

Nuclear Innovation Cooperation

In the Low-Carbon Perspective

NEA NI2050 Initiative

***3d ADVISORY PANEL MEETING
JUNE 2016***

AGENDA

DAY 1 (Chair: *Fiona Rayment, Kathryn McCarthy, Franck Carré*)

13.30-14.00: *Objectives for this meeting + NI2050 Website Development and Access + State of Play of Survey*

14.00-16.00: *Outcomes Experts Meetings 1.2 + 2.2 and 4*

16.30-18.00: *NEA Science Div activities and NI2050 + NEA NEST + Overall Discussion*

DAY2 (Chair: *Kathryn McCarthy*)

08.30-10.30: *Outcomes Experts Meetings 1.1 + 2.1*

NEA Safety Div activities and NI2050

10.30-12.30: *Outcomes Experts Meetings 3.1 + 3.2*

NEA RadWaste Div activities and NI2050

12:30-13.00: *Overall Discussion*

14:00-16:00: *Brainstorming on next steps and Conclusions*

OBJECTIVES OF THIS MEETING

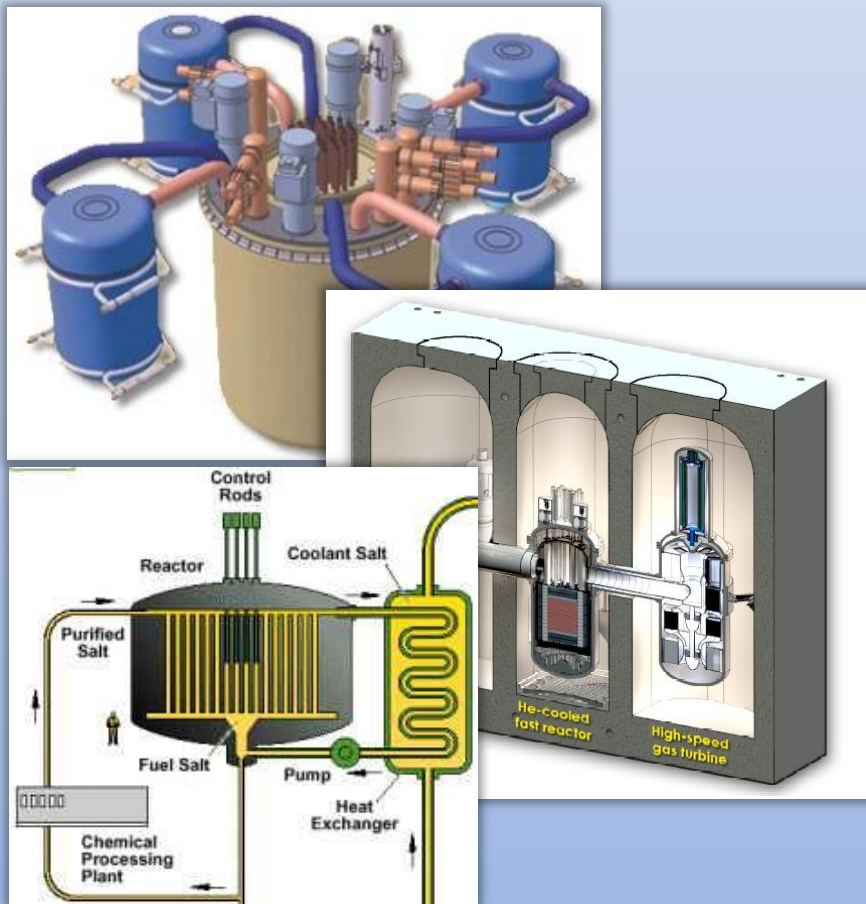
Context:

- *Original Set of Questions – Launch Conference – Adv Panel set-up*
- *Half Way of the NI2050 process: Survey + Roadmapping*
- *7 Experts Meetings have taken place in March and April (100 experts for 3 d)*
- *Scope of the Experts Meetings and Method of Work*
- *Timeline for Next Steps*

Objectives:

1. *Take stock and discuss: (Survey and) Outcomes of Experts Meetings*
2. *Understand what is done already in related NEA **projects** (and others?)*
3. *Clarify the overall objective of the NI2050*
4. *Agree on a (non exhaustive) **list of potential large issues/stakes** and associated long term R&D **programmes** to be developed (incl infrastructures up to Demos)*
5. *Discuss/Agree the ways to develop these long term R&D programmes*

Nuclear Innovation 2050 – A Roadmap for the Future of Nuclear Fission Technology



- What technologies will be needed in the coming decades to meet growing demand and align with policy goals?
- What research and development is needed to make these technologies available?
- Is the global community doing the R&D needed to prepare for the future? What and How to do better?



Technology Roadmap

Nuclear Energy

2015 edition

2035

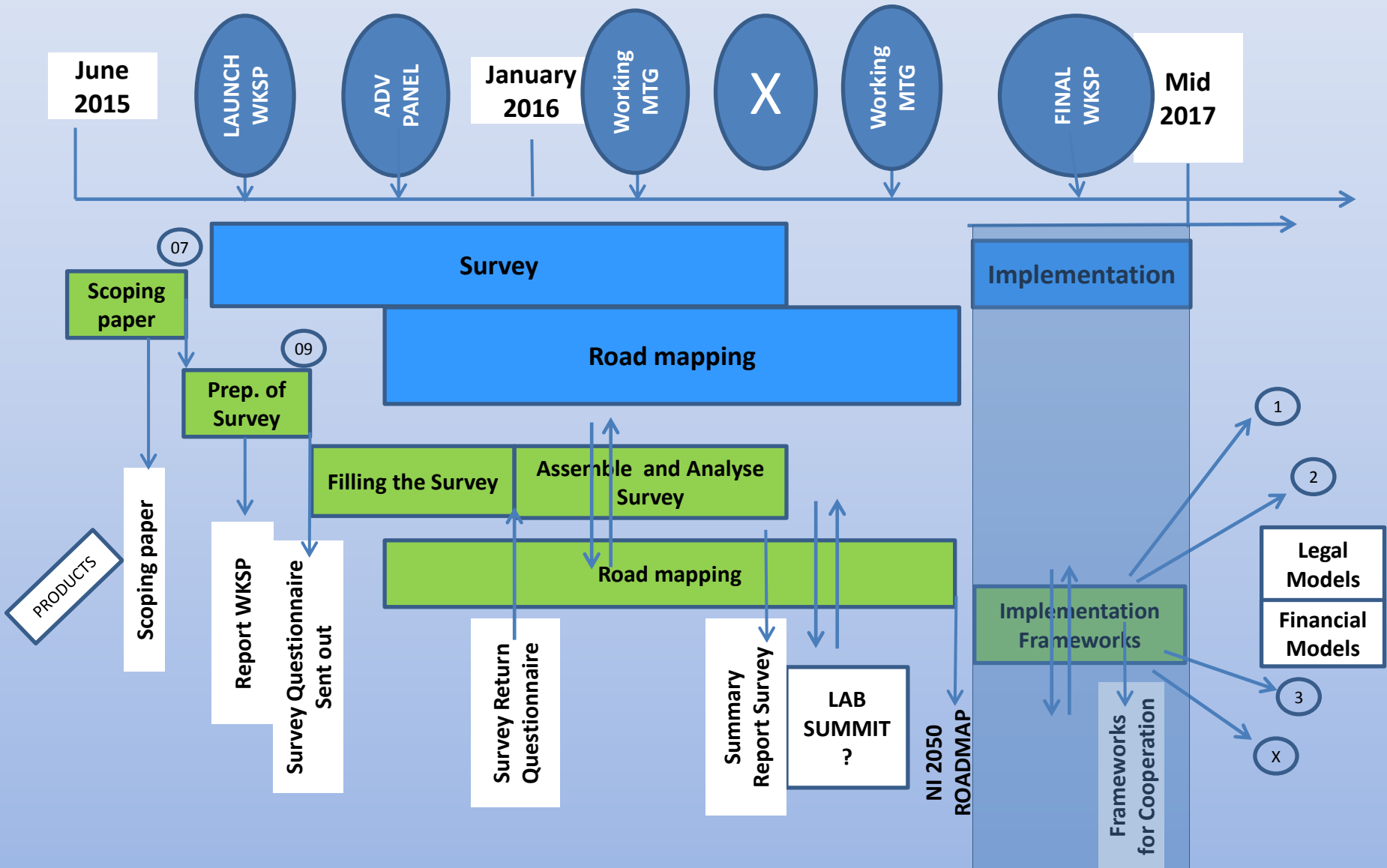
2040

2045

2050



NI 2050 Process and timeline



METHOD FOR THE EXPERTS MEETINGS MARCH-APRIL 2016

In practical terms, experts, by working together and based on their vision, knowledge and experience of roadmapping, are asked to:

