bratislava Forum gives the opportunity to propose and initiate such a process among the stakeholders.

Now, the first priority will be to come to an agreement about the principle of this approach between all the interested parties representing all the relevant energy technologies. Once the agreement is reached, the considerable amount of available studies should help to support the multi-criteria approach and to identify areas of consensus and areas needing more investigation.

Supporting references and former ENEF assessments

In the case of nuclear energy, ENEF has achieved on its own or collected and discussed several significant assessments that follow the approach proposed here:

- ENEF SWOT analysis (2008-2012)
- ENEF Socio-economic benefits of the nuclear industry in the EU to 2050 (2012 evaluation)

- OECD/NEA Nuclear Energy and Renewables, System Effects in Low-carbon Electricity Systems, 2012
- Paul Scherrer Institute: A global energy perspective: Costs and benefits of future energy systems and policies
- UK Spring project (2008-2011): Assessing the sustainability of nuclear power – what does it mean?
- William D’haeseleer: Synthesis on the Economics of Nuclear Energy (November 2013)
- EURELECTRIC Life cycle assessment of electricity generation (November 2011 2011)
    - "MULTICRITERIA DECISION ANALYSIS – PSI – Energie Spiegel 2010"

Document 7:

Society and Energy – Deciding the Future – The need for analysis, transparency and dialogue in determining the energy mix – a proposal from the ENEF – Working Paper of WG TRANSPARENCY

Draft 6
ENEF Transparency Working Group
Task Group- Foundation Principles for Energy Production

Society and Energy – Deciding the Future

The need for analysis, transparency and dialogue in determining the energy mix – a proposal from the European Nuclear Energy Forum

Introduction

Energy is increasingly a focus of political concern. Numerous uncertainties and the polarising of public opinion is resulting in sub-optimal short term decisions or policy delay and confusion, affecting all stakeholders in the energy chain. The Transparency Working Group of ENEF explored whether there are universally applicable foundation principles which could help the continuing formulation and adaptation of energy policy in a rapidly changing world and offer pointers towards an effective governance process. Both the Opportunites and the Risks Working Groups have been developing complementary approaches focussing on technical analysis and this package of work taken together will provide an invaluable methodology establishing how decisions can be made which reflect the numerous trade-offs, technical, sectoral and national complexities in an all-energies policy
We suggest that any decision about energy policy needs to reflect the most inclusive stakeholder base possible. It will involve a 'total systems' approach, a combination of technical and societal factors, and will be 'values' –based. The key which will unlock progress on this complex issue is trust. Although ENEF is dealing with nuclear in the first instance, this paper has been written with an all-energy perspective.
We therefore propose a three-stage approach as outlined in 3.3 to take forward this ground-breaking work. *(*discuss detail with other WGs and the coupling of the MCA paper)*

1. How we determine Founding Principles

1.1 As human beings we have an amazing ability to develop and change our world; energy is essential to this and in how we work and live. Most of us are now urban dwellers, but wherever we live we depend on long chains of supply for energy and most of our needs.

1.2 At the same time the human community has expanded numerically and geographically. This results in substantial current and potential impacts on the natural environment. Energy production and use have also had major effects. For example significant air pollution and legacy issues created by toxic and radioactive wastes. Perhaps the central symbol of such impacts are greenhouse gas emissions (GHG) and consequent global climate change.

1.3 The international community, in an attempt to reconcile GHG impacts with energy demands, has formulated a number of international agreements such as those to curb emissions and targets for reducing emissions. In a changing world the EU and its member states have been at the forefront of proposing ways to achieve the economic, social and environmental balance that will sustain a flourishing world.[10]

1.4 The EU is founded on values of peace, democracy, human dignity, pluralism, tolerance, and solidarity; the ethical and practical principles that are necessities for global community to prosper. These values specifically provide the foundation for the opinion "An ethical framework for assessing research production and use of energy" from the EGE.[11] This opinion also recognises safety, access, participation and research as pillars of the energy debate, which together with the cross cutting theme of justice, for example as exemplified in the Aarhus Convention, helps to put the discussion in the EU and its member states (MS) into a proper global context.

1.5 The EU is faced with several challenges, two of the most pressing being the necessity of energy security and the need for infrastructure investments of at least EUR 1.1 trillion by 2020 as part of a radical energy transition. Energy policy is shaped by the potential for future impacts of the energy mix, the need for a secure and safe supply and one which is affordable for citizens and competitive for industry.

1.6 Some long term targets relating to energy have been agreed by the EU. The goal of an energy system which would cut greenhouse gas emissions (GHG) by 80-95% by 2050 compared with 1990 is well established and provides a framework within which medium term targets and practical measures are being developed. The non-use of energy, through efficiency and reduction measures and the switch to renewable sources of energy are similar objectives.

