QUESTIONAIRE

INPRO Dialogue Forum "Drivers and Impediments for Regional Cooperation on the Way to Sustainable Nuclear Energy Systems"

30 July – 3 August 2012,

VIC Boardroom A, IAEA Headquarters, Vienna

Short instruction:

(1) The Questionnaire has 6 Sections

(2) Please, try to fill out as many positions of the Questionnaire in all its 6 sections as possible

(3) Leave the box blank only if you definitely don't know the answer

(4) Numerical scale of 1 through 5 is always suggested to indicate your rating of the priorities (preferences, importance). '1' is always for the lowest rating and '5' is always for the highest rating. In your ratings, please, also use the numbers in-between (i.e., 2, 3, 4) to fine-tune your evaluations. The higher the number you indicate, the higher is your rating.

(4) Several issues or positions in the tables below may have the same rating, i.e., each number on a 1 through 5 scale could appear in each table as many times as deemed necessary by you.

(5) Please, note that filling out the Questionnaire is requested from each participant of the Dialogue Forum, as it had been indicated in the Prospectus

(5) Please, fill out the Questionnaire electronically and forward it to us (V.Kuznetsov@iaea.org; Y.Busurin@iaea.org) before 27 July 2012.

(6) As the exception, if you really feel you will be able to provide more reliable answers after listening to some lectures and presentations at the Forum, an option to fill out the Questionnaire manually during the meeting or submit it on a USB stick will be available.

(7) In Section 6, please do not forget to indicate your country, which would help us better systematize and analyze the responses regarding where the countries stand regarding a nuclear power programme.

Thank You!

Scientific Secretaries

Vladimir Kuznetsov
Nuclear Engineer
NE/NENP/INPRO,
International Atomic Energy Agency,
Wagramerstrasse 5, P.O. Box 100,
A-1400 Vienna,
Austria
Room A-2447
Tel.: +43-1-2600-25150
Fax: +43-1-2600-29598
Email: V.Kuznetsov@iaea.org

Yury Busurin
Nuclear Engineer
NE/NENP/INPRO,
International Atomic Energy Agency,
Wagramerstrasse 5, P.O. Box 100,
A-1400 Vienna,
Austria
Room A-2447
Tel.: +43-1-2600-26716
Fax: +43-1-2600-29598
Email: Y.Busurin@iaea.org

Section 1. Please, prioritize the importance of collaboration with other countries on particular issues in each of the empty boxes below using a 1 to 5 scale (1 – low priority, 5 – highest priority).

- Please, note the question is about the importance of collaboration with other countries on a particular issue, not about the priority of the issue
- Please, read short explanatory comments in Attachment 1 before proceeding

#	**Issues to be addressed in transition to sustainable nuclear energy systems (NES)**	**Short term (up to 2030)**	**Medium term (2030-2050)**	**Long term (2050-2100)**	**Comments** **Please, insert a couple of comments to explain your rating**
		Priority: 1 to 5	**Priority: 1 to 5**	**Priority: 1 to 5**	
1	U resources - yellowcake				
2	Enrichment				
3	Low enriched uranium (LEU) fuel manufacture				
4	Nuclear power plants (NPPs)				
5	Potential for non-electrical applications				
6	Long-term spent fuel storage				
7	Reprocessing of LEU fuel for water cooled reactors and mixed oxide (MOX) fuel fabrication				
8	High Level Waste (HLW) management				
9	Final disposal of waste				
10	Management of minor actinides				
11	Special plants: Accelerator Driven Systems (ADS), Molten Salt Reactors (MSR)				
12	Advanced fuel cycles				
13	Incorporation of Thorium				

Section 2. With respect to a nuclear energy project in your country, please, indicate your vision of the importance of economic indicators in each of the empty boxes below using a 1 through 5 scale (1 – lowest importance, 5 – highest importance).