1. Establish a list of priority R&D issues/topics to accelerate innovation and readiness of technologies
2. Fill the Template for each selected issue/topic (see template)
3. Give a priority ranking to the selected issues/topics (see proposed criteria)
4. Evaluate the potential for cross-cutting issues (see proposed list)
5. Evaluate the necessary physical infrastructures and skills
6. Provide conclusions (mini-report) in the form PPTs for presentation.

NEXT STEPS

- 1. Consolidate the outcomes of the Survey**
- 2. Consolidate the outcomes of the Experts Meetings**
- 3. Evaluation by the Advisory Panel in June**
- 4. Possible further dedicated Experts Meetings in Sept/Oct**
- 5. Advisory Panel Meeting in December/January + one**
- 6. Drafting of Report**
- 7. Final Workshop ?Sept 2017? – Launch of the discussion on Cooperation Frameworks**
- 8. NDC discussion and decision on follow-up in June 2017**

SOME PRELIM IDEAS for the June ADV PANEL brainstorm

Clarification of NI2050 Objectives:

- NE in low carbon 80% 2050+***
- Develop and bring technologies to market cheaper and quicker***
- Look for some (not exhaustive list) priority large Programmes (and associated infrastructures), including phases towards Demonstration***
- Having a potential for real cooperation***
- With Action Plan for next 20 years: 2035 towards 2050+***
- Integrate Competencies and Skills (E&T) – NEST***

= Going from bottom-up **projects** (adhoc, scattered and short term) towards top-down **programmes** (long term and integrated, ia infrastructures) – make it happen (quicker and cheaper)...

SOME PRELIM IDEAS for the June ADV PANEL brainstorm

Examples of Stakes/Long Term Programmes:

- ***Safety = No Release out site:*** Severe Acc prevent/remediation (expand Nuegna and NEA JP); ATF (expand NEA activities)
- ***Waste Mgmt:*** extended SNF storage + GD International R&D Center (expand IGDTP on real case)
- ***Decommissioning:*** International R&D Center on real case
- ***Fukushima*** Center for Sev Accident/Corium Mgmt, Decomm of damaged plant
- ***Future Reactors and Fuels:*** GIF phases towards Demonstration – see SSCs
- ***Waste Mgmt:*** Transmutation (prepare the Demonstration phase for transmutation of MAs)
- ***Flexibility in Elec and non Elec uses:*** Hybrid systems, SMRs and cogeneration demonstration (HTR?)
- ***Crosscuttings:*** Adv Materials and manufacturing and NDT (harmonisation, C&S); Modelling and Simulation + Validation; I&C/IT and big data; Power Conversion Systems;...
- ***Sharing/Pooling Infrastructures*** for irradiation/PIE, T&H loops,...
- ***E&T, competence and skills:*** NEST dimension of NI2050

NI2050 WEBSITE

- ***Fully operational***
- ***Contains all agendas, presentations, templates, records,... of Adv Panel Meetings and Experts Meetings***
- ***Link was sent to all Members of Advisory Panel and participants of Experts Meetings***
- ***Password Protected – do we keep it like this ? Or extend to NDC, NSC, CSNI, RWMC,... ? Or full opening... ?***

NI2050 SURVEY

- 13 June 2016: Returns received from:

Australia, Austria, Canada, Czech, EC, Finland, Germany, Italy, Japan, Korea, Netherland, Poland, Slovenia, Spain, UK, US

Partial inputs: France, Belgium, Russia (?)