1.7 Although the EU treaty encourages collaboration and co-operation 'energy sovereignty' remains paramount. This is in spite of the active promotion of a single market and recognition of advantages from the collaborative optimisation of supply and distribution by the European Commission. Each MS is contributing to the targets and objectives in its own way. Each country has the right under the EU treaty to choose its energy policy and mix - every country has a different pattern of generation, distribution and use. Energy sovereignty might therefore be regarded as a political necessity but clearly can come into conflict with other principles.

1.8 It is also the case that energy resources and history vary. Therefore, when it comes to decisions about energy policy, each country will differ. Though the overall objective might be accepted the methods of achieving it will diverge and the balance between the three main generic sources of energy, fossil fuels, renewables and nuclear will be different.

1.9 Different energy mix strategies will emerge according to where the emphasis is placed relative to the values felt to be important to a particular society, a reality which will always ensure a degree of divergence between Member States and which inevitably creates difficulties in agreeing EU-wide policies. At the same time energy policy also needs to reflect the citizens' desire for fairness and an increasing concern for their voice to be heard.

1.10 Energy policy is therefore a bridge between the hard facts of what is technically and economically possible and the realities of what is acceptable and capable of being practically

[10] This paper adopts the approach to and definition of sustainable development as set out by the OECD.
[11] The European Group on Ethics in Science and New Technologies, January 2013.

implemented in a society. It is also charged with the responsibility of delivering agreed targets and objectives.

1.11 In this complex situation what structure is appropriate for EU-level, national, regional and local discussions about the energy mix and how can such dialogue assist in underpinning an effective and transparent governance mechanism which will deliver agreed objectives such as those proposed in the Climate and Energy Framework 2020-2030?

2 Transparency is needed for Trust

2.1 Trust between nations in the formulation and implementation of agreements is fundamental to progress in the energy debate. The trust of citizens in their governments, scientists, and technical experts in evolving policy which will determine the choice of energy supply types is also essential. Trust between governments, regulators and energy providers is necessary for companies to plan for long term investment and operation of energy supply systems.

2.3 Trust is vital between consumers and suppliers, especially in a competitive market situation. Current discussions in Europe concerning fracking, nuclear and some aspects of renewable energy bring this into sharp focus.

2.4 There can be no trust without transparency. Transparency makes the hidden visible. It is looking through the stated claims and commitments of participants in any discussion to ensure that they are genuine and comprehensive. It is closely related to the quest for scientific objectivity and is developed by asking penetrating questions of all parties to a discussion and evaluating the responses.

2.5 This process can transform and add value to a data-based approach such as multicriteria analysis and can build a level playing field in which all energy forms can be assessed in their widest possible context. It also means that no energy form can be dismissed out of hand and that single outcome solutions can be scrutinised within an agreed methodical process.

2.6 Such a comprehensive process may overcome the limitations of existing approaches, especially when determining the energy mix at a national level. The three major energy sources (fossil fuels, renewables, nuclear) are, to a certain extent, not directly comparable with each other. A final decision on which to use will always need to be 'qualitative' in the sense that it will (need to) be a deliberate decision informed by knowledge (in the form of facts and opinions), but inspired by a 'moral consensus' that can only take shape in that deliberation itself.

3 A Questions Based Approach for the energy mix

3.1 When starting to create a dialogue, a well determined structure is needed and roles and responsibilities of different stakeholders in the dialogue need discussion and clarification. It is also important is to determine what information is available and when, who is responsible for what information and how and when the stakeholders can participate. How the contributions are going to be made public should also be taken into account. A framework is essential for this complex interrogation on energy but this will vary for the type of dialogue. It would involve:

- A series of issues, giving rise to questions, could be tabled, adapted to the forum, meeting or policy dialogue which was taking place. These, taken together, would give an ***enquiry profile*** for each energy source –identifying essential questions, both technical, economic and societal – to which answers need to be given or a position developed. A proposed list of such issues is offered in section 4 together with related queries which would go some way towards ensuring a quality assessment process.

- The responses from such an approach would enable policy makers and energy consumers to evaluate, within a given framework, the relative merits of each type of energy supply. It would also, potentially, give citizens, something like a level playing field on which to make their own assessment. Each of the stakeholders in the energy debate, policy makers, providers, and consumers, would also have to formulate and table their own questions, and responses, as part of the process.

3.2 This method implies that numerous interest groups use the framework to engage in a process which will vary considerably in its content and outcome. These interest groups can be seen as strands in the overall debate, for example energy providers, types of energy consumers, regional or local authorities, cities, rural communities etc. Rather than decision makers immediately having the task of synthesising responses these should be the basis of further dialogue between stakeholders which will identify consensus, divergence, possible trade-offs and areas of factual uncertainty.