- Please, read Attachment 2 for the definitions and short explanations

#	Indicator	Short term (up to 2030)	Medium term (2030-2050)	Long term (2050-2100)	Please, comment on your rating, if necessary
		Importance: 1 to 5	Importance: 1 to 5	Importance: 1 to 5	
1	Levelized Unit Electricity Cost (LUEC)				
2	Investment cost				
3	Payback period				
4	Net Present Value (NPV)				
5	Internal Rate of Return (IRR)				

Section 3. With respect to your country, please, indicate your preferences regarding the approach to final disposal of radioactive waste in each of the empty boxes below using a 1 to 5 scale (5 – most preferred, 1 – least preferred).

#	Approach	Short term (up to 2030)	Medium term (2030-2050)	Long term (2050-2100)	Please, explain your preferences, if necessary
		Preference: 1 to 5	Preference: 1 to 5	Preference: 1 to 5	
1	National solution				
2	Solution fully or partially outsourced to supplier				
3	Regional solution				
4	International solution				
5	Controlled spent nuclear fuel storage over a long period, pending the availability of proven and efficient technologies for final disposal				
6	Final disposal of spent nuclear fuel without reprocessing				
7	Final disposal of only fission products that remain after the reprocessing and recycle of spent nuclear fuel (possibly in a supplier country)				

Section 4. Please, indicate which stages of the front-end nuclear fuel cycle your country has mastered (or considers to master) indigenously

#	**Fuel cycle front-end stage**	**Short term (up to 2030)**	**Medium term (2030-2050)**	**Long term (2050-2100)**	**Please, provide comments, if necessary**
		'Yes' or 'No'	**'Yes' or 'No'**	**'Yes' or 'No'**	
1	Mining and milling				
2	Conversion				
3	Fuel pellet manufacturing				
4	Fuel assembly manufacturing				

Section 5. Please, indicate which of the issues mentioned below are (or may become) important with respect to a nuclear energy project in your country. Please, use a 1 to 5 scale (1 – not important, 5 – very important)

#	Issue	Importance: 1 to 5	Please, amend your rating with a comment, if necessary
1	Land requirements		
2	Water requirements		
3	Legal and institutional infrastructure		
4	Logistic considerations		
5	Political considerations/ Political willingness		
6	Public perception and acceptance		
7	Energy independence		
8	Public health and environmental issues		
9	Security of supply		
10	Considerations of global climate change		
11	Size of electrical grids		
12	Industrial base		
13	Financial resources		
14	Cost sharing		
15	Human resources		
16	Technology transfer		
17	Physical infrastructure		
18	Other issues (please, name them and rate their importance in the free rows below)		
19			

Section 6. Please, answer the following questions

(6.1) Does your country have national laws prohibiting or restricting return of spent nuclear fuel to suppliers from other countries. Please, indicate ‘yes’ or ‘no’. If your answer is ‘yes’, please, comment on the nature of the existing restrictions

(6.2) Does your country have national laws prohibiting or restricting trans-boundary transport of spent nuclear fuel? Please, indicate ‘yes’ or ‘no’. If your answer is ‘yes’, please, comment on the nature of the existing restrictions

(6.3) In relation to a nuclear energy project, assume a service or a particular product could be provided by several suppliers. How many suppliers would, in your view, guarantee the security of supply? Please, provide a number (e.g., ‘5’) or a range (e.g., 2-3).

(6.4) Please, indicate your country

Attachment 1. Short explanatory comments to Section 1

#	**Issues to be addressed in transition to sustainable NES**	**Characteristics/ comments**
1	Uranium resources - yellowcake	- There is an already established open market - International trading is possible. Price will define competitiveness of other fuel cycle options - Some uncertainty about future prices exists - Limited number of producers may determine the need of cooperation
2	Enrichment	- Proliferation sensitive - Technologies and commercial facilities are available with a few countries, though investments may be required - Again, there is already international trading of these services. However, it is a sensitive technology and economies of scale favour a limited number of larger facilities instead of a large number of smaller facilities - International legal framework to assure enrichment services is essential (how much fuel needs to be stored?) - Multiple sources of supply would be desirable, preferably in different geographical regions - Safety, security and legal issues of low enrichment uranium (LEU) transportation need to addressed
3	Low Enriched Uranium (LEU) fuel manufacture	- Commercial facilities and services are available - Fuel manufacture facilities collocation with enrichment facilities is not necessary - Change in availability from a single supplier to several suppliers may be needed to prevent possible critical situations when a supplier cannot respect the already engaged commitments for a variety of reasons - One or few suppliers may be available for some fuel designs. - Standardization of fuel or flexibility for fuel is desirable (but difficult today)