- Very diversified in terms of coverage, nature and depth of the information

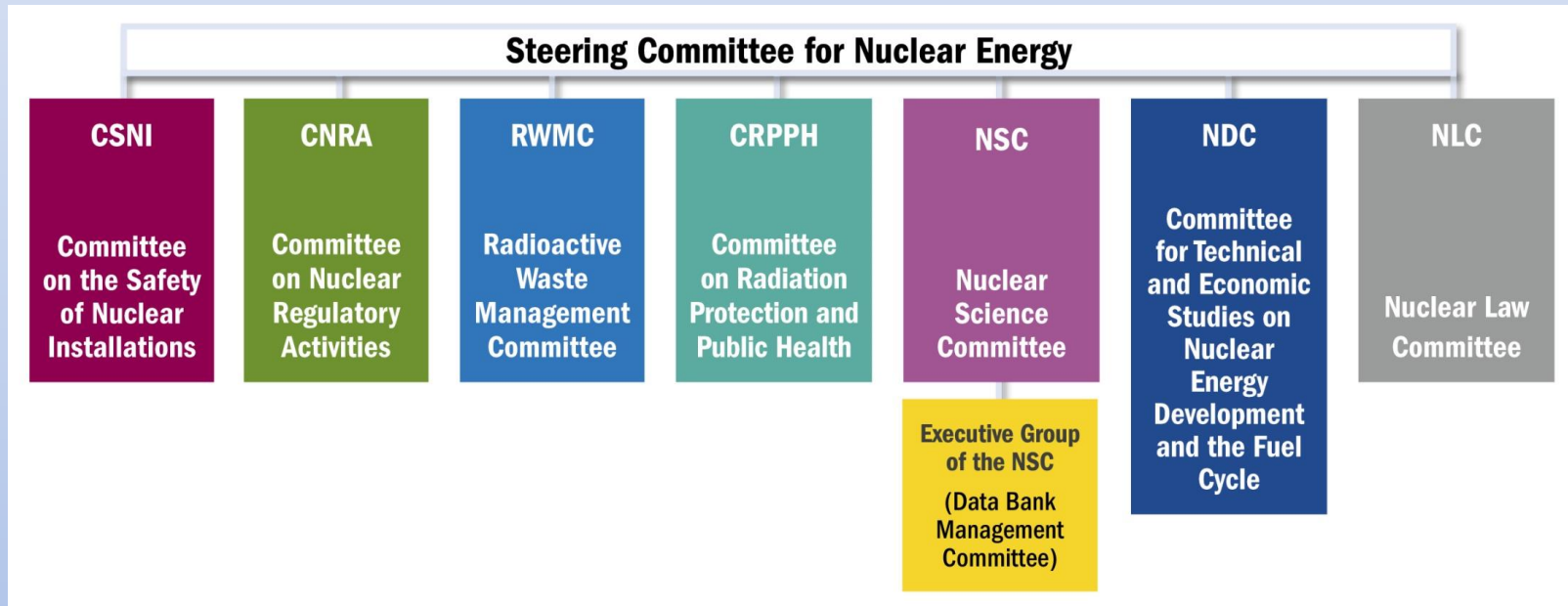
- Will need a major effort to debug – uncertainties will remain (ia Public/Private)

- Comparison with IEA R&D yearly survey partially possible (only Public)

- Exel Tables in making with graphs – some examples...

BACKUP SLIDES

NEA Mission and **Committee** Structure



The NEA's Committees bring together top governmental officials and technical specialists from NEA member countries and strategic partners to solve difficult problems, establish best practices, and to promote international collaboration

Major NEA **Cooperative** Funded Activities

Secretariat-Serviced Organisations

- **Generation IV International Forum** — with the goal to improve sustainability (including effective fuel utilisation and minimisation of waste), economics, safety and reliability, proliferation resistance and physical protection.
- **Multinational Design Evaluation Programme** — initiative by national safety authorities to leverage their resources and knowledge for new reactor design reviews.
- **International Framework for Nuclear Energy Cooperation** — forum for international discussion on wide array of nuclear topics involving both developed and emerging economies.

20+ Major Joint Projects

(Involving countries from within and beyond NEA membership)

- **Nuclear safety research** and experimental data (thermal-hydraulics, fuel behaviour, severe accidents).
- **Nuclear safety databases** (fire, common-cause failures).
- **Nuclear science** (thermodynamics of advanced fuels).
- **Radioactive waste management** (thermochemical database).
- **Radiological protection** (occupational exposure).