3.3 Three stages can therefore be outlined:

- Identify principles and issues underlying a debate about energy and frame a response process. *(this paper)* (Assumes a joint approach coupled with the MCA paper)*
- Set up mechanisms (forums, round-tables, virtual dialogues etc) where stakeholder responses can be compared, evaluated and discussed.
- Use outcomes from such mechanisms to inform, influence or stimulate further discussion with decision-makers and also underpin effective governance processes.

Concerning this last point it is important that stakeholder involvement processes should also become part of formal politics, recognised as a strong element in more inclusive formal political decision making.

3.4 ENEF, as one of the established forums for discussion on energy issues, proposes that one leading strand in this debate should be between seven generic groups of energy source providers, and also include energy savings and efficiency as an eighth reference group. These would therefore comprise energy savings and efficiency, intermittent renewables, non-intermittent renewables, nuclear, coal, gas, oil, and new (unproven/undeveloped) technologies.

3.5 Each group in this strand, through a response to the issues in section 4, will set the scene for an active debate relevant to EU energy policy. This need has been implicitly recognised in the composition of the first Berlin Energy Forum and could form the substance of the second such meeting.

4. Process principles for determining an energy policy profile

4.1 The following issues are suggested as the basis for evolving an ‘enquiry profile’ for energy source components of a future energy mix. Given the vital role of energy savings and efficiency in any future energy policy we suggest that a similar profile is developed for this as a reference point, using the same issues, where applicable. Several of these issues can then be scrutinised using a multicriteria analysis (MCA) approach and the case for doing this has been developed by a parallel working group within ENEF. MCA is a methodology which, applied to the energy sector looks, for example, at various means of producing electricity (the whole energy chains from original resources to distribution) through a number of factors pertaining to economic, environmental and societal aspects. Sufficient data and analysis are available from other energy sectors to feed a multi-criteria analysis of the whole electricity supply system (including generation, transport and distribution). At the European level the implementation of this methodology as one part of the process of dialogue could help define pertinent energy priorities at national and European level. Other issues, those less capable of quantitative analysis, will require different techniques.

4.2 Issues:

- Determining costs of energy production over the full lifecycle of the plant and associated ancillary facilities
- Identifying the role and importance of a stable, secure, non-interruptible energy source
- Research and development priorities
- Personal health and social impact
- Intergenerational health and safety and legacy issues
- GHG and other environmental impacts
- Other potential impacts – e.g. nuclear proliferation, land use priorities, ownership stucture etc
- Labour issues and working conditions
- Long term resource use and scarcity

4.3 Questions to provide a quality assurance process

- Have all relevant factors been included in the analysis?
- Have all disputed areas been identified?
- Has appropriate risk analysis been undertaken and uncertainties identified?
- Has data been assembled to reflect and cost the full range of related risk probabilities?

- Has the process been subject to both independent and adversarial scrutiny?
- Have the views of all relevant participants been heard?
- Have participants identified their own priority and ranking for the various issues under analysis?

5. The wider dialogue

5.1 ENEF believes that underlying societal values related to energy production and use require more discussion. Such values, articulated and accepted by the citizen, would enable greater policy coherence and develop greater trust. Decisions taken by a country on energy sources are ultimately derived from that society's value judgments, over and above technical and economic considerations. Decisions about energy policy are therefore based on a set of factors beyond a purely rationalist/scientific base. In these circumstances, particularly as national, regional, local and personal views about energy will vary, an appeal to a consistent, common, perspective can reach beyond a tendency to personal, local, short-term or national interest.

5.2 The journey towards a low-carbon future will follow many routes. The principles and associate discussion framework offer guidance on a general direction of travel but have to be translated and applied to specific policies and actions. To be effective this needs to involve public participation, engagement and action and will entail the development of 'knowledge-based and transition attitudes' by citizens as actors in the political process and as energy consumers.

5.3 'If I am affected I should be consulted.' As a citizen everyone plays a part in determining the future of the energy system. In addition there are numerous stakeholders with specific roles, some with statutory responsibilities, others acting within the market structure, as lobbyists, researchers, advisers etc. Decision-making on energy has a history of lack of clarity and transparency. The roles and responsibilities of the various stakeholders need clear definition as does their commitment to a fully transparent process.

5.4 ENEF will provide a response to the questions outlined in 4.2 and will seek the involvement of representatives from other energy sources and perspectives in this deliberation. This, together with equivalent responses from other stakeholders in the energy chain, can then form one of the next steps in what is an increasingly vital European dialogue on energy.

6. Extending this approach to a governance framework

6.1 It is abundantly clear that a practical governance framework for the implementation of an EU energy policy is urgently needed. Without agreed and effective governance the theoretical approach outlined in this paper, involving dialogue and public engagement, will be of little value. The nature and scope of such a governance framework lies beyond the immediate scope of this paper but a number of relevant points emerge from it not least the need for a governance process which will step beyond national self-interest and emphasise European solidarity in the context of global responsibility.