



Belgian Nuclear Society (BNS)

Evening Lecture – 26 February 2015

Tractebel Engineering - Avenue Ariane laan, 7, 1200 Brussels

Scientific and political challenges in Euratom nuclear fission research (Generation IV reactor systems)



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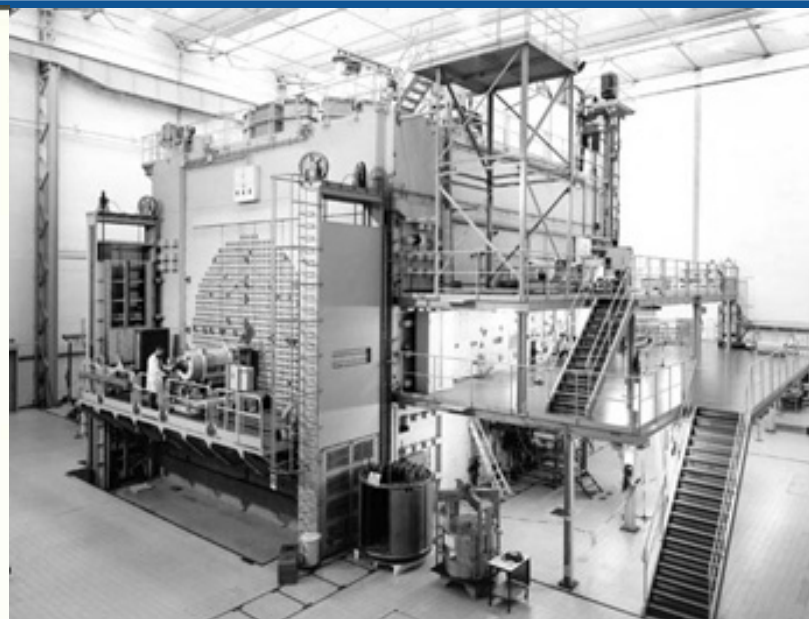
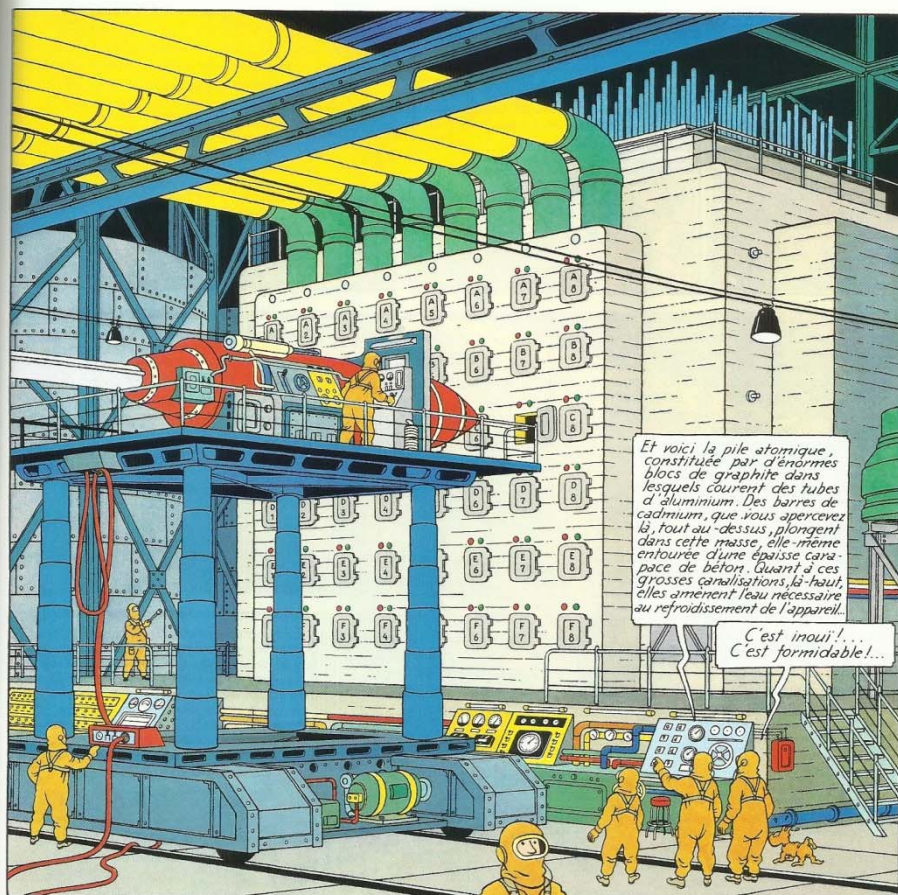
1 - Introduction: facts and questions about nuclear

2 - Analysis of society and industry requirements (stakeholders, lessons learnt, KSC)

3 - Towards a common vision (world-wide excellence in nuclear safety and security)

4 - Common implementation instruments (Euratom and EU policies, H-2020, GIF-ESNII)

5 - Conclusion: meeting social and industrial needs ("new governance for R&I")



BR1 reactor SCK-CEN, Mol

The BR1 reactor became critical for the first time in 1956.

BR1 is the oldest research reactor for non-military applications that is still in operation in the world.

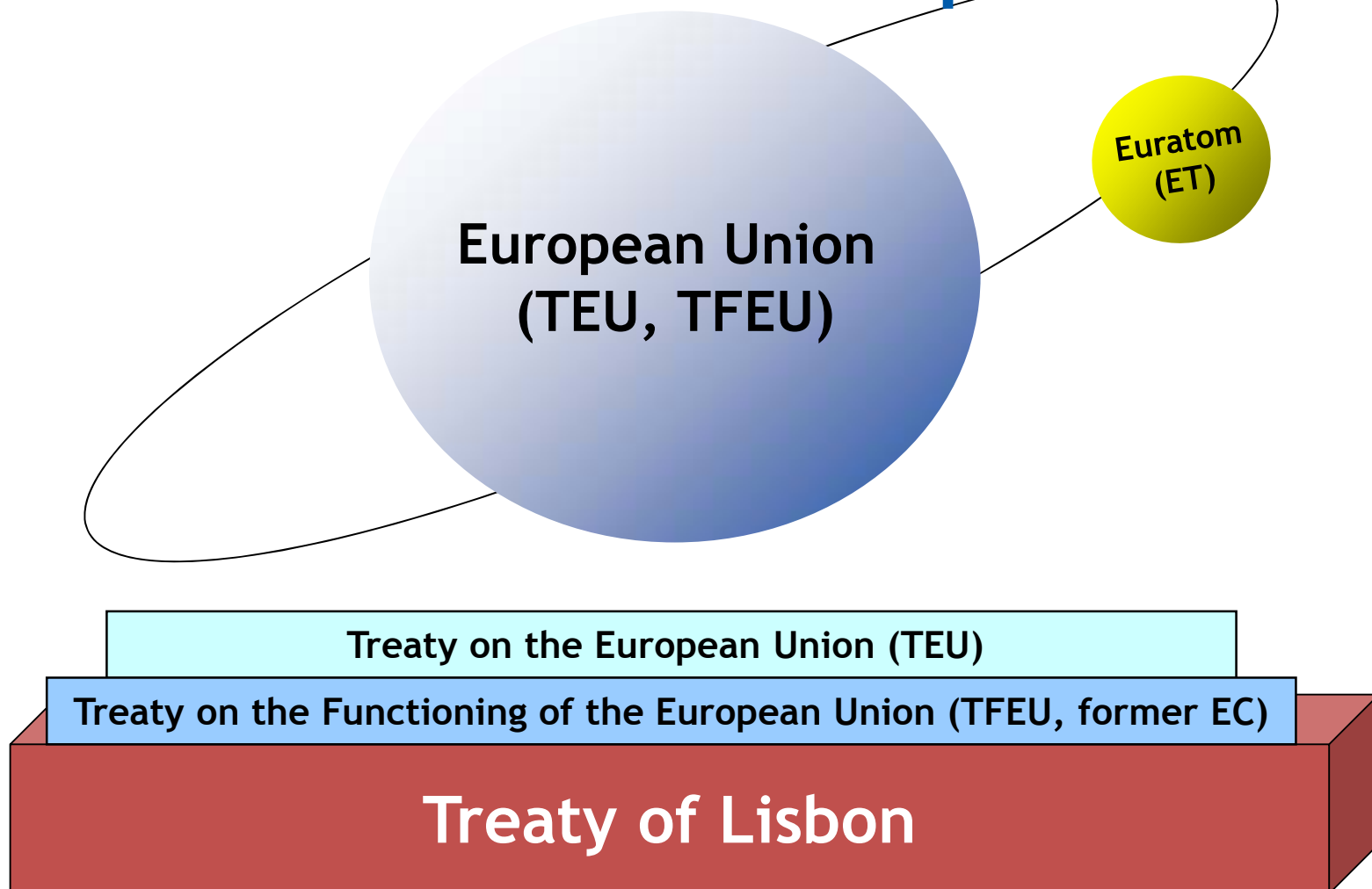
Thanks to its original concept, BR1 is, after more than 50 years of continuous work, still a unique instrument for applied and fundamental research.

"Objectif Lune" Hergé, 1953





Structure of the European Union





Euratom Treaty (1957) - 4 fields of action

- Nuclear energy **development**
(Including Research Activities)
(art. 4-11)



- **Health and safety**
(art. 30-39)



- **Safeguards** (Guarantees for peaceful uses)
(art. 77-85)



- **External relations**
(art. 101-106)





ENERGY UNION PACKAGE (2015)

A Framework Strategy for a Resilient Energy Union with a Forward-Looking Climate Change Policy

**Communication from the Commission to the European Parliament,
the Council, the European Economic and Social Committee,
the Committee of the Regions and the European Investment bank**

COM(2015) 80 final, Brussels, 25.2.2015

Excerpt: Section 2.5. An Energy Union for Research, Innovation and Competitiveness

A new strategy for Research and Innovation (R&I) must be at the very heart of the Energy Union. Equally, putting the EU at the forefront of smart grid and smart home technology, clean transport, as well as clean fossil fuel and the world's safest nuclear generation, is central to the aim of turning the Energy Union into a motor for growth, jobs and competitiveness.

....

– Nuclear energy presently produces nearly 30% of the EU's electricity (see *European Energy Security Strategy*, COM (2014) 330). The EU must ensure that Member States use the highest standards of safety, security, waste management and non-proliferation. The EU should also ensure that it maintains technological leadership in the nuclear domain, including through ITER, so as not to increase energy and technology dependence.

http://ec.europa.eu/priorities/energy-union/index_en.htm

"Stress Tests" after the Fukushima accident (Great East Japan Earthquake, 11/03/2011)



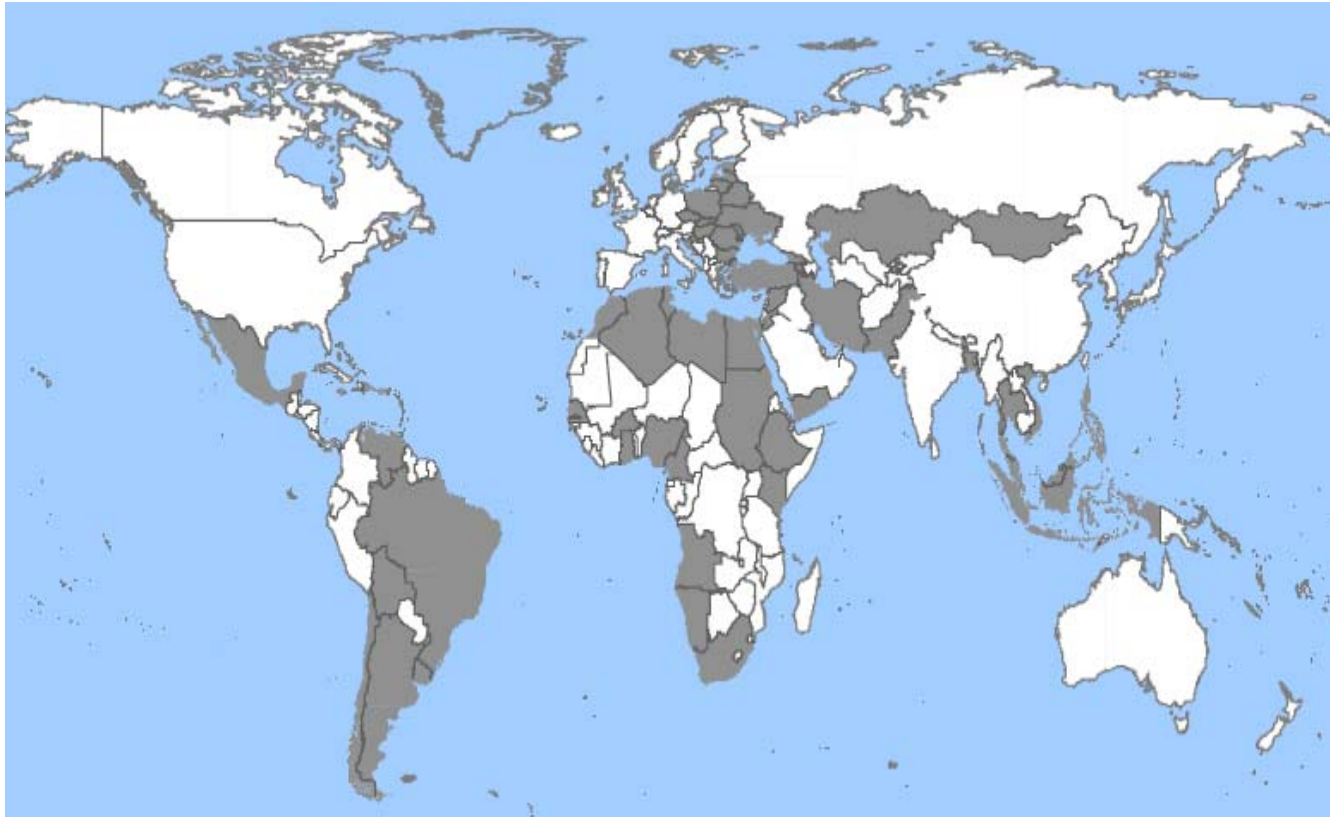
The European Council requested on 24/25 March 2011 that the safety of all EU nuclear plants should be reviewed, on the basis of a comprehensive and transparent risk and safety assessment ("stress tests").

These "stress tests" are defined as targeted reassessments of the safety margins of nuclear power plants, developed by ENSREG, including the EC.

"Final report on the Peer Review of EU Stress Tests", 26 April 2012 -
<http://www.ensreg.eu/node/407>

=> impact on revised "Euratom Safety Directive"
(Council Directive 2014/87/Euratom 08/07/2014)

Emerging Nuclear Energy Countries (> 45 countries) (mostly developing countries / IAEA - INPRO 2014)



Nuclear power is under serious consideration in over 45 countries which do not currently have it
(in a few, consideration is not necessarily at government level).

- In Europe: Italy, Albania, Serbia, Croatia, Portugal, Norway, Poland, Belarus, Estonia, Latvia, Ireland, Turkey.
- In the Middle East and North Africa: Iran (reactor now operating), Gulf states including UAE, Saudi Arabia, Qatar & Kuwait, Yemen, Israel, Syria, Jordan, Egypt, Tunisia, Libya, Algeria, Morocco, Sudan.
- In west, central and southern Africa: Nigeria, Ghana, Senegal, Kenya, Uganda, Namibia.
- In South America: Chile, Ecuador, Venezuela, Bolivia, Peru.
- In central and southern Asia: Azerbaijan, Georgia, Kazakhstan, Mongolia, Bangladesh, Sri Lanka
- In SE Asia: Indonesia, Philippines, Vietnam, Thailand, Malaysia, Singapore, Australia, New Zealand.
- In east Asia: North Korea.