Terms of Reference for the NI2050 Roadmap (Top-Down Step 2) and for the Adv Panel:

TERMS OF REFERENCE (ToRs) as per Adv Panel Jan 2016

For the NEA NI2050 Roadmapping of Nuclear Fission R&D and Advisory Panel

Background

The NEA NI2050 Initiative, launched in July 2015, is aiming at mapping the actual nuclear fission R&D programmes and infrastructures (step 1), highlighting R&D (see footnote) priorities to enable innovation and foster the longer term role of nuclear fission in the sustainable low carbon energy future (step 2), and evaluating the potential for cooperation to implement some of these priorities, in particular where there are gaps and synergies in terms of programmes and infrastructures (step 3). See Figure 1.

While step 1 is to be performed via a survey managed by the NEA Secretariat (NDD), the step 2 will take the form of a high level roadmapping of R&D priorities. It will require the recourse to high level expertise having a far reaching vision, technical knowledge, and experience of similar roadmapping processes. As one of the outcomes of the NI2050 Launching Workshop (7 and 8 July 2015 Paris), the NEA Secretariat was tasked to draft Terms of Reference for the roadmapping process, including for an Advisory Panel providing the necessary guidance and expertise.

Terms of Reference for the NI2050 Roadmap (Top-Down Step 2) and for the Adv Panel:

TERMS OF REFERENCE (ToRs)

For the NEA NI2050 Roadmapping of Nuclear Fission R&D and Advisory Panel

Footnote

R&D:

There was extensive debate at the first Advisory Panel Meeting on “R&D” (Research and Development) vs “RD&D” (Research, Development and Demonstration). “R&D” will be further used, but “demonstrators” are fully part of the scope of the roadmapping. As a result of the discussion it was decided to propose an ad-hoc clarification of the notion of demonstrator vs prototype/FOAK (First of A Kind). A Demonstrator is an experimental facility designed to prove the technical and industrial feasibility, as well as the safety case (licensability), of a technology in its integrality (e.g. a demonstrator reactor). The aim is not to produce energy (e.g. electricity) in an economic way, but such production might be part of the scope of the demonstration. Such “demonstrators” are flexible tools, allowing diverse configuration and experiments to take place (e.g. on materials and fuels), and may be associated with additional specific support facilities and labs (i.a. hot cells for PIE). The next stage, after the demonstrator, is the prototype, for which the aim is to produce energy (e.g. electricity) and prove the economic viability of the technology. A FOAK is the first fully commercially operated plant based on the given technology.

ToRs for the Roadmapping of R&D priorities

Objective

The objective of the NI2050 roadmapping is to identify R&D strategies and associated priorities to achieve commercial readiness of innovative sustainable nuclear fission technologies in a fast and cost effective manner. For the 2050 perspective, the IEA ETP 2DS (2 Degree Scenarios of the 2015 Energy Technology Perspectives of the International Energy Agency) serves as the reference.

Scope

The roadmapping will be organised along 5 main categories (see Figure2). Each of these five categories will be further elaborated as necessary in the course of the roadmapping. Both R&D programmes and infrastructures will be mapped. Infrastructures cover “physical infrastructures” (facilities, labs and tools) but may also cover “human resources and skills” as appropriate.

ToRs for the Roadmapping of R&D priorities

Methodology

Maximum use will be made of existing roadmaps (GIF, European Technology Platforms, national roadmaps, Owners/Users Groups of facilities,...).

Priorities consistent with the objective will first be mapped for the four first categories (see Figure 2). These will then be consolidated, together with priorities for cross cutting topics.

Once priorities are established in the roadmapping, they can then be cross-checked with the outcomes of the survey mapping the actual R&D (step 1), leading to the identification of some gaps and synergies which may better be addressed (efficiency, cost, use of resources,...) through cooperation.

A concrete outcome, beyond the survey results and the roadmap per se, might therefore be to define a limited number of priorities/gaps/synergies, not yet properly taken care of, for which there is willingness to cooperate.