4	Nuclear Power Plants (NPPs)	- Generation III, III+ nuclear power plants (NPPs) are available - Generation IV and other advanced designs are under development (significant R&D required in most cases) - Present-day NPP construction is an area of commercial competition, but cooperation is required for development of new-generation reactors - Country specific requirements for NPPs are generically needed - Standardization of design would help in licensing - Generic design concerning safety aspects should be collaborative (demonstration projects, crosschecking of results, etc.)
5	Potential for non-electrical applications	- Non-electrical applications have high potential in the longer-term - This area is very important for advancing broader use of nuclear power to address climate change - Generic design concerning safety aspects should be collaborative (demonstration projects, crosschecking of results, etc.)
6	Long-term spent fuel storage	- Technical solutions exist - Commercial facilities are available. - Degradation of Pu, accumulation of minor actinides are the issues - International/ multi-national facilities could be considered - Legal and commercial framework needs to be worked out - Has clear advantages for countries with small/ medium nuclear program, but in-site temporary solutions are available
7	Reprocessing of Low Enriched Uranium (LEU) fuel for water cooled reactors and Mixed Oxide (MOX) fuel fabrication	- Proliferation concerns exist - Competence is available in several countries for aqueous reprocessing - Typically attached with fuel supply (would be important in medium and longer term) - Current policies in several countries are to go on without reprocessing (but policies may change in a medium or longer term) - It is important to have only a few countries with competence for reprocessing (because of proliferation concerns), but monopoly that might arise may raise concerns

		- Recycling of used fuel is central to sustainability. Given the sensitivity of technologies and the economies of scale, this is a very important area for collaboration. Generically, reprocessing is not limited to the boiling water reactor (BWR)/ pressurized water reactor(PWR) low enriched uranium (LEU), and the recycled product is not limited to mixed oxide (MOX) fuel
8	High Level Waste (HLW) management	- Typically attached with reprocessing - Fission products are the essential part of HLW - Proliferation sensitive in a number of aspects: management of separated streams after reprocessing must be addressed: Pu separation, fast reactor fuel fabrication (Pu, minor actinides (MA)), process losses destination, fission product conditioning - Decisions in this area will be key to implementation of any collaborations
9	Final disposal of waste	- Waste stream from a nuclear energy system includes low level waste (LLW), intermediate level waste (ILW) and high level waste (HLW) which, in turn, includes spent nuclear fuel - Spent nuclear fuel appears to be the area of highest concern owing to its accumulation being proportional to energy production (in present-day once-through nuclear fuel cycles), and because it contains plenty of highly radiotoxic long-lived isotopes (actinides) - Spent fuel could be disposed of without reprocessing, after a necessary storage period - As an alternative, spent nuclear fuel could be reprocessed with actinides recycled as reactor fuel and minor actinides and long-lived fission products being transmuted in special plants or in fast reactors. In this case, HLW will be substantially reduced in volume and its radioactivity and radiotoxicity will decay down to natural uranium level just in ~500 years after final disposal - International/multi-national approach wouldl be essential for some users of nuclear energy - Decisions in this area will be key to implementation of any collaborations
10	Management of Minor Actinides (MA)	- Typically attached with reprocessing - May be of proliferation concern if streams of certain MA are separated - Advanced fast reactors or accelerator driven systems (ADS) could be used to burn MA - While an important topic for sustainability, it may be less important for collaboration