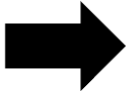
(<http://www.world-nuclear.org/info/Country-Profiles/Others/Emerging-Nuclear-Energy-Countries/>)



European
Commission

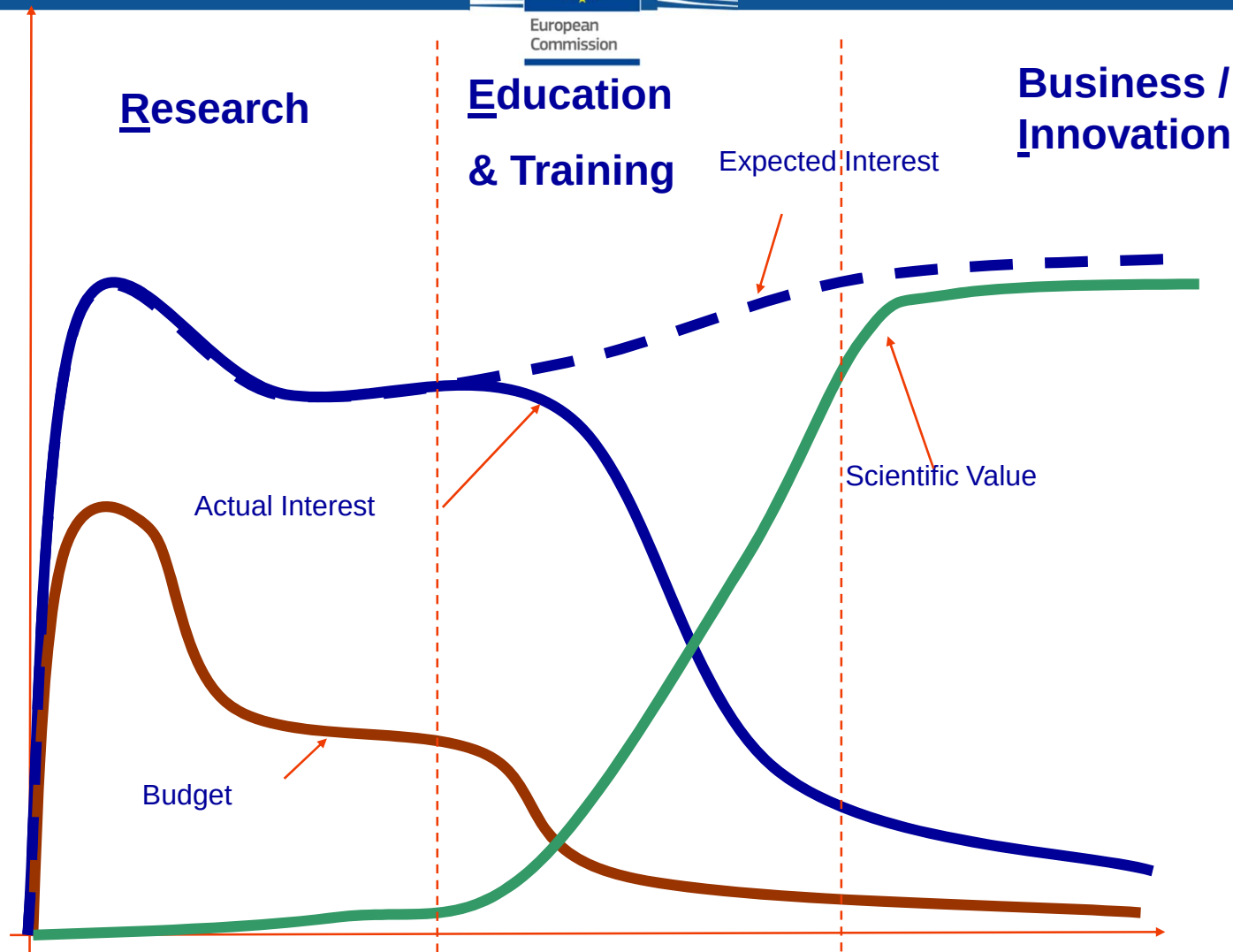


Research and Training:



Historically

Today



Knowledge Triangle
Research, Innovation and Education (RIE) cycle management



Definition of education and training ("learning outcomes" expressed in terms of KSC)

- **Education is a basic and life-long learning process**
 - broader than training, encompassing the need to maintain completeness and continuity of expertise across generations
 - essentially a knowledge creation process, involving primarily academic institutions as "suppliers", and students as "customers"

=> it deals mainly with knowledge (and understanding)
- **Training involves acquiring specific skills and competences required to properly perform a well-defined job or function, usually to an established standard**
 - a knowledge, skills and competence (KSC) building process, involving primarily experts in continuous professional development (e.g. mix of industry and academia) as "suppliers", and learners (e.g. professionals) as "customers"

=> mostly about skills and attitudes, in addition to knowledge (= competencies, IAEA)

EU policy: free movement of KNOWLEDGE = "FIFTH FREEDOM" – complementary to the other "freedoms" of the "EU internal market" => PEOPLE, GOODS, CAPITAL AND SERVICES + KNOWLEDGE





European
Commission

VOUS ETES **POUR** L'ENERGIE NUCLEAIRE PARCE QUE VOUS PENSEZ AUX EMISSIONS DE CO₂

Personne n'ignore que le changement climatique est principalement dû aux émissions de CO₂. Nous en envoyons chaque année plus de 25 milliards de tonnes dans l'atmosphère, les centrales à combustibles fossiles sont, en partie, responsables de ces émissions. Ce qui n'est pas le cas des centrales nucléaires. Certains disent que la production d'une quantité égale de déchets radioactifs est préférable à l'émission incombible de CO₂. D'autres refusent de remplacer un mal par un autre et disent qu'on peut éviter les déchets radioactifs en investissant massivement dans les énergies renouvelables. Qui a raison? Qui a tort? Y avez-vous déjà vraiment réfléchi?

www.forumnucleaire.be

NUCLEAIRE
FORUM
NUCLEAIRE

Research and
Innovation

VOUS ETES **CONTRE** L'ENERGIE NUCLEAIRE PARCE QUE VOUS PENSEZ AUX DECHETS RADIOACTIFS

Personne n'ignore que l'industrie nucléaire produit des déchets qui restent radioactifs pendant de longues années. Et il n'y a actuellement pas de solution pour les éliminer. Qui peut accepter que notre génération transmette un tel héritage à ses enfants? Certains disent par contre que la quantité de déchets nucléaires est faible, que le confinement est une solution tout à fait fiable, et, surtout, que le danger des émissions de CO₂ est bien plus grand. Qui a raison? Qui a tort? Y avez-vous déjà vraiment réfléchi?

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"Ethical framework for assessing research, production, and use of Energy" (Ethics Opinion n° 27, issued on January 16, 2013)



"2012 Interdisciplinary Study

- *Benefits and limitations of nuclear fission for a low carbon economy:*
- *Defining priorities for Euratom fission research & training (Horizon 2020)"*

(<http://www.eesc.Europa.eu/?i=portal.en.events-and-activities-symposium-on-nuclear-fission-forum>)

- The EGE was asked by President J.M. Barroso on 19/12/2011 to contribute to the debate on a sustainable energy mix in Europe by studying *the impact of research into different energy sources on human well-being*.
- In their conclusions, the EGE recommends achieving a fair balance between four criteria - *access rights, security of supply, safety, and sustainability* - in light of *social, environmental and economic concerns*.
- Safety culture is mentioned in Section 3.6.4 Safety (p 59) :
"Reducing the risks down to purely technical aspects would not fulfill the requirement for an integrated approach and comprehensive assessment. Consequences in terms of the environment and health should receive the same amount of attention as the cultural, social, economic, individual and institutional implications. A safety culture embraced by governments and operating organisations is necessary in the production, storage and distribution of energy in maintaining a low level of risk."

("European Group on Ethics in science and new technologies" (EGE), a team linked with the Bureau of European Policy Advisers (BEPA), reporting directly to the President of the EC)

http://ec.Europa.eu/bepa/European-group-ethics/docs/publications/opinion_no_27.pdf

Key questions requiring advanced technology (R&I) and good governance (policy making) (1/2)

(1) Sustainability

- **S-Q1: how to enhance fuel utilisation ? (is Uranium recyclable material or waste ?)**
 - **Is Plutonium an asset or a liability ? (U-238 in FRs => Pu-239)**
- **S-Q2: How to minimise volume, heat and toxicity of ultimate radioactive waste ?**
(fast versus thermal neutron spectrum, Generation IV, transmutation)
=> strategies for the “power reactor – waste management” system

(2) Safety and Reliability

- **SR-Q1: how safe is safe enough ? (integral approach needed)**
(eliminate the “technical” need for offsite emergency response)
- **SR-Q2: What is the impact of managerial and human factors on safety performance ?**
(safety culture)

=> strategies to optimise the “risk / benefit” factor
in all applications of nuclear fission energy and ionising radiation



Key questions requiring advanced technology (R&I) and good governance (policy making) (2/2)

(3) Socio-economics

- **SE-Q1: How to evaluate the total social costs of energy technologies ?**
= private (capital + O&M + fuel) + external (system effects + accidents + avoided CO2)
- **SE-Q2: How to improve public engagement in decision making (energy governance) ?**
⇒ **strategies for reducing social costs of energy and improve public participation for the benefit of both society and industry**

(4) Proliferation resistance

- ***PR-Q1: Is the nuclear proliferation risk over-estimated ?
(weapons of mass destruction, CBRN threats)***
 - ***PR-Q2: How to combat radiological terrorism ?
(related to "small weapons" causing contamination)***
⇒ ***strategies for counter-terrorism measures
(e.g. international legal instruments, detection techniques)***



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European Technological Platforms and authoritative expert associations (1/2)

The ETPs bring together the main stakeholders in nuclear fission research, namely:

- *research organisations* (e.g. public and private sectors, industrial and radio-medical)
- *systems suppliers* (e.g. nuclear vendors, engineering companies, medical equipment)
- *energy providers* (e.g. electrical utilities, co-generation plants for process heat)
- *nuclear regulatory authorities* and associated technical safety organizations (TSO)
- *higher education and training institutions*, in particular universities
- *civil society* (e.g. policy makers and opinion leaders), interest groups and NGOs.

⇒ common approach within the main areas of Euratom research and training programmes, i.e.

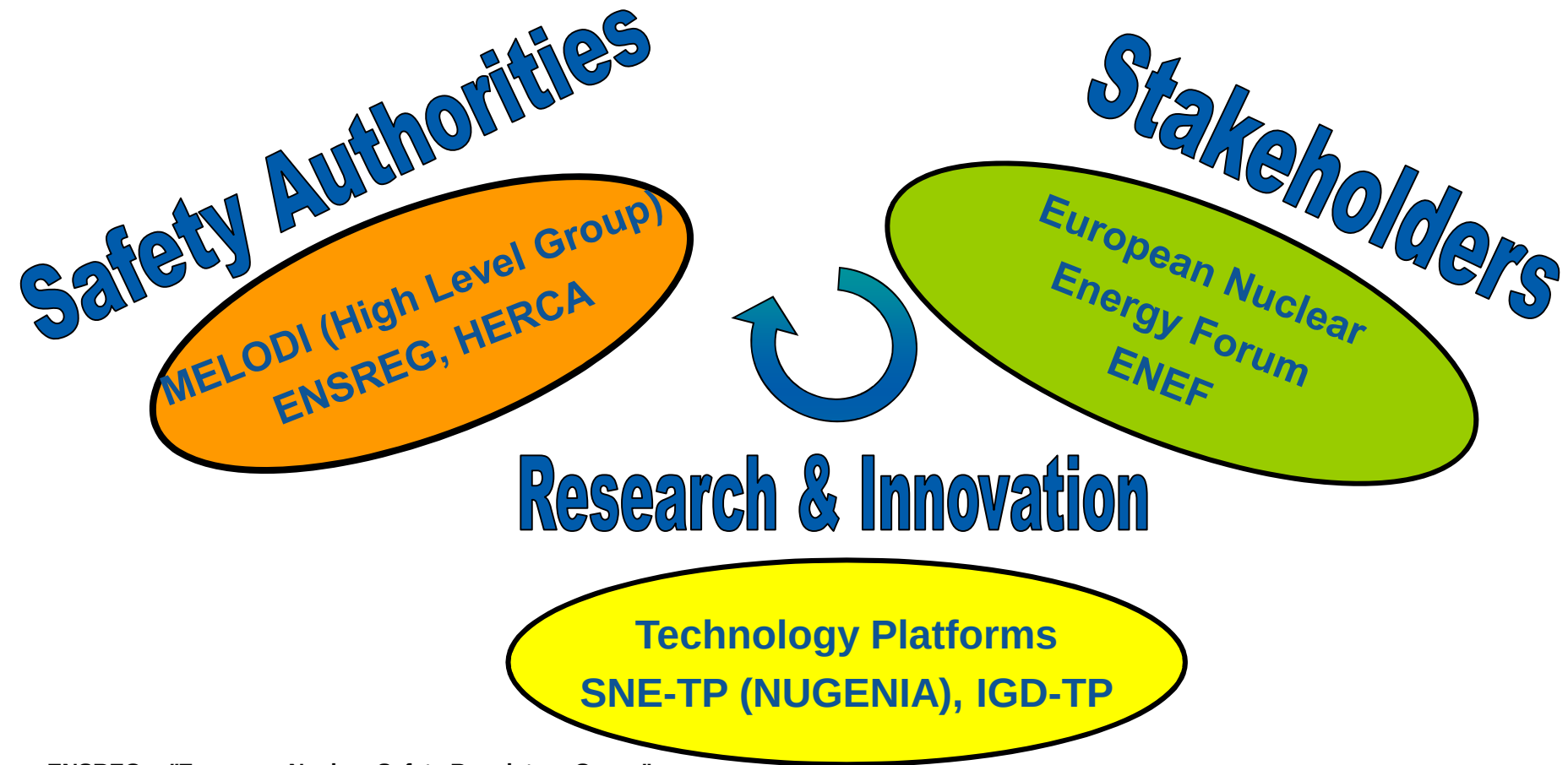
- (1) Safe operation of reactor systems
- (2) Management of ultimate radioactive waste
- (3) Radiation protection, including medical applications of ionising radiation.

⇒ guidance documents produced by ETPs:

“Vision Report”, “Strategic Research and Innovation Agenda” and “Deployment Strategy”.



European Technological Platforms and authoritative expert associations (2/2)



- ENSREG = "European Nuclear Safety Regulators Group"
http://ec.europa.eu/energy/nuclear/ensreg/ensreg_en.htm
- HERCA = "Heads of European Radiological Protection Competent Authorities" - <http://www.herca.org/index.asp>
- MELODI = "Multidisciplinary European Low Dose Initiative"
<http://www.melodi-online.eu/>

- ENEF = "European Nuclear Energy Forum"
http://ec.europa.eu/energy/nuclear/forum/forum_en.htm

- SNE-TP = "Sustainable Nuclear Energy Technology Platform"
- NUGENIA = "NUclear GENeration II & III Association"
- IGD-TP = "Implementing Geological Disposal of Radioactive waste"

- <http://www.snetp.eu/>
- <http://www.nugenia.org/>
- <http://www.igdtp.eu/>

Three Mile Island accident (USA, Pennsylvania, Harrisburg, 28 March 1979)

INES level 5

Facts: while the reactor involved was destroyed, all radioactivity was contained – as designed – and there were no deaths or injuries.