Process

An Advisory Panel, made of NEA member countries high level experts and NEA Secretariat, will guide the Roadmapping. The first task will be to define more precisely the scope and methodology for the roadmapping (eg which “process and criteria” to use for the prioritization). Following this, specialised Experts Meetings will be organised, under the umbrella and responsibility of the Advisory Panel, to highlight R&D priorities for the first four categories of the roadmapping. The Advisory Panel will consolidate the outcomes, cross check with the priorities for the cross cutting issues, and look for duplications and synergies. A final list of priorities should then be elaborated and cross-checked with the outcome of the survey, leading to the identification of potential gaps and synergies, for which cooperation might be proposed.

ToRs for the Advisory Panel

Membership and Chairpersons

A list of members for the Advisory Panel, to ensure the proper combination of the necessary high level vision, expertise and experience, will be proposed to the NDC. The list (see list in annex) is based essentially on the list of participants invited by the NEA Secretariat for the first meeting of October 2015, complemented by an invitation to the chairs of the main NEA Standing Technical Committees, to ensure the necessary coordination for this broad NEA Initiative, and by the IAEA as observer. NDC may propose additional members for the Advisory Panel.

A chairperson will be proposed by the NEA Secretariat for each meeting of the Advisory Panel and endorsed by consensus by the participants of the meeting.

The specialised Experts Meetings should be chaired by a member of the Advisory Panel to ensure the global consistency of the overall process. The NEA Secretariat will call for volunteers and propose the list of chairs (and co-chairs as appropriate) for approval by the Advisory Panel. Members of the Advisory Panel will nominate the experts for the specialised Experts Meetings (they may also decide to participate themselves). NEA Secretariat may propose additional experts. The experts will need to have a global long term vision of R&D perspectives and needs in their field in terms of programmes and infrastructures, a deep technical expertise, and a good knowledge of existing roadmaps used as basis.

ToRs for the Advisory Panel

Timeline and location for meetings

Following a first (pilot) meeting of the Advisory Panel of October 2015, a second meeting (to define the mandate, task, methodology, expected outcomes for the expert meetings) was organised in January 2016. The first Experts Meetings should take place between February and April. The Advisory Panel should further meet in May/June and September/October, to deliver the NI2050 “roadmap” and lists of priorities/gaps/synergies for a Final NI2050 Workshop towards the end of 2016/early 2017.

The NEA Secretariat will provide support for the preparation, recording and reporting of all the meetings. Unless otherwise proposed, meetings should be organised in Paris.

Duration of the Advisory Panel

The Advisory Panel is established until the date of the NDC Meeting mid-2017. The NDC will then decide about the future, upon proposal by the NEA Secretariat.

Endorsement by the NDC and Information of the NEA Committees

These Terms of Reference will be presented for endorsement by the NDC (Meeting of January 2016). The progress of the NEA NI2050 Initiative will be reported at each meeting of the NDC, and to other NEA Standing Technical Committees as requested. The NEA Steering Committee will also be informed on a regular basis.

Membership Adv Panel

Participants Adv Panel Meeting Jan 2016

Fiona Rayment (Chair) UK NNL and NIRAB

Hamid Ait Abderrahim BE SCKCEN and Chair of SNETP Board

Robert Speranzini CA NCL/AECL

Harri Tuomisto FI Fortum

Pierre-Yves Cordier + Sylvestre Pivet/Marc Delpech + Fanny Bazile FR CEA

Hideki Kamide + Shigeaki Okajima + Tomoyasu Mizuno JP JAEA

Grzegorz Wrochna PO NCBJ and Chair of NC2I

Sergei Vorobyev RF Rosatom

Kathrin McCarthy + Kemal Pasamehmetoglu USA DOE/INL

Ik Jeong Korea (KAERI) (excused at meeting)

Mrs L Xiao China (CAEA) (excused at meeting)

Membership Adv Panel

Participants Adv Panel Meeting Jan 2016

Roger Garbil and Said Abousahl EC DG RTD and JRC Euratom
Stefano Monti IAEA NE, as Observer

Jean-Paul Minon Chair NEA RWMC (Ondraf Niras)
John Herczeg Chair NEA NSC (DOE)
Jean-Claude Micaelli Rep for CSNI (IRSN)

François Storrer GIF Policy Director
Enrique Gonzales SNETP roadmap
Giovanni Bruna ETSO and NUGENIA roadmap
Henri Pelin World Nuclear Association + Abderrahim Al Mazouzi EDF/NUGENIA
Hervé Bernard CEA/EERA and Noel Camarcat EDF/ESNII (both excused at meeting)