11	Special plants: Accelerator Driven Systems (ADS), Molten Salt Reactors (MSR)	- ‘Standard’ fast reactors possibly could manage a good amount of MA, but special plants could maximize the efficiency - Could realistically be considered in a longer term for MA burning or fissile material breeding. - Fusion neutron sources might be a solution, if proven. - Could be considered as part of the options for sustainability (waste management, thorium usage, etc.)
12	Advanced nuclear fuel cycles	- Claimed to be proliferation-resistant by some, but argued to be proliferation sensitive by others - Pyro-processing is under development, but RD&D are required to commercialize it - Separation processes (pyro, aqueous, fuel fabrication routes, etc.) must advance in parallel with the general objectives of advanced nuclear systems. The coverage of many sub-processes and aspects favours collaboration
13	Incorporation of Thorium	- May be not so interesting in the near term when uranium is sufficient - Demonstrated in current generation reactors on a limited scale - Potential for near-term deployment with once-through nuclear fuel cycle exists - Has higher potential for sustainable fuel cycles with reprocessing. Not so useful without reprocessing. - Does not present any unique collaborative issues versus uranium based options

Attachment 2. The definitions of, and some comments on, economic indicators

2.1. Definitions

(1) *Levelized Unit Electricity Cost (LUEC)*

$$\mathrm{LUEC} = \frac{\sum_t \frac{(\mathrm{Investment}_t + \mathrm{O\&}M_t + \mathrm{Fuel}_t + \mathrm{Carbon}_t + \mathrm{Decommissioning}_t)}{(1+\mathrm{r})^t}}{\sum_t \left(\frac{\mathrm{Electricity}_t}{(1+\mathrm{r})^t}\right)}$$

where:

$\mathrm{Electricity}_t$:	The amount of electricity produced in year "t";
$P_{\mathrm{Electricity}}$:	The constant price of electricity;
$(1+r)^{-t}$:	The discount factor for year "t";
$\mathrm{Investment}_t$:	Investment cost in year "t";
$\mathrm{O\&M}_t$:	Operations and maintenance cost in year "t";
Fuel_t:	Fuel cost in year "t" (includes fuel cycle cost);
Carbon_t:	Carbon cost in year "t";
$\mathrm{Decommissioning}_t$:	Decommissioning cost in year "t".

Table. Structure of nuclear electricity generation cost (for large reactors) [1]

Discount rate	**5%**	**10%**
Investment cost	58.6%	75.6%
O&M	25.2%	14.9%
Fuel costs[1]	16.0%	9.5%
Carbon costs	0.0%	0.0%
Decommissioning	0.3%	0.0%

[1] Fuel costs comprise the costs of the full nuclear fuel cycle including spent fuel reprocessing or disposal [1]

(2) *Investment cost* = Overnight cost + Interest During Construction

(3) *Payback period* = the period of time required for the return on an investment to "repay" the sum of the original investment

(4) *Net Present Value (NPV)*

The net present value (NPV) of a time series of cash flows, both incoming and outgoing, is defined as the sum of the present values (PVs) of the individual cash flows. Each cash inflow/outflow is discounted back to its present value (PV). Then they are summed.

(5) *Internal rate of return*

The internal rate of return on an investment or project is the annualized effective compounded return rate or discount rate that makes the net present value of all cash flows (both positive and negative) from a particular investment equal to zero.

2.2. Comments

(1) "The notion of LUEC is a handy tool for comparing the unit costs of different technologies over their economic life. It would correspond to the cost of an investor assuming the certainty of production costs and the stability of electricity prices. In other words, the discount rate used in LUEC calculations reflects the return on capital for an investor in the absence of specific market or technology risks." "It is also closer to the real cost of investment in electricity production in regulated monopoly electricity markets with loan guarantees and regulated prices rather than to the real costs of investments in competitive markets with variable prices" [1].

(2) "Projects with small capital outlay (*investment cost*) and short *payback period* are typically more attractive to private investors operating in liberalized markets where the figures of merit are the net present value (NPV) and the internal rate of return (IRR) rather than the levelized unit product cost assuming the certainty of the production costs and the stability of the product prices" [2].

References

[1] INTERNATIONAL ENERGY AGENCY AND NUCLEAR ENERGY AGENCY, ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT, Projected Costs of Generating Electricity, 2010 Edition, OECD PUBLICATIONS, Paris (2010).

[2] NUCLEAR ENERGY AGENCY, ORGANISATION OF ECONOMIC COOPERATION AND DEVELOPMENT, Current Status, Technical Feasibility and Economics of Small Nuclear Reactors, Nuclear Development, June 2011: http://www.oecd-nea.org/ndd/reports/2011/current-status-smallreactors.pdf