=> Institute of Nuclear Power Operations (INPO - 1980) : promote "excellence" in safety and reliability in the operation of NPPs

Some lessons learned from TMI:

- specific design choices: e.g. far more attention on other than worst case scenarios, such as the possible impact of "small break" LOCA
- more robust safety assessment methods (based on PSA /level 1, 2, 3/ + deterministic approach) and study of accident consequences
- specific operating procedures: e.g. emergency operator procedures and severe accident management guidelines (SAMG)
- importance of human failures: MTO (Man – Technology - Organisation) => comprehensive system perspective on NPP safety.



Chernobyl disaster (Ukraine, ex-Soviet Union, 25 April 1986)

INES level 7

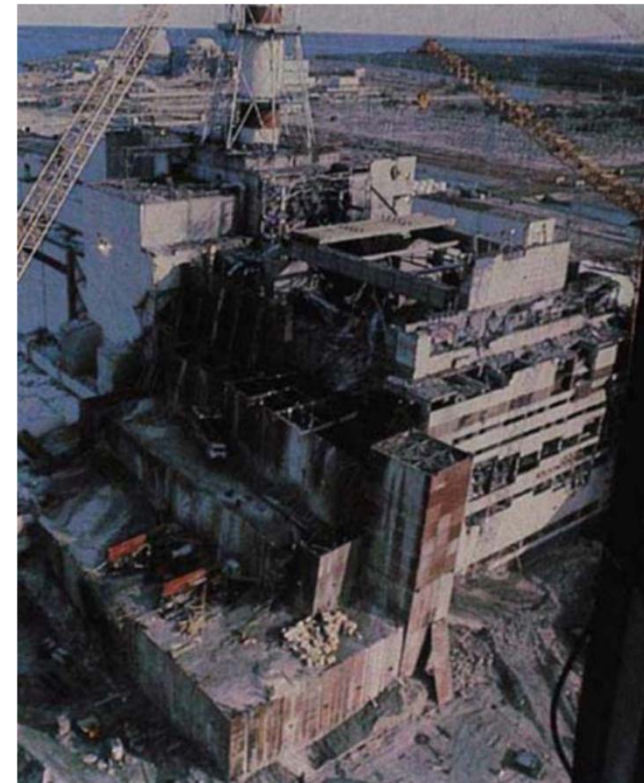
Facts: soviet reactor RBMK-1000 – unique design: a boiling light water reactor made of graphite moderated pressure tubes with “positive void coefficient” under certain conditions

⇒ World Association of Nuclear Operators (WANO – 1989):
NPPs worldwide work together to assess, benchmark and improve performance through mutual support, exchange of information and emulation of best practices (> 130 members, > 430 NPPs)

Some lessons learned from Chernobyl:

- *"an event at one plant impacts every plant and nuclear safety is everyone's business"* => development of the "safety culture" concept and strategy based on prevention and workers' participation

- development of laws and regulations related to safety and health at work, in particular, regarding radiation protection (e.g. Euratom BSS) and prevention of severe accidents as well as preparedness and response for a nuclear and radiological emergency (e.g. INSAG, 1986)



Fukushima Daiichi accident (Great East Japan Earthquake, 11 March 2011)

INES level 7

Some lessons learned from Fukushima:

- improvements of plant (multi-reactor) robustness in extreme situations (seismic events, fires, floods, extreme weather conditions)
- safety improvements in areas beyond the design basis (severe accident management) including w.r.t. Spent Fuel Pools
- importance of organizational and societal preconditions that might lead to major structural and/or societal failure (e.g. combination of cultural, political, financial, professional, and industrial pressures)

=> *absolute need for independent national regulatory authorities.*

=> “stress tests” for all 131 NPPs (European Council on 24/25 March 2011) : targeted reassessments of safety margins (conducted in all EU Member States + Switzerland and Ukraine + Armenia, Turkey, Russia, Taiwan, Japan, S Korea, S Africa, Brazil)

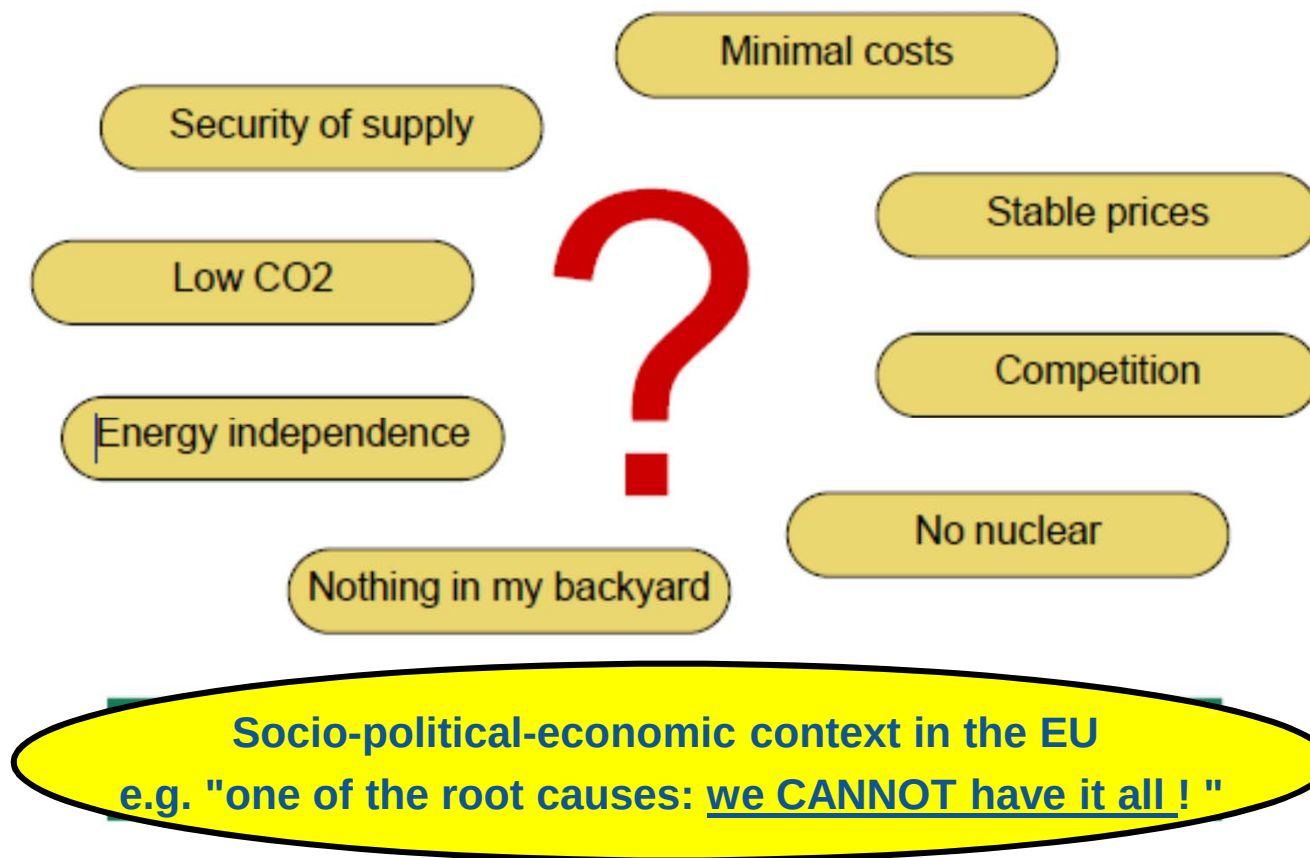
=> Revised Euratom Safety Directive "*establishing a Community framework for the nuclear safety of nuclear installations*" (Council Directive 2014/87/Euratom of 8 July 2014)



Fukushima Nuclear Accident Independent Investigation Commission (NAIIC), inquiry report (chairman = Prof. K. Kurokawa, 5 July 2012) :

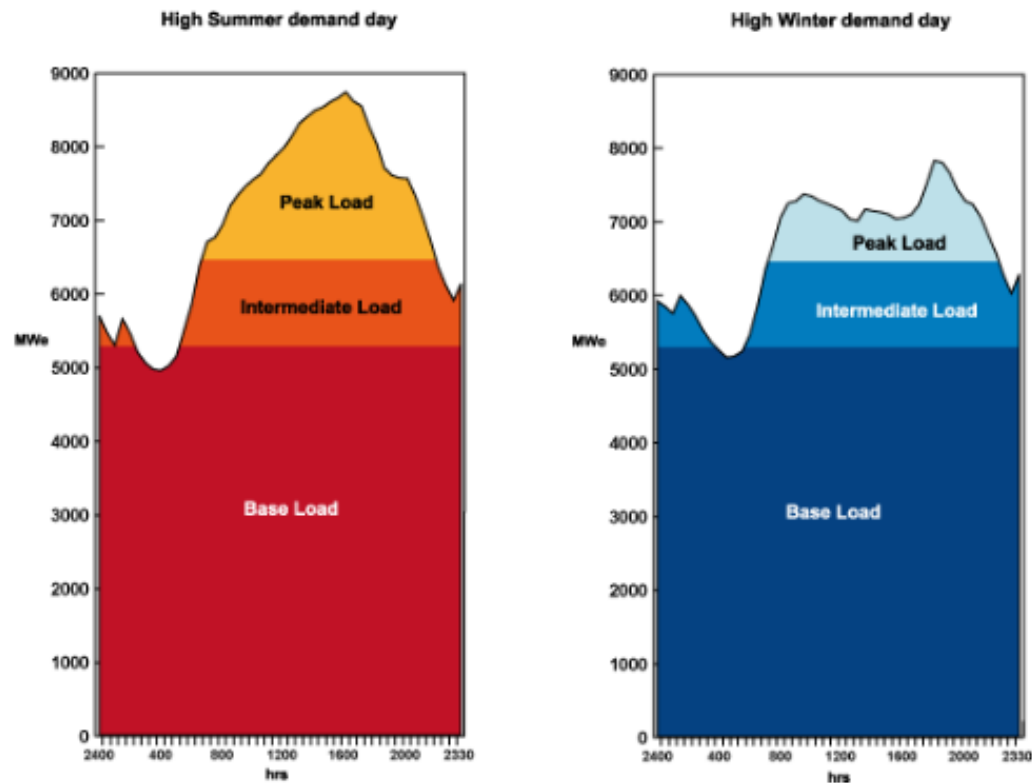
“Its fundamental causes are to be found in the ingrained conventions of Japanese culture: our reflexive obedience; our reluctance to question authority; our devotion to ‘sticking with the program’; our groupism; and our insularity...”

Energy market design is dysfunctional in many countries



Load curves for typical electricity grid (USA)

Supply needs to match demand instantly and reliably over time

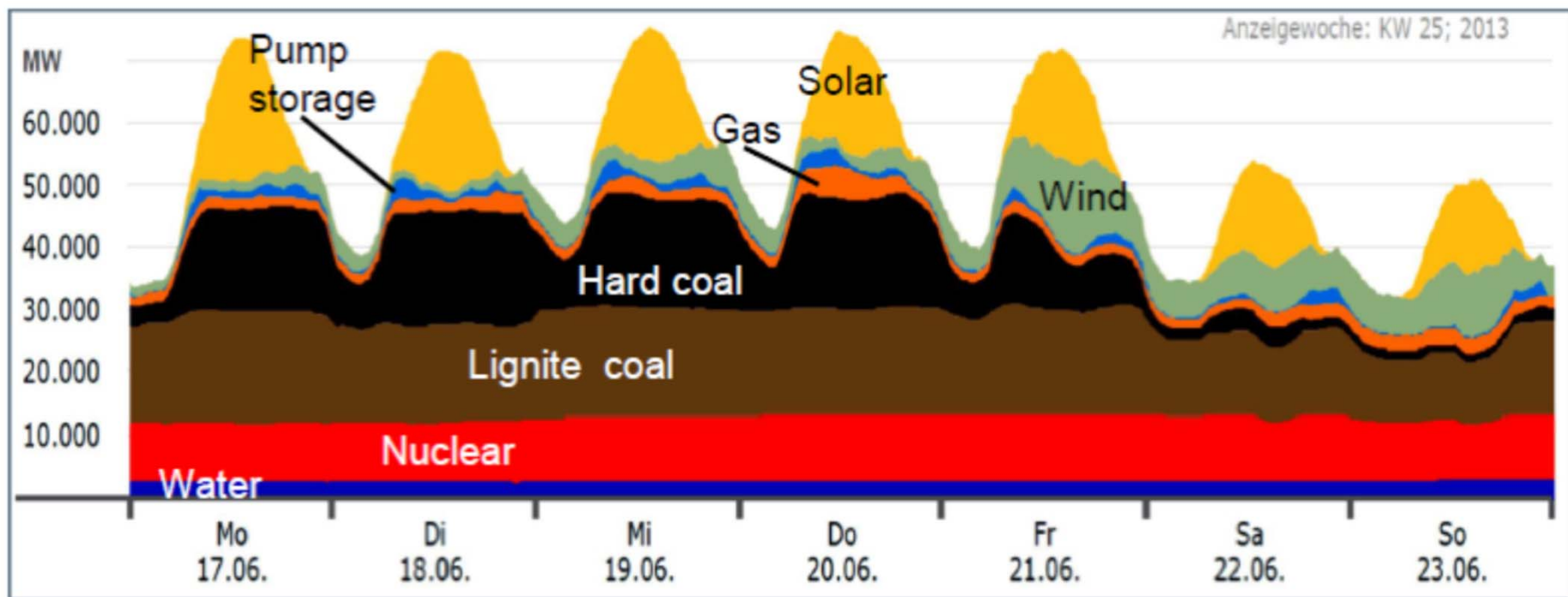


Much of the electricity demand is in fact for continuous 24/7 supply (base-load), while some is for a lesser amount of predictable supply. Intermittency and non-dispatchability of renewables $\Leftrightarrow$ Constant rate of production of conventional power sources $\Leftrightarrow$ Energy storage

Source :