Thierry Dujardin in advisory role
NEA Staff (Divisions Development, Science, Safety, Rad and Waste)

OUTCOME 11: Water Cooled Reactors

Topics	Ranking	
1. <i>Passive systems</i>	2.9	3
2. <i>Molten core retention</i>	2.7	3
6. Small Modular Reactors (SMRs)	2.2	2
8. Improved technology for a long life time components and low maintenance	2.2	2
10. Emergency management	2.1	2
5. Accounting for external natural conditions including global warming	2.1	2
9. Impact of the plant on the environment and vice-versa	2.0	2
12. Integration of plant in the energy mix – grid effect	2.0	2
4. Instrumentation and monitoring	1.9	2
3. Use of digital technology to control the plant in safe manner	1.8	2
11. Siting	1.5	2
7. Supercritical Water Reactor (SCWRs)	1.2	1

The ranking relies upon expert judgment of the Experts

OUTCOME 21: Fuel for Water Cooled Reactors

Innovative advanced modelling tools and innovative experimental methods to validate them	3.0	X
Fuel for flexible operation mode (load following)	2.9	
Innovative solutions for excess reactivity control (burnable poisons)	2.9	
ATF: cladding, fuels and structures with lower hydrogen production and increased ability for fission products retention	2.8	
Progress methods and codes in order to allow assessing the effectiveness of ATF candidates materials	2.8	X
High burn-up fuel: Fuel cycle prolongation, targeting parity MOX vs UOX, Th-Pu oxide fuel, applicability to other systems	2.7	
Simplifying the safety demonstration, targeting significant reduction of safety systems and maintenance, to liberate new economic margins	2.7	
Cold fuel	2.6	
Cost effectiveness/reduction of operating cost	2.6	

Color code
advanced fuel and materials
fuel cycle
advanced modelling
cost effectiveness

OUTCOME 21: Fuel for Water Cooled Reactors

Development of Accident Tolerant Control Rods (ATCR)	2.6	
Spent fuel safety in cooling pools; assessment of spent fuel integrity during and after long-term storage (including handling and transportation)	2.3	X
Stronger fuel assembly structure	2.3	
Advanced fuels for water-cooled small modular reactors (SMRs)	2.1	
Innovative solutions to protect and limit RPV fluence (for LTO)	2.0	
Thoria fuel characterization	1.9	X
Use of U-enriched fuel beyond 5% for commercial use	1.8	X
High uranium density fuels for LWR fuels	1.8	
Use of recycled material for fuel	1.8	X

Color code
advanced fuel and materials
fuel cycle
advanced modelling
cost effectiveness

OUTCOME 12: Fuel for Advanced Reactors (ex only SFR)

No.	Issue	Contents	Priority	Rationale for the priority	Facilities		Potential collaboration
					Existing	Planned	
1	Core design	<ul style="list-style-type: none"> - Code development/qualification - Measurements 	2	Impact on safety (including MAs bearing fuels)	MASURCA BFS PHENIX JOYO (pins) MONJU (S/As) AR-1	ASTRID	Yes, Code Benchmarking
2	Core Materials	<ul style="list-style-type: none"> - Cladding (e.g., ODS) - New reflector material - Fuel Development* (for R&D on fuel cycle, MOX with MA for cross-cutting) 	3	<ul style="list-style-type: none"> - Higher Burn-Up - Operation improvement 	BOR60 BN600 JOYO MONJU	MBIR JHR ASTRID BN800 MYRRHA	Yes, irradiations
3	Severe accidents	<ul style="list-style-type: none"> - TIB or PIB (detection, behavior) of local fault - Provisions to control the core melt relocation (FAIDUS,...) - Core catcher design and materials - Long term cooling of damaged core and core catcher (RVACS,...) 	3	After Fukushima Daiichi NPP accident prevention and mitigation of severe accident is a key issue for future SFRs	IGR in Kazakhstan ATHENA (for damaged core cooling, 50-100 M€) PLUTON (Obninsk)	PLINIUS-2 (long term cooling) STELLA-2 (30 M€) MBIR (dedicated loop for fuel melting studies)	Yes, Code V&V and demonstration of counter measures
4	Passive shutdown systems	<ul style="list-style-type: none"> - System comparative behavior (based on different physical principles, Curie point, fusible materials, hydraulic) - Qualification. 	2		JOYO for irradiation of key component	ASTRID BN1200	Yes, code Benchmarking

A : Timeliness
B : Necessary / Essential Nature
C : Potential for Cooperation

OUTCOME 22: Fuel for Advanced Reactors

NI2050 R&D Priority Issues / Topics	Priorities				
	A	B	C	(A+B)/2	Priority ranking (A+B+C)/3
Oxide fuel performance – Qualification by irradiation tests	3	3	3	3	3
Oxide fuel performance – Analytical method development	3	3	3	3	3
Oxide fuel Reprocessing Closed cycle/multi-recycling applications (U/Pu)	3	3	2	3	2.7
and MA separation technology development	3	3	3	3	3
Oxide fuel fabrication Large scale application for MA bearing fuels	2	2	3	2	2.3
Oxide fuel fabrication Novel technologies for MOX fuel and remote fabrication	3	3	3	3	3
Metallic fuel performance	3	3	3	3	3
Metallic fuel Pyro-electrochemical processing	3	3	3	3	3
Metallic fuel fabrication	3	3	3	3	3
Nitride fuel performance	3	3	3	3	3
Nitride fuel Reprocessing Combined pyro-hydro reprocessing	3	3	3	3	3
Nitride fuel fabrication Large scale application including remote fabrication N-15 enrichment	3	3	3	3	3
Advanced austenitic claddings	3	3	3	3	3
Innovative claddings (ODS, SiC/SiC, etc.)	2	2	3	2	2.3

OUTCOME 22: Fuel for Advanced Reactors

TOPIC	EXISTING INFRASTRUCTURE	FUTURE PLANNED
metal fabrication	Yellow	Yellow
nitride fabrication	Yellow	Yellow
MOX driver fuel fabrication	Green	Yellow
novel oxide and MA fabrication	Yellow	Red
innovative claddings manufacture facility	Yellow	Red
MTR	Yellow	Yellow
Experimental fast reactors	Yellow	Yellow
Fast reactor power plant	Yellow	Yellow
Safety reactors	Yellow	Yellow
oxide fuel analytical methods and data	Green	Green
Hot cells	Yellow	Red
Dedicated facilities and analytical tools for safety tests (see other template)	Red	Red
Transportation	Red	Red
metal pyroprocess	Yellow	Yellow
oxide multirecycling	Yellow	Yellow
nitride reprocessing	Yellow	Yellow

OUTCOME 31: Decommissioning

Topics	Ranking	Rounded ranking
1. Characterization and survey prior to dismantling (C&S)		
2. Segmentation and dismantling (S&D)		
3. Decontamination and remediation (D&R)		
4. Materials and waste management (M&W)		
5. Site characterization and environmental monitoring (S&E)		
Cross cutting topics		
Robotic and automation system application		
Modelling (Estimation of types, volumes, dose rate, cost, time,...)		
Data and Knowledge management		
Wireless communications and data sharing technologies		
Scanning and pattern recognition technologies		

The ranking has relied upon expert judgment of sub group members

Holistic Approach to RW

- Zero waste concept - Δ
- Urgency \rightarrow avoiding legacy
- Materials of choice
- Methodology
- Early characterization as support for dismantling

Characterization / P/C (legacy)

- Way to optimize routes
- Sorting
- Mutualisation of infrastructure
- Demonstration

T/C

- “interim products” – one step in the journey to disposal (e.g., retrievals from past facilities)
- Thermal treatments
- Mutualisation
- Mobile/remote technologies (small volumes and EOL)

Storage (extended)

- Monitoring/inspection

Flexibility of Practice/EBS

- For new waste types
- Transportation (e.g., multi-purpose cask)
- Deep borehole as alternative to disposal

Competence Maintenance / KM

- Linked with societal acceptance
- Necessity to maintain research capabilities (outside SC; finding exciting options, early development/timeline)
- Skills wider than nuclear
- Database creation and long-term maintenance (i.e., technology evolution)

Demonstrator and Witness for WM Infrastructure and Disposal

OUTCOME 32: Waste Mngmt