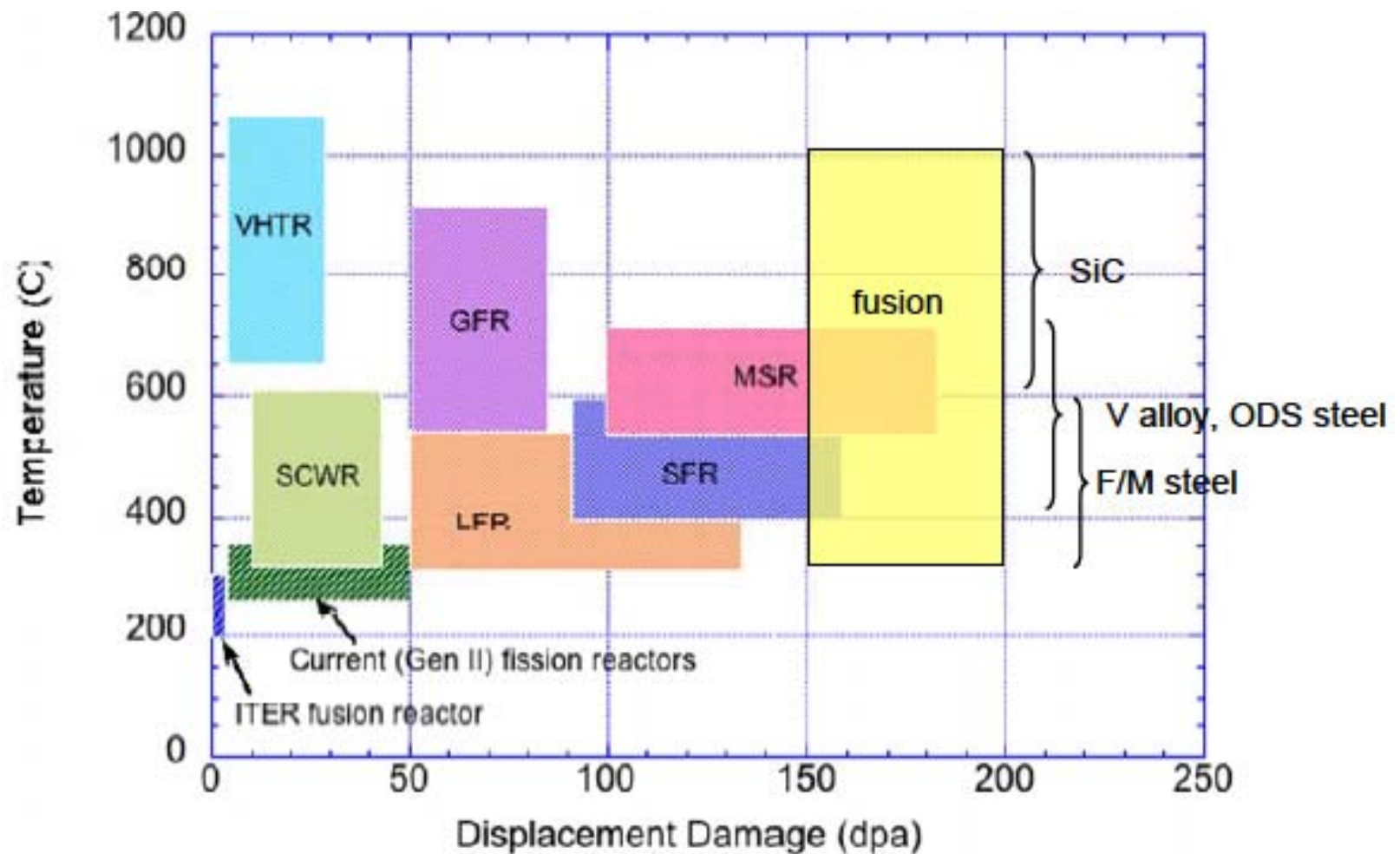
OECD/IEA Electricity Information 2008 and World Energy Needs and Nuclear Power (WNA, January 2014)
- <http://www.world-nuclear.org/info/Current-and-Future-Generation/World-Energy-Needs-and-Nuclear-Power/>

**Weather-related fluctuation of renewable energy (solar and wind power)
with significant influence on operation regime of conventional power plants
(one week time span in June 2013, in Germany – SIEMENS)**



Hard coal and gas-fired units are following load and balancing renewables during peak load conditions. Typical base load lignite coal, and even nuclear units, has to follow load during minimum load periods because of priority dispatch of renewables.

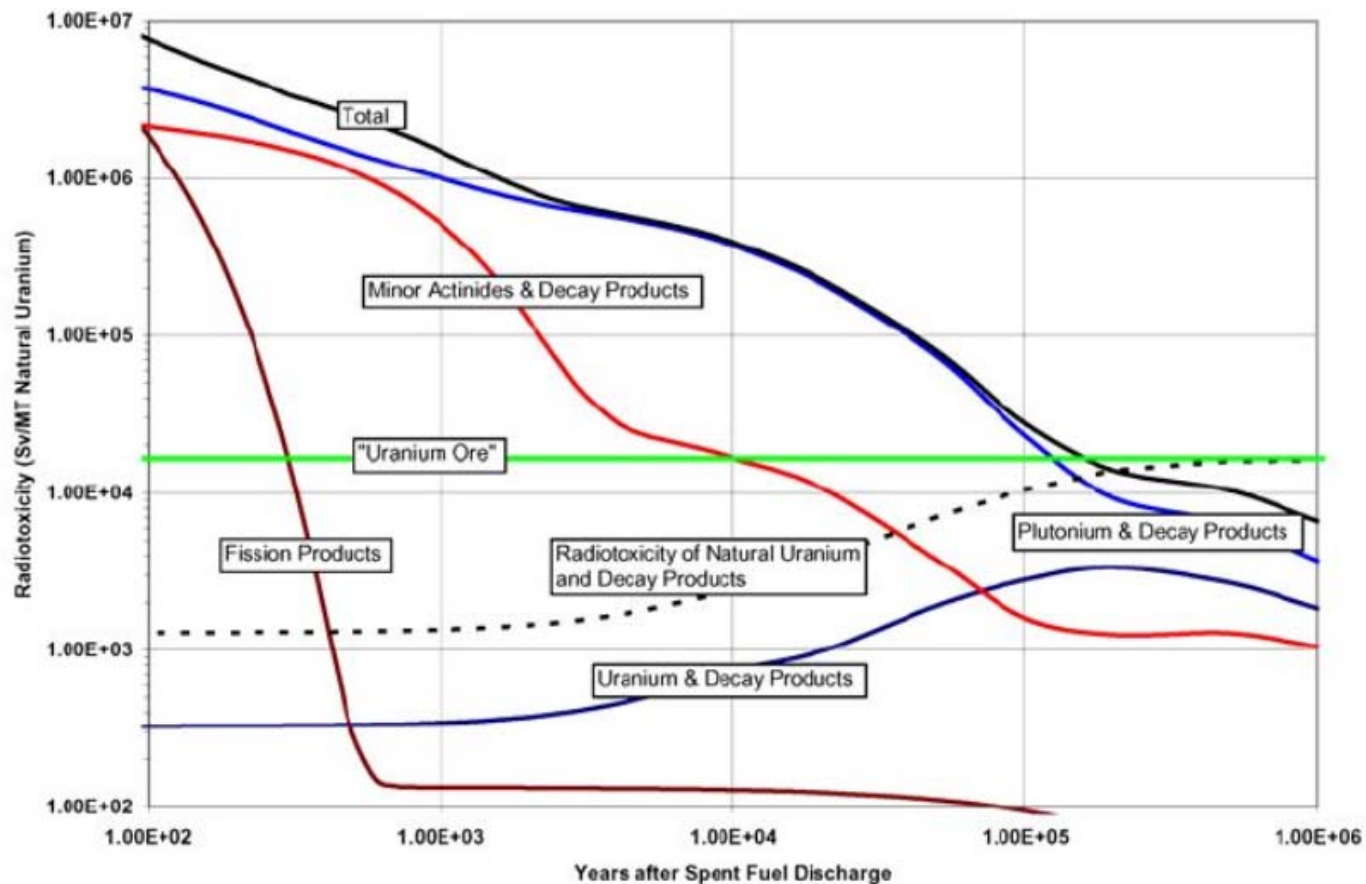
Maximum temperature and displacement (dpa) for components in different nuclear reactors



Radiotoxicity of spent nuclear fuel

Focus on radiotoxicity of plutonium and minor actinides (Np, Am, Cm)

(source: Salvatores, NEA report 6090, 2006)

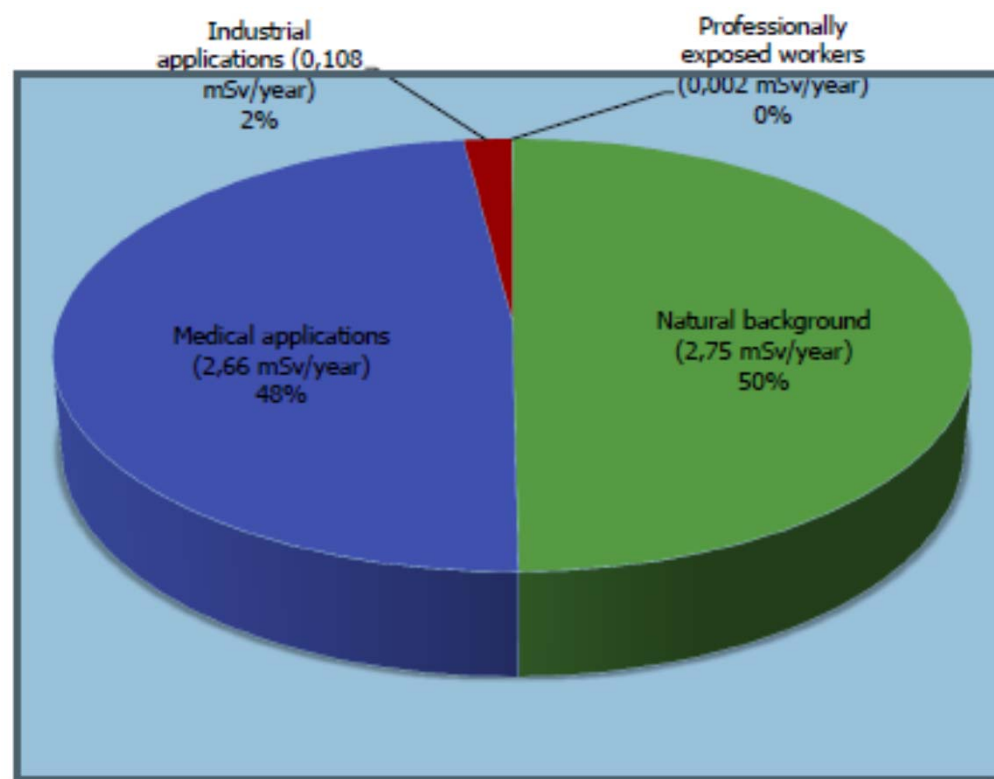
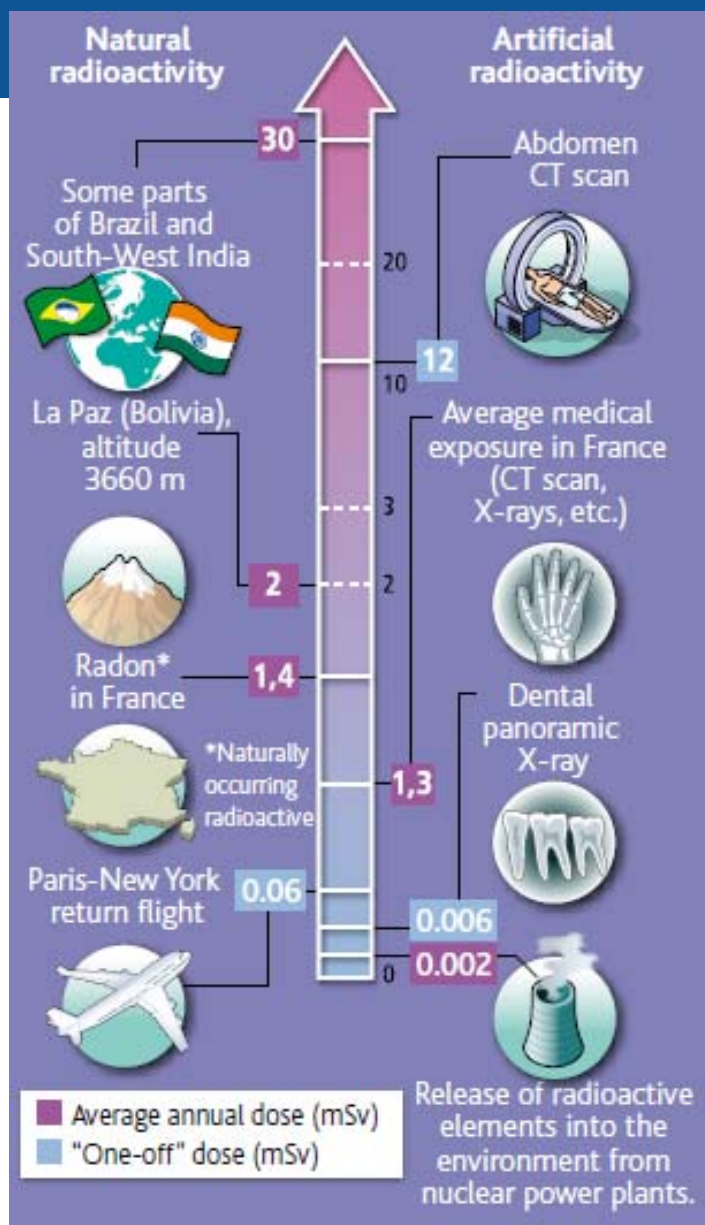


The radioactivity of spent fuel evolves over time as the various elements decay. The same is true of its radiotoxicity (Sv/MT Natural Uranium): that of fission products decreases very rapidly in a few hundred years and then persists at low level for millions of years, because of the presence of long-lived fission products.

The radioactivity of plutonium (mostly of half-lives 24 000, 6 500 and 87 years) represents less than 10 % of the total toxicity of the spent fuel when it comes out of the reactor. With the passage of time and the disappearance of the short-lived products, this proportion increases. Also minor actinides (Np, Am, Cm) contribute significantly to the radiotoxicity balance during a few thousand years.

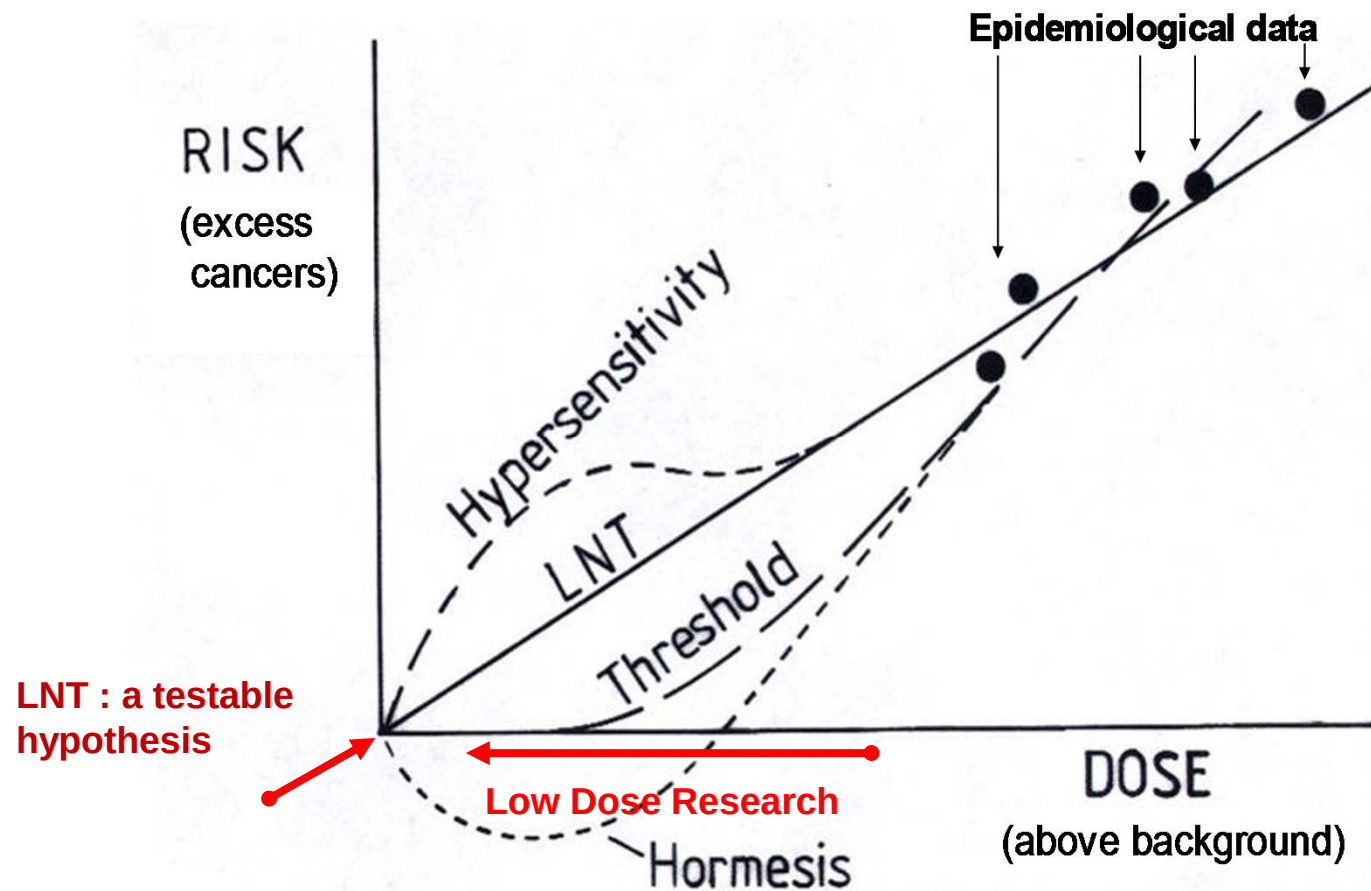
After several thousands of years, plutonium dominates and represents nearly 90 % of the radiotoxicity.

Some sources of radiation exposure for humans



**Average exposure dose per caput in Belgium :
5,5 mSv (FANC 2013)**

Radiation protection: low dose risk extrapolation (linear no-threshold” /LNT/ model versus “hormesis”)



statistical significance below 100 mSv ? (UNSCEAR) => pros and cons of epidemiology versus fundamental sciences

- **Safe and harmonised** management of radioactive waste
- **Enhanced safety** of design and operation of existing and future reactors
- **Lift uncertainty about health risks after low radiation dose** due to industrial and medical applications
- **Ensure transfer of ~~knowledge~~ Knowledge, Skills and Competences (KSC)** to future generation in the field
- **Integration of European research** programming and implementation
- **Challenges need to be addressed worldwide**





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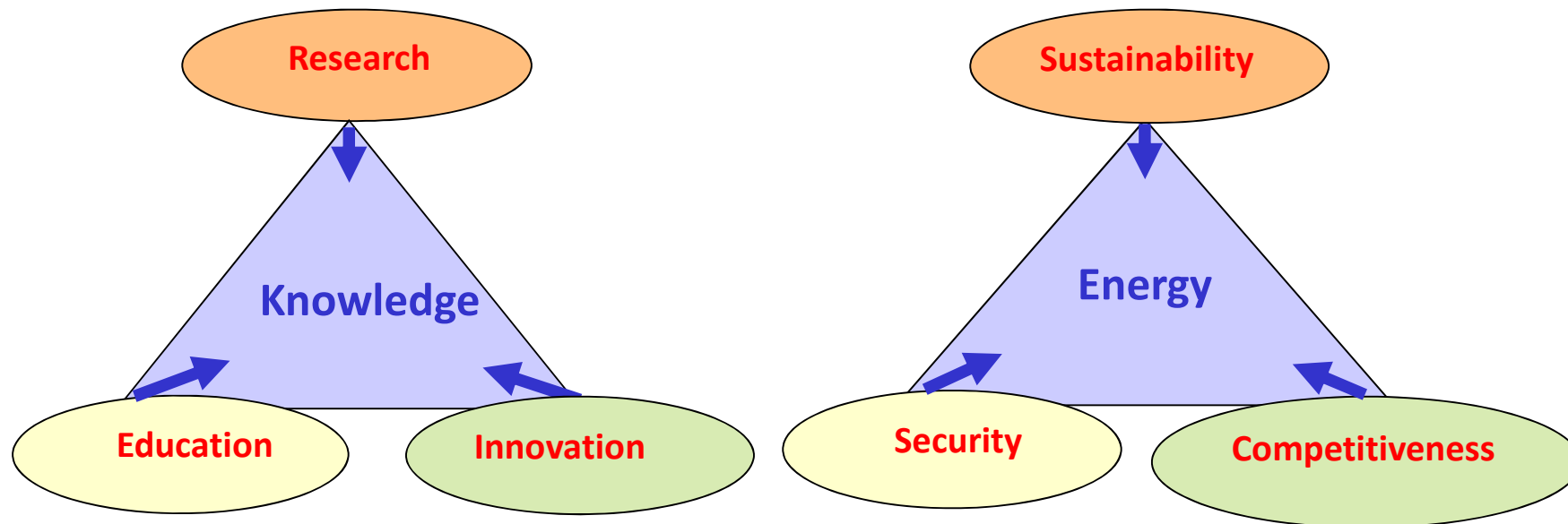
5 - Conclusion: meeting social and industrial needs ("new governance for R&I")



EUROPEAN
COMMISSION

Community research

Research and Innovation in the "European Energy Union" (new Juncker Commission 2014-2019)



<= RD & DD =>

Research, Development Demonstration, Deployment

<= Education (knowledge creation) ⇔ Training (competence building) =>

**"European Energy Union" will rest on five pillars, including "research, innovation and competitiveness"
(EC President, Jean-Claude Juncker and Vice-President Maroš Šefčovič, November 2014)**





VISION REPORTS OF THE TECHNOLOGICAL PLATFORMS SNE-TP, IGD-TP AND OF MELODI (1/3)

1 - SNE-TP : A Vision Report (September 2007)

Excerpt:

"This vision report proposes a vision for the short-, medium- and long-term development of nuclear fission energy technologies, with the aim of

- achieving a sustainable production of nuclear energy,**
- a significant progress in economic performance, and**
- a continuous improvement of safety levels as well as resistance to proliferation.**

In particular, this document proposes actions to harmonise Europe's training and education, whilst renewing its research infrastructures."

- SNE-TP - http://www.snetp.eu/www/snetp/images/stories/Docs-VisionReport/sne-tp_vision_report_Eur22842_en.pdf**



VISION REPORTS OF THE TECHNOLOGICAL PLATFORMS SNE-TP, IGD-TP AND OF MELODI (2/3)

2 - IGD-TP: A Vision Report (November 2007)

Excerpt:

"Our vision is that by 2025,
the first geological disposal facilities for spent fuel, high-level waste, and other
long-lived radioactive waste will be operating safely in Europe".

Our commitment is to:

- build confidence in the safety of geological disposal solutions
- encourage the establishment of waste management programmes that integrate geological disposal as the accepted option for the safe long-term management of long-lived and/or high-level waste;
- facilitate access to expertise and technology

- IGD-TP - http://www.igdtp.eu/Documents/VisionDoc_Final_Oct24.pdf



VISION REPORTS OF THE TECHNOLOGICAL PLATFORMS SNE-TP, IGD-TP AND OF MELODI (3/3)

3 - MELODI: A Vision Report (High Level Group report, November 2008)

Excerpt :

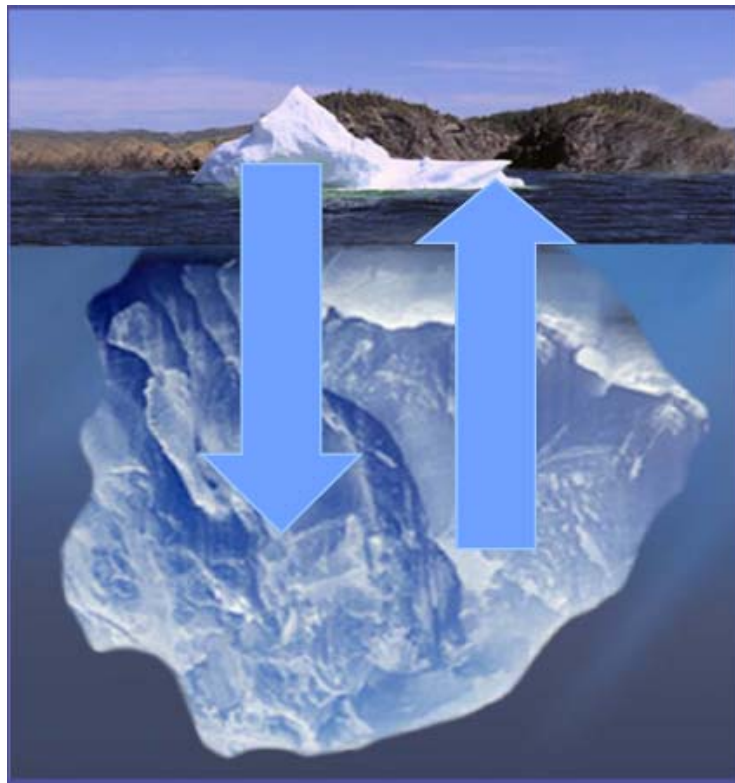
"Better quantification of risks at low dose and how they vary between individuals will impact policy in many areas, for example:

- the management of spent fuel or high level waste where the concern is potential exposure of populations to very small doses over extremely long time periods;**
- decisions on screening programmes (e.g., mammography) where a balance must be sought between the benefits and the potential harm;**
- the identification of those who are more "radiosensitive", through genetic screening."**

- MELODI - <http://www.melodi-online.eu/>
(originated from "High Level Group" - <http://www.hleg.de/>)**



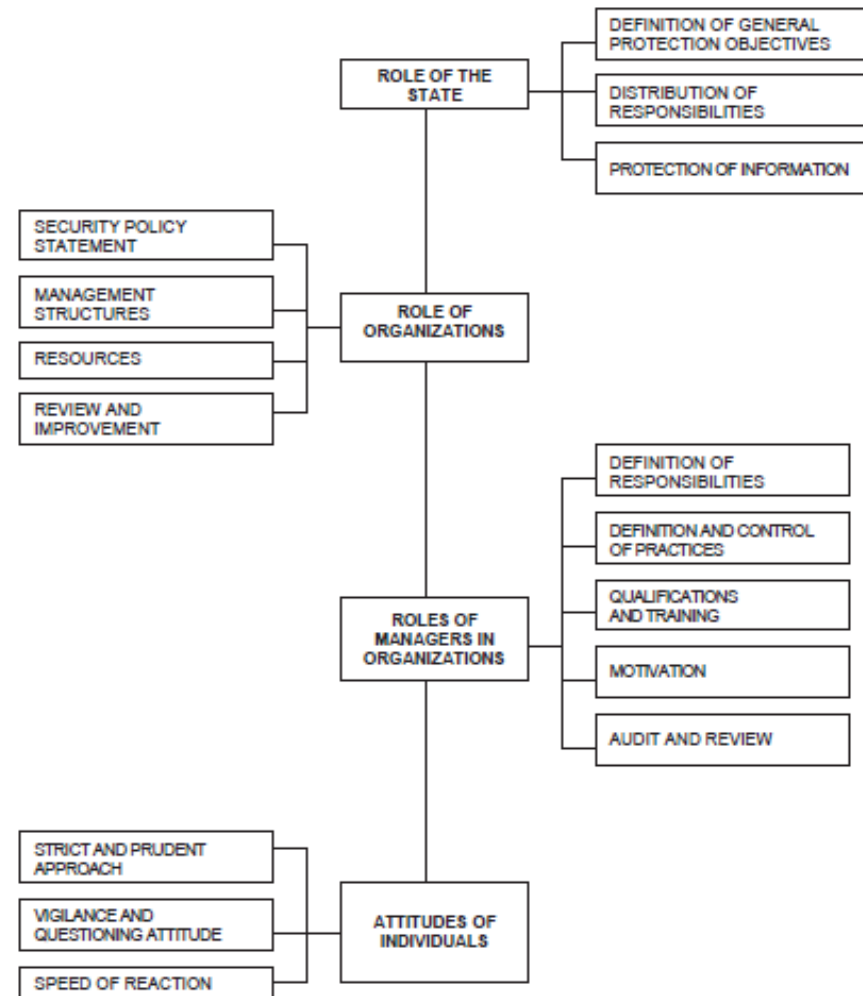
What is safety culture ?



Most of the culture is below the surface.
Above the surface we find the visible aspects of culture:
 - artefacts, people's actions, language use.
Below the surface we find:
 - norms, values, fundamental assumptions of reality

Source: "Regulatory Oversight of Safety Culture in Nuclear Installations"
 (IAEA TECDOC 1707, Vienna, March 2013)

What is security culture ?



Source: "Nuclear security culture – implementing guide"
 (IAEA Nuclear Security Series No. 7, Vienna, 2008)



Nuclear safety culture (WANO)

WANO Guideline 2006-02,
“Principles for a Strong Nuclear Safety Culture”, Jan. 2006

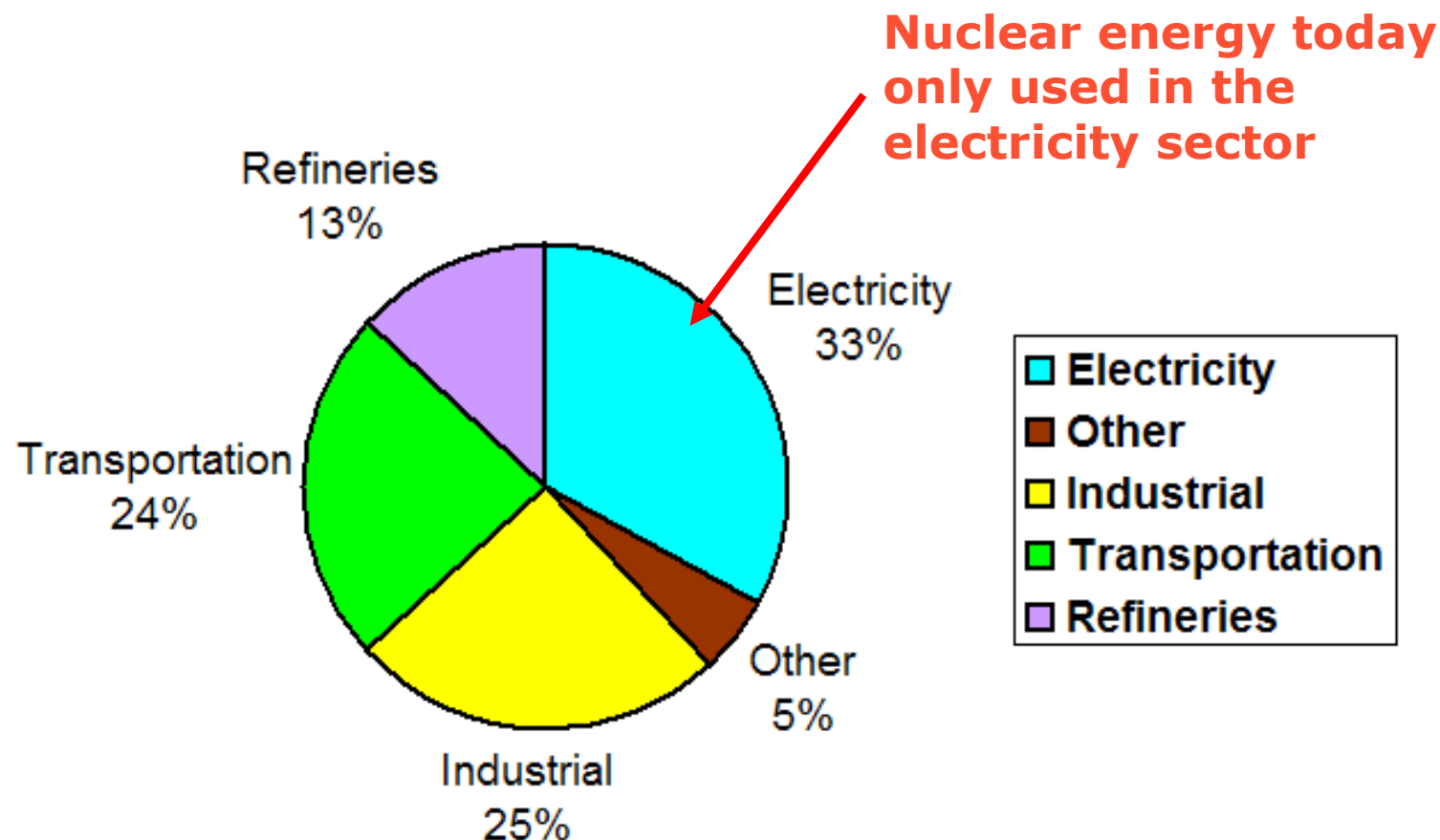
The following eight *Principles for a Strong Nuclear Safety Culture* have been adopted by member utilities worldwide:

1. Everyone is personally responsible for nuclear safety
2. Leaders demonstrate commitment to safety
3. Trust permeates the organisation
4. Decision-making reflects safety first
5. Nuclear technology is recognised as special and unique
6. A questioning attitude is cultivated
7. Organisational learning is embraced
8. Nuclear safety undergoes constant examination.

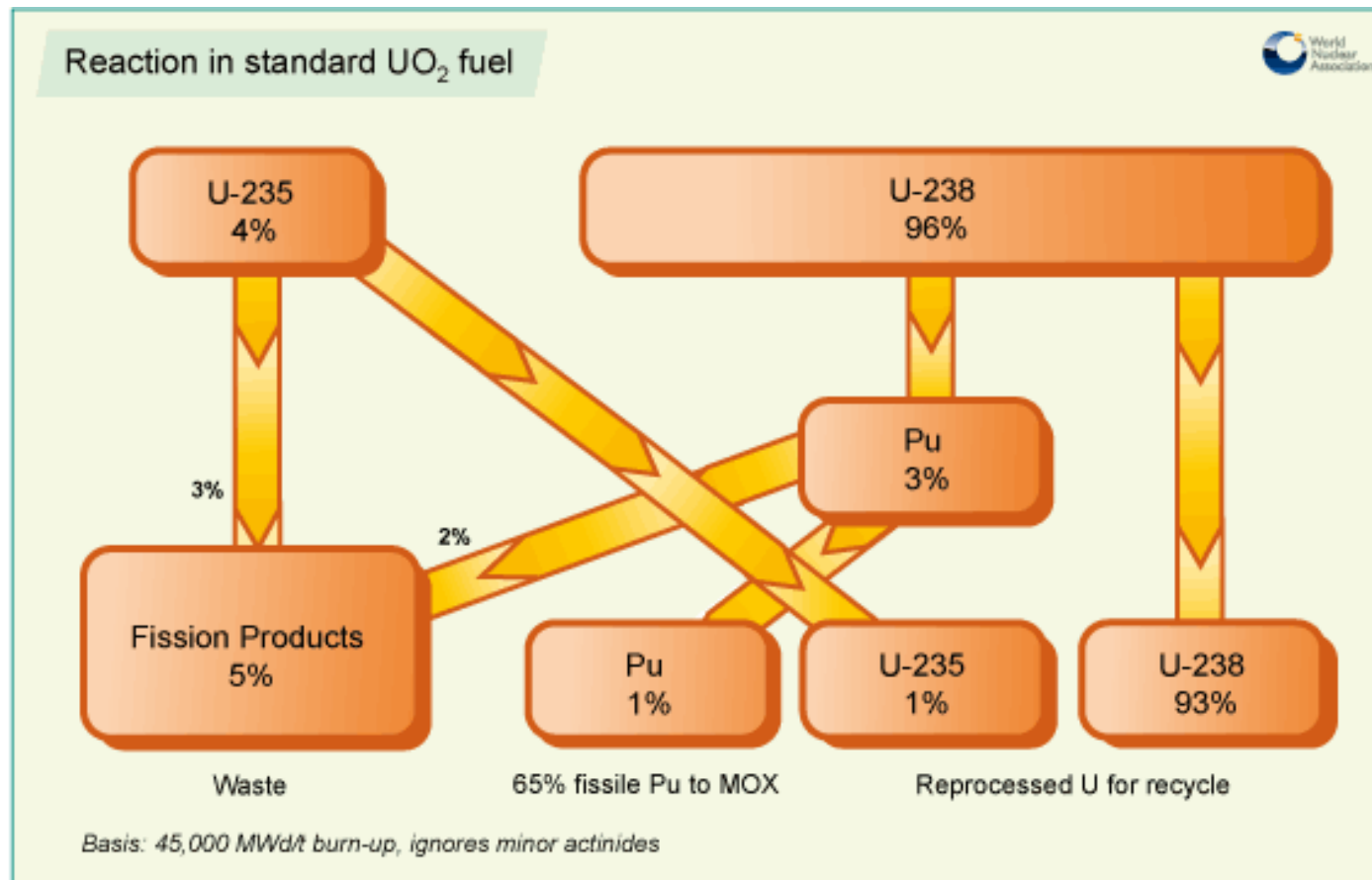
Euratom FP7 project NUSHARE (Jan 2013 – Dec 2016)

- *develop and implement education, training and information (ETI) programmes in nuclear fission and radiation protection, strengthening competences required for achieving excellence in nuclear safety culture*
- *3 target groups: 1. policy makers and opinion leaders / 2. regulators and TSOs / 3. industry*
- *website <http://www.enen-assoc.org/en/training/nushare.html>*

World CO₂ Emissions by Energy Sector (nuclear: an answer to global warming ?)



Fuel removed from a reactor, after it has reached the end of its useful life, can be reprocessed to produce new fuel



Source: <http://www.world-nuclear.org/info/Nuclear-Fuel-Cycle/Fuel-Recycling/Mixed-Oxide-Fuel-MOX/>

GIF Member States involvement in the 6 systems

										
VHTR		◆	◆	◆	◆		◆	◆	◆	
GFR		◆	◆	◆			◆			
SFR		◆	◆	◆	◆			◆	◆	◆
LFR		◆		◆				○		◆
SCWR	◆	◆		◆					◆	◆
MSR		◆	◆	○	○			○	○	◆

VHTR – Very-High-Temperature Reactor SA
GFR – Gas-Cooled Fast Reactor SA
SFR – Sodium-Cooled Fast Reactor SA
LFR – Lead-Cooled Fast Reactor MoU
SCWR – Supercritical Water-Cooled Reactor SA
MSR – Molten Salt Reactor MoU

◆ System Arrangement (SA)
 ◆ Memorandum of Understanding (MoU)
 ○ Observer

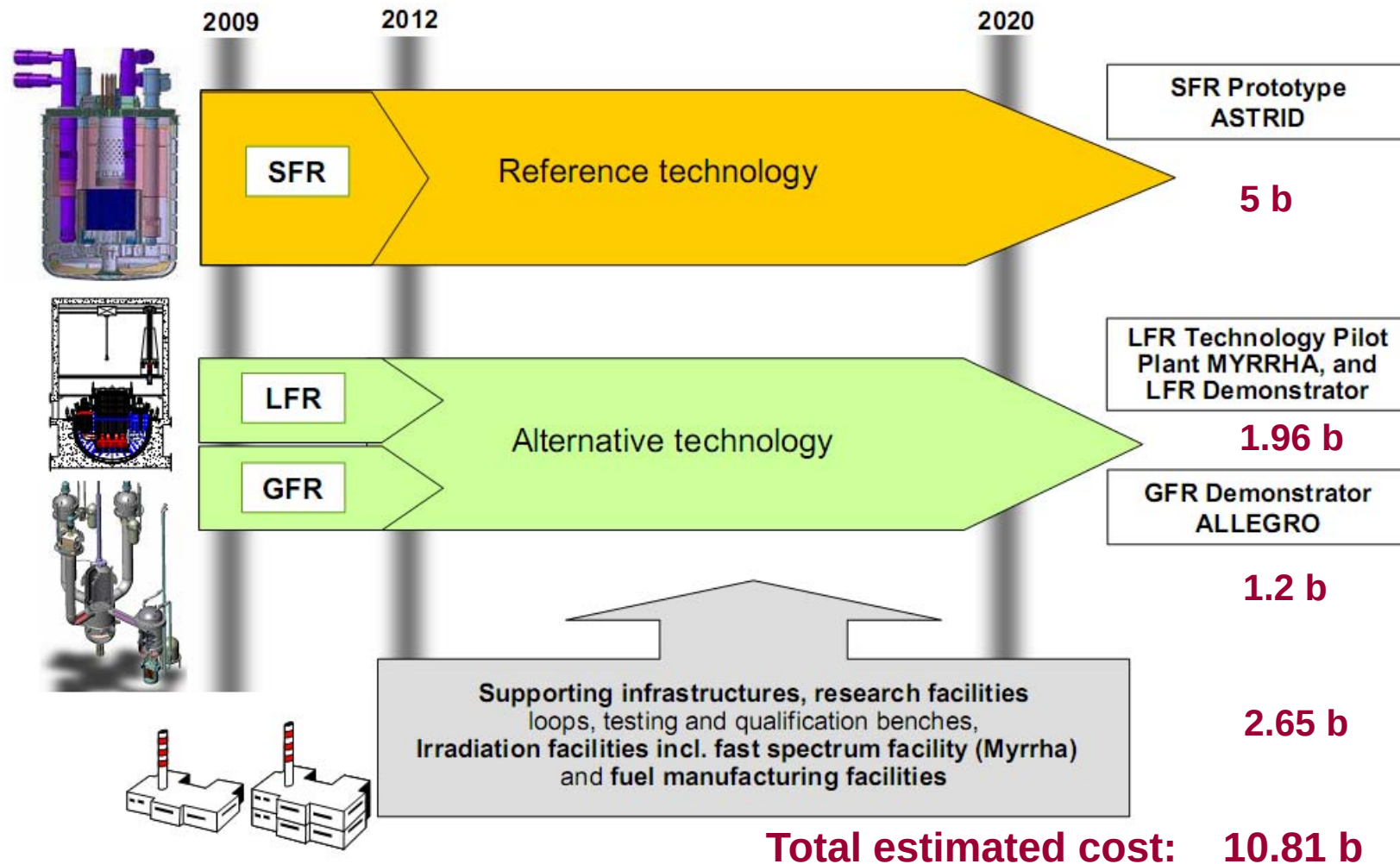
Website: www.gen-4.org

EC DG JRC: Implementing Agent of Euratom
 EC DG RTD: Indirect actions in support to GIF

ESNII: governance



2040: Target for the deployment of Gen-IV Fast Neutron Reactors with Closed Fuel Cycle.
ESNII TF under the umbrella of SNETP, a task force with 20 members (10 industry, 10 research)



Industry opinion about Gen IV in the EU – EDF vision (2010)

- *The Gen IV SFR, associated to a closed fuel cycle, seems the unique choice compatible with an industrial deployment before the second half of the century*
- *Beyond its specific contribution in term of sustainable use of the uranium resources, to be deployed by 2040, this technology will have to show favourable characteristics in term of :*
 - **Safety**
 - **Reactor operation**
 - **Availability, surveillance, maintenance**
 - **Coherency and performances of the associated fuel cycle**
 - **Rationality of the system "reactor/fuel cycle/management of the ultimate waste": safety & security, radioprotection, efficiency**
 - **Competitiveness of the system "reactor + cycle"**
 - **Investment "reactor + cycle", cost for operation, cost of cycle, cost for the management of the ultimate waste**

(Source EDF)



ENEN (EUROPEAN NUCLEAR EDUCATION NETWORK)

A non-profit international organization established on September 22, 2003 under the French law of 1901 and located at CEA-INSTN (Saclay) Paris.

Mission

The preservation and further development of higher nuclear education and expertise in all areas of nuclear fission and radiation protection (education and training)

Composition (as of December 2014)

⇒ 65 members (universities, research institutions and industry) from 17 EU Member States, plus Switzerland (2 univ), Russian Federation (2), Ukraine (2), Japan (3) and South Africa (1)

⇒ further international collaboration: partnership agreements with ENS, IAEA / ANENT (Asia), Canada and WNU

Website = <http://www.enen-assoc.org/>



Reminder: ENEN = spin-off of Euratom FP-5 coordination action "*European Master of Science in Nuclear Engineering*" (/ 2002 – 2003 /, 22 partners, coordinator = SCK-CEN, budget of 200 000 Euros) (contract FIR1-CT2001-80127)
http://cordis.europa.eu/fp5-euratom/src/lib_finalreports.htm#training

OVERVIEW OF EURATOM FISSION WP 2014-2015

Interdisciplinary Study on "Benefits and limitations of nuclear fission for a low-carbon economy" (Feb. 2013) and Symposium FISA and Euradwaste (Oct. 2013)

- Safety / Safety culture
- Socio-economics in the overall energy mix
- Civil society
- Education and training

HORIZON 2020 main orientations

- Challenge oriented & Emphasis on impact





Table of Contents (focus on # 4)

- 1 - Introduction: facts and questions about nuclear**
- 2 - Analysis of society and industry requirements (stakeholders, lessons learnt, KSC)**
- 3 - Towards a common vision (world-wide excellence in nuclear safety and security)**
- 4 - Common implementation instruments
(Euratom and EU policies, H-2020, GIF-ESNII)**
- 5 - Conclusion: meeting social and industrial needs ("new governance for R&I")**

European Nuclear Initiatives

**Nuclear
safety**



**Waste
management**



**Radiation
protection**



**Emergency
preparedness
& response**





Revised Nuclear Safety Directive (Council Directive 2014/87/Euratom of 8 July 2014)

Safety objectives for nuclear installations
European system of topical peer reviews
Transparency
Independence and role of national regulators

Continuous improvement of nuclear safety throughout the EU

EXCERPT: "Whereas:

11. In order to ensure that the proper skills are acquired and that adequate levels of competence are achieved and maintained, ... all staff ... undergo a continuous learning process. This can be achieved through ... training programmes and training plans, ... as well as appropriate budgetary provisions for training."

EXCERPT of Article 8a : "Nuclear safety objective for nuclear installations"

1. Member States shall ensure that the national nuclear safety framework requires that nuclear installations are designed, sited, constructed, commissioned, operated and decommissioned with the objective of preventing accidents and, should an accident occur, mitigating its consequences and avoiding:

- (a) early radioactive releases that would require off-site emergency measures but with insufficient time to implement them;*
- (b) large radioactive releases that would require protective measures that could not be limited in area or time.*



Nuclear Waste Directive (Council Directive 2011/70/Euratom of 19 July 2011)

Legally binding standards for **safe** and **responsible** management of radioactive waste and spent fuel

Main bases

- ✓ **IAEA Safety Standards**
- ✓ **Joint Convention**



EXCERPT: Article 8 is devoted to *"Expertise and skills"*

"Member States shall ensure that the national framework requires all parties to make arrangements for education and training for their staff, as well as research and development activities to cover the needs of the national programme for spent fuel and radioactive waste management in order to obtain, maintain and to further develop necessary expertise and skills."





"Revised BSS" – Council DIRECTIVE 2013/59/Euratom (1/2) laying down basic safety standards (BSS) for protection against the dangers arising from exposure to ionising radiation (Brussels, 05.12.2013)

Of particular interest is the incorporation in the revision of a new Chapter IV:
"Requirements for radiation Protection Education, Training and Information".

Chapter X ("*Requirements for regulatory control*" / "*Section 1 – Institutional Infrastructure*") requires Member States to have systems in place for the education, training and recognition of

- "*Radiation protection experts*" (Article 82)
- "*Medical physics experts*" (Article 83) website
- "*Radiation protection officers*" (Article 84).

- website http://ec.europa.eu/energy/nuclear/radiation_protection/radiation_protection_en.htm

More information on the EUTERP website and in the FP7 Euratom projects:
RPE and RPO in "ENETRAP III" // MPE in "EUTEMPE RX"

- website <http://www.enen-assoc.org/en/training/for-nuclear-community.html>



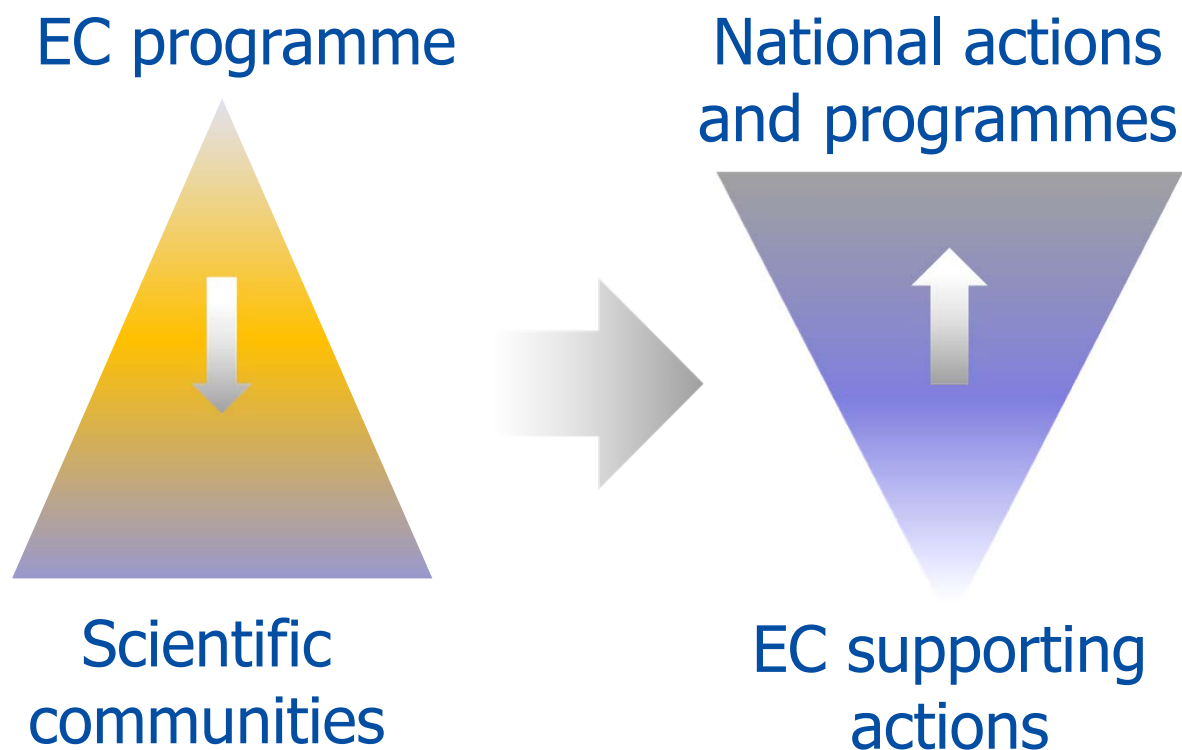
Key points of "Revised BSS" – Council DIRECTIVE 2013/59/Euratom (2/2)

- ❑ Better protection of workers (in particular medical staff and workers in workplaces with indoor radon and in activities processing naturally occurring radioactive material)
- ❑ Better protection of the public (in particular from radon in dwellings)
- ❑ Better protection of patients (in particular with regard to the avoidance of incidents and accidents in radio-diagnosis and radio-therapy)
- ❑ Obligations to ensure transparency (Communication with undertakings and individuals subject to medical exposure)
- ❑ Emergency preparedness and response
 - Establishment of national management systems, including Assessment of emergency situations;
 - Requirement for the establishment of specific Response plans for specific postulated events;
 - Establishment of long term strategies for existing exposure cases;
 - Improved cooperation at the international level;
 - Requirement for prompt provision of information to public;
 - Guidelines and training for the protection of emergency workers).

Emergency preparedness and response



From a project-related logic to a programme-related logic

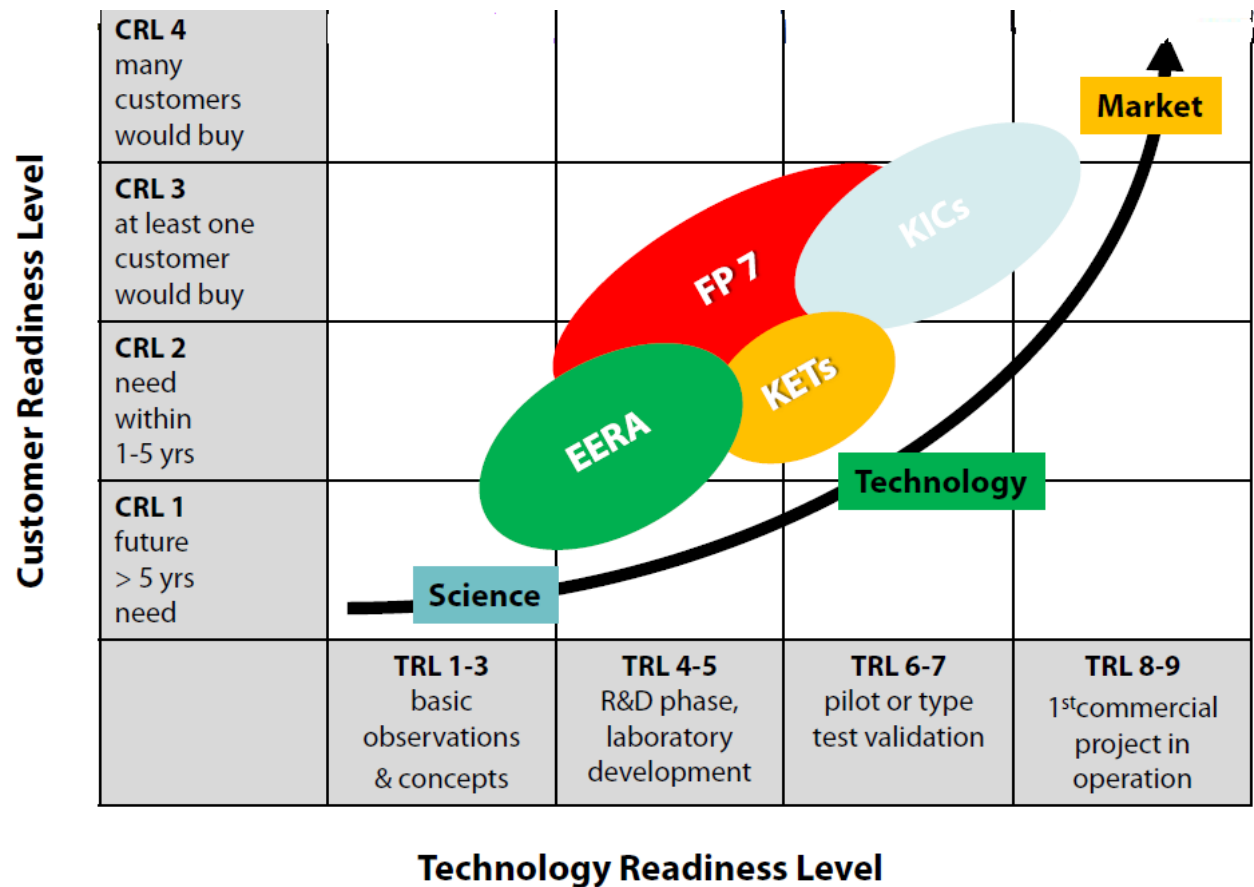


- TRL 1 Basic principles observed and reported
- TRL 2 Technology concept and/or application formulated
- TRL 3 Analytical and experimental proof of concept
- TRL 4 Component /subsystem / technology validation in laboratory environment
- TRL 5 Component /subsystem /technology validation in relevant environment
- TRL 6 Prototyping demonstration in relevant environment
- TRL 7 Prototyping demonstration in operational environment
- TRL 8 System completed and qualified (demonstration in operational environment)
- TRL 9 Technology proven through successful mission operations.

Technology Readiness Levels (NASA 1980's) -

<http://www.nasa.gov/content/technology-readiness-level/>

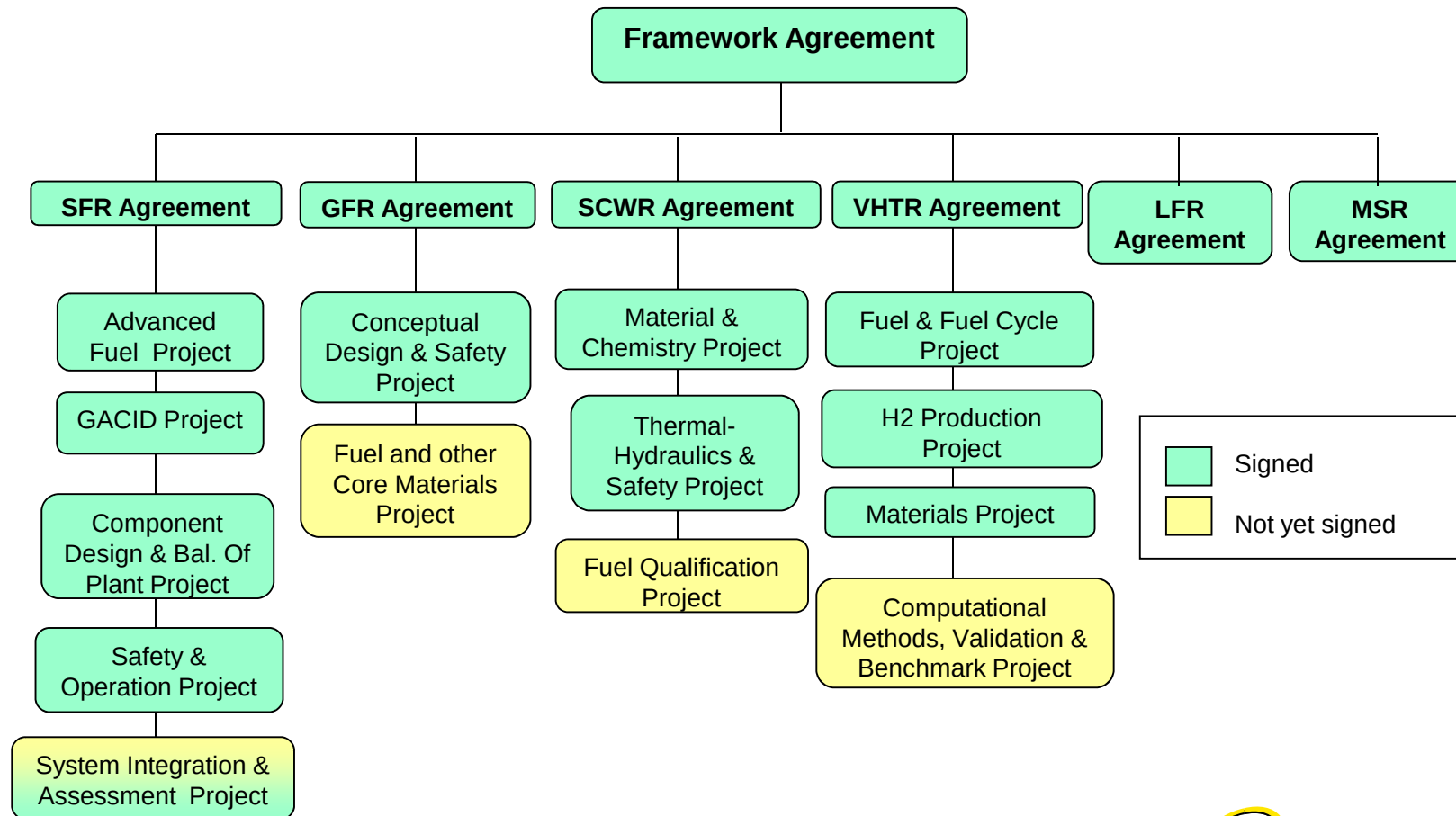
Customer Readiness level vs Technology Readiness Levels



Source: EuroMaster in Nuclear Energy

European Institute of Innovation and Technology - Knowledge and Innovation Communities" (KIC) - <http://www.kic-innoenergy.com/education/msc-programmes/msc-emine.html>

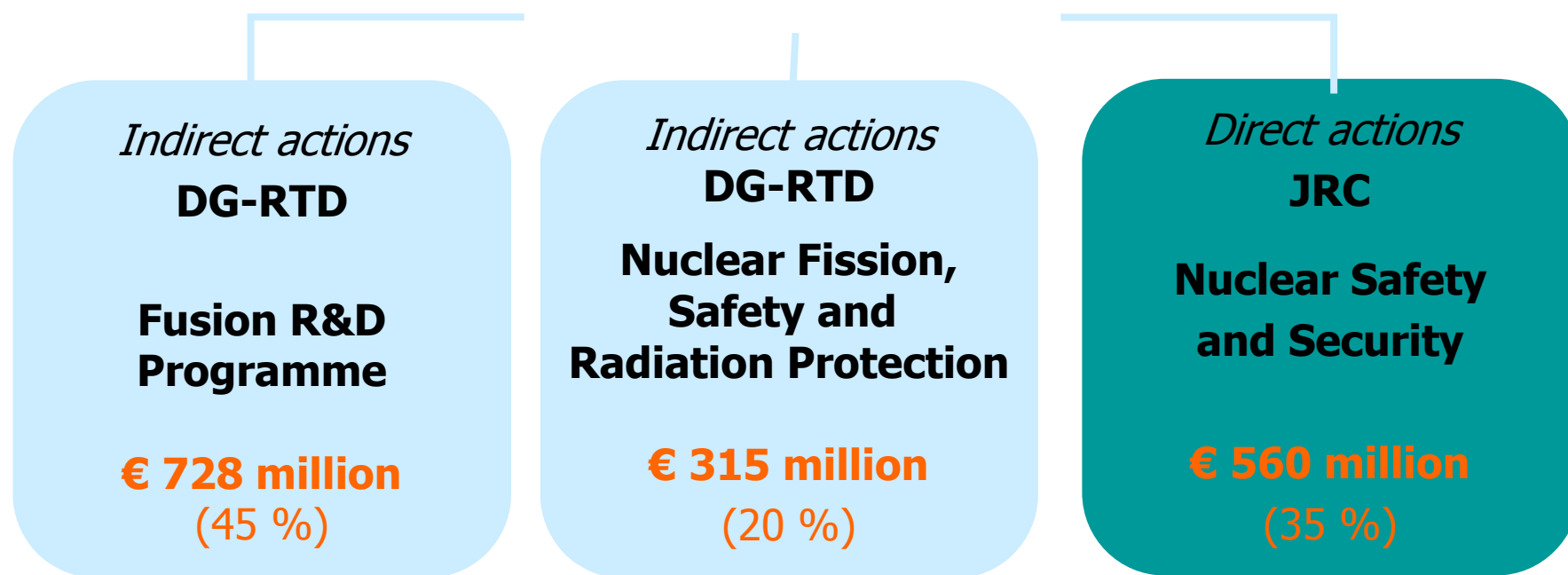
Status of GIF agreements (May 2014)





Euratom Programme (2014-18) complementing Horizon-2020

→ Council Regulation of 16 December 2013



Total budget: € 1603 million

→ Council Decision of 13 December 2013

European joint undertaking for ITER (called "Fusion for Energy")
ITER (2014-2020): € 2915 million in current values (outside H2020)



“EUROPEAN HUMAN RESOURCE OBSERVATORY IN THE NUCLEAR ENERGY SECTOR”



[\(http://ehron.jrc.ec.europa.eu/\)](http://ehron.jrc.ec.europa.eu/)



1ST SITUATION REPORT ON EDUCATION AND TRAINING IN THE NUCLEAR ENERGY FIELD IN THE EU (COM(2011) 563, BRUSSELS, 16.9.2011)

http://ec.europa.eu/energy/nuclear/safety/doc/com_2011_0563_en.pdf

"**EHRO-N** is therefore the initiative to fill this gap, especially as it can provide a continuous monitoring and scanning of future challenges. **EHRO-N will be the central information source** for all stakeholders in the EU interested in the optimisation and rounding up of the initiatives taken. Member States are therefore invited to fully support the Commission in developing this promising tool."

=> follow-up: The "Second Situation Report on Education and Training in the Nuclear Energy Field in the EU" was published as a «Commission Staff Working Document» on 3 October 2014 (Brussels, SWD(2014) 299 final / 13874/14)

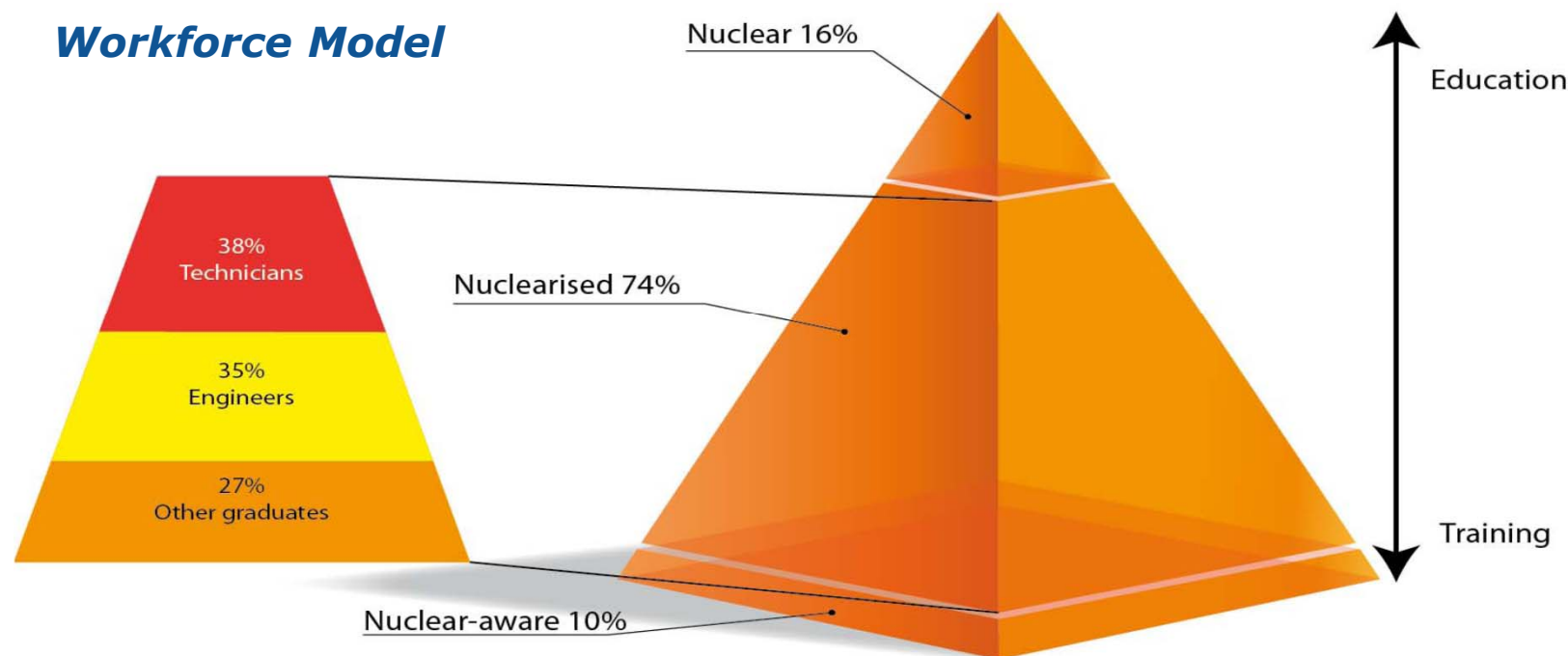
=> First EHRO-N report on the supply and demand for nuclear experts for the present and future nuclear projects in the EU by 2020 (analysis done on data received from spring 2010 to spring 2011).

“PUTTING INTO PERSPECTIVE THE SUPPLY OF AND DEMAND FOR NUCLEAR EXPERTS BY 2020 WITHIN THE EU-27 NUCLEAR ENERGY SECTOR”, April 2012, EHRO-N report, JRC-IET, EUR 25291 EN

Competence Pyramid

Hypothetical graphical representation of
the nuclear energy sector in the EU-28 by type of employees

Workforce Model



**SOURCE: "EUROPEAN HUMAN RESOURCE OBSERVATORY
IN THE NUCLEAR ENERGY SECTOR" - [HTTP://EHRON.JRC.EC.EUROPA.EU/](http://ehron.jrc.ec.europa.eu/)**



EDUCATION: "An agenda for new skills and jobs - A EU contribution towards full employment", COM(2010) 682 => lifelong learning and cross-border mobility

- **Bologna Declaration on the "European Higher Education Area"**
(June 1999 - 47 signatory States)
=> ***"European Credit Transfer and accumulation System" / ECTS /***
- **Copenhagen Declaration on "enhanced European cooperation in VET"**
(November 2002 – signed by all 28 EU Member States)
=> ***"European Credit system for Vocational Education and Training" / ECVET /***

European System: 1 year = 60 ECTS

1 ECTS ~ 10 Hours



BOLOGNA 1999:
MUTUAL RECOGNITION OF ACADEMIC GRADES

COPENHAGEN 2002:
Lifelong learning and cross-border mobility

ANDERSON AND BLOOM TAXONOMY ADAPTED FOR RPE (INCLUDING TAXONOMY ACTION VERBS)

COGNITIVE DOMAIN (THINKING, KNOWLEDGE)

	Knowledge	Comprehension	Application	Analysis	Synthesis	Evaluation
Definition	<i>Remembers previously learned material</i>	<i>Grasps the meaning of material (lowest level of understanding)</i>	<i>Uses learning in new and concrete situations (higher level of understanding).</i>	<i>Understands both the content and structure of material.</i>	<i>Formulates new structures from existing knowledge and skills.</i>	<i>Judges the value of material for a given purpose.</i>
Example Verbs	▪ define ▪ identify ▪ label ▪ list ▪ name ▪ recall ▪ state	▪ describe ▪ discuss ▪ explain ▪ locate ▪ paraphrase ▪ give example ▪ translate	▪ apply ▪ carry out ▪ demonstrate ▪ illustrate ▪ prepare ▪ solve ▪ use	▪ analyze ▪ categorize ▪ compare ▪ contrast ▪ differentiate ▪ discriminate ▪ outline	▪ combine ▪ construct ▪ design ▪ develop ▪ generate ▪ plan ▪ propose	▪ assess ▪ conclude ▪ evaluate ▪ interpret ▪ justify ▪ select ▪ support

RPE = Radiation Protection Expert

("Basic Safety Standards" (BSS) - **COUNCIL DIRECTIVE 2013/59/-** Act adopted on 05/12/2013
=> Chapter IV "*Requirements for Radiation Protection Education, Training and Information*")

http://ec.Europa.eu/energy/nuclear/radiation_protection/radiation_protection_en.htm

Source = FP7 Euratom EFTS project ENETRAP II /2009-2012/ (<http://enetrap2.sckcen.be/>)





Table of Contents (focus on # 5)

- 1 - Introduction: facts and questions about nuclear**
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- 5 - Conclusion: meeting social and industrial needs
("new governance for R&I")**

Meeting industrial and societal needs through Euratom and international research and training programmes

- improve continually sustainability, safety & reliability, socio-economics and proliferation resistance of nuclear installations
 - contribute to the creation and transfer not only of *knowledge* but also of *skills* and *competences* (with emphasis on safety culture)
 - ensure scientific and technological excellence in all parts of the European Union (and world-wide) through shared programmes
 - develop a new governance for research and innovation (R&I) in nuclear fission (i.e. rules, processes and behaviour)
- => a new way of “developing / teaching science” aiming at continuously improving applications of nuclear fission energy and ionising radiation**

Nuclear Generation IV is lagging behind => other Generations 5, 6, 7 are already on the market



Génération 5

82, rue du Bon Pasteur
73000 CHAMBÉRY
France

Tel : 04 79 96 99 59 Fax : 04 79 96 96 53
Depuis l'étranger :
Tel : 33 479 96 99 59 Fax : 33 479 96 96 53

<http://www.generation5.fr>
e-mail : contact@generation5.fr

Assistance technique gratuite de 8h45 à 12h30 et 13h30 à 17h30
au 04 79 96 38 70
ou par e-mail : support@generation5.fr



Generation 6. Jamais la science et la nature ne vous avaient rendue aussi belle. Seule la double formule, créée par Clarins, permet de réunir des actifs végétaux, solubles dans l'huile ou dans l'eau, dans leur concentration la plus efficace. Generation 6 réactive l'ensemble des fonctions vitales de la jeunesse de la peau.

Generation 6.
Le nouveau Double Serum.

CLARINS PARIS

Traitement Multi-Régénérant
Phyto-Intensif

Double Serum

Generation 6

Extra-Firming
Botanical Intensive Care

Une sélection des produits
de soins de beauté à l'usage commun
www.clarins.com



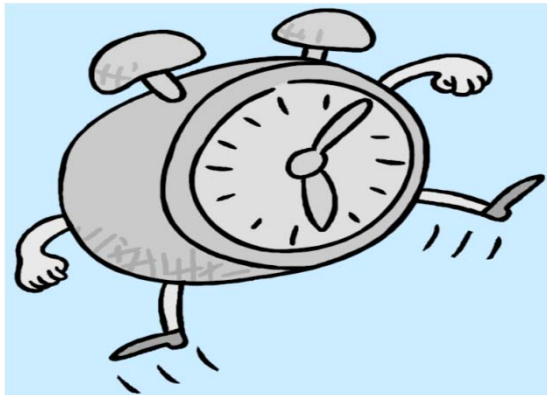
GENERATION 7

ACCELERATED TEAMING

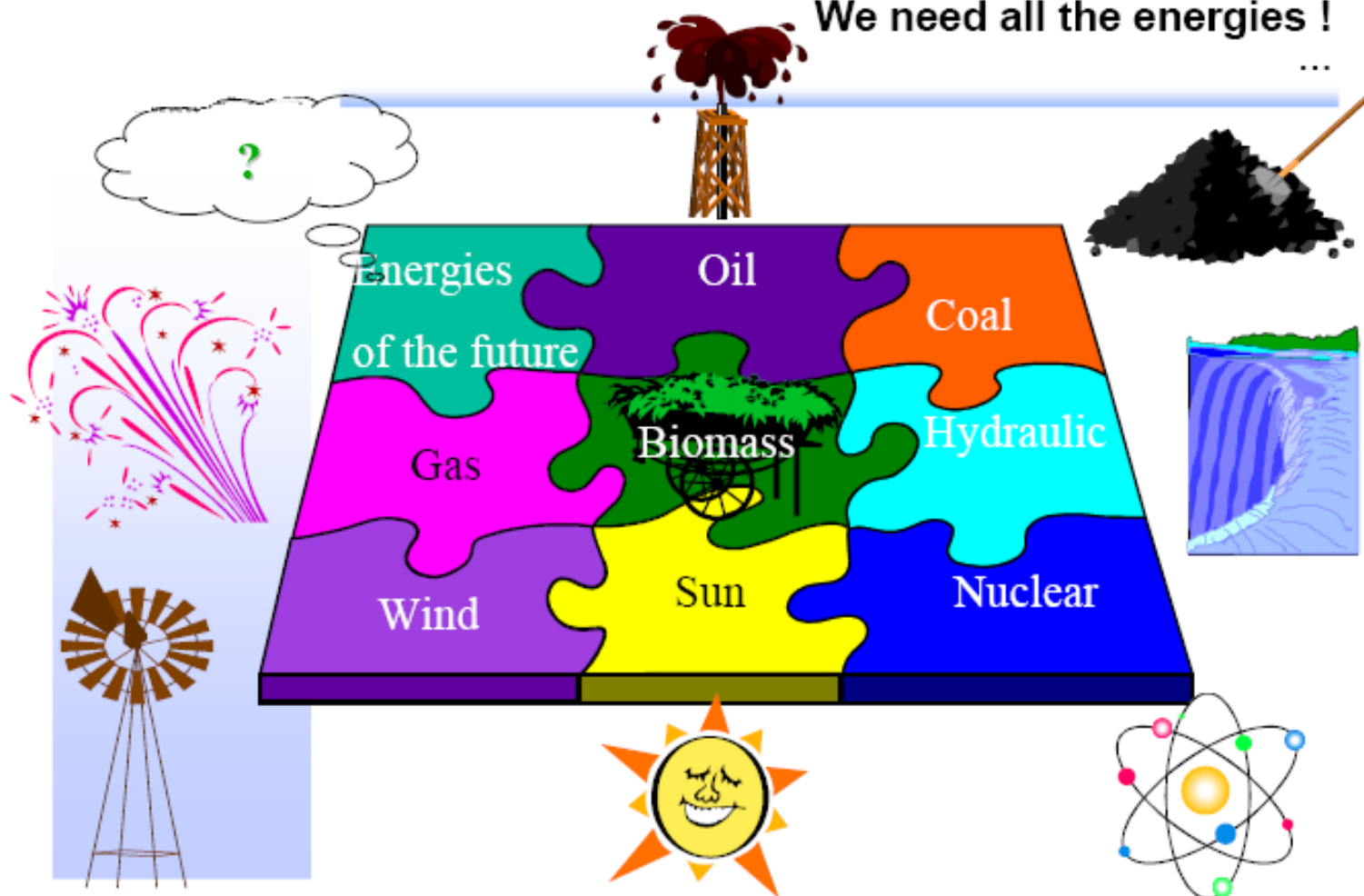
A high-impact, action-oriented training and coaching intervention with spectacular results – in just 7 steps

Designed for organisations striving for increased performance from high-potential leadership teams

Thank you for your attention - ご清聴ありがとうございました



We need all the energies !



Article 194 of the Lisbon Treaty :

"Union policy on energy shall aim, in a spirit of solidarity ...: .. Such measures shall not affect a Member State's right to determine the conditions for exploiting its energy resources, its choice between different energy sources and the general structure of its energy supply". (http://europa.eu/lisbon_treaty/index_en.htm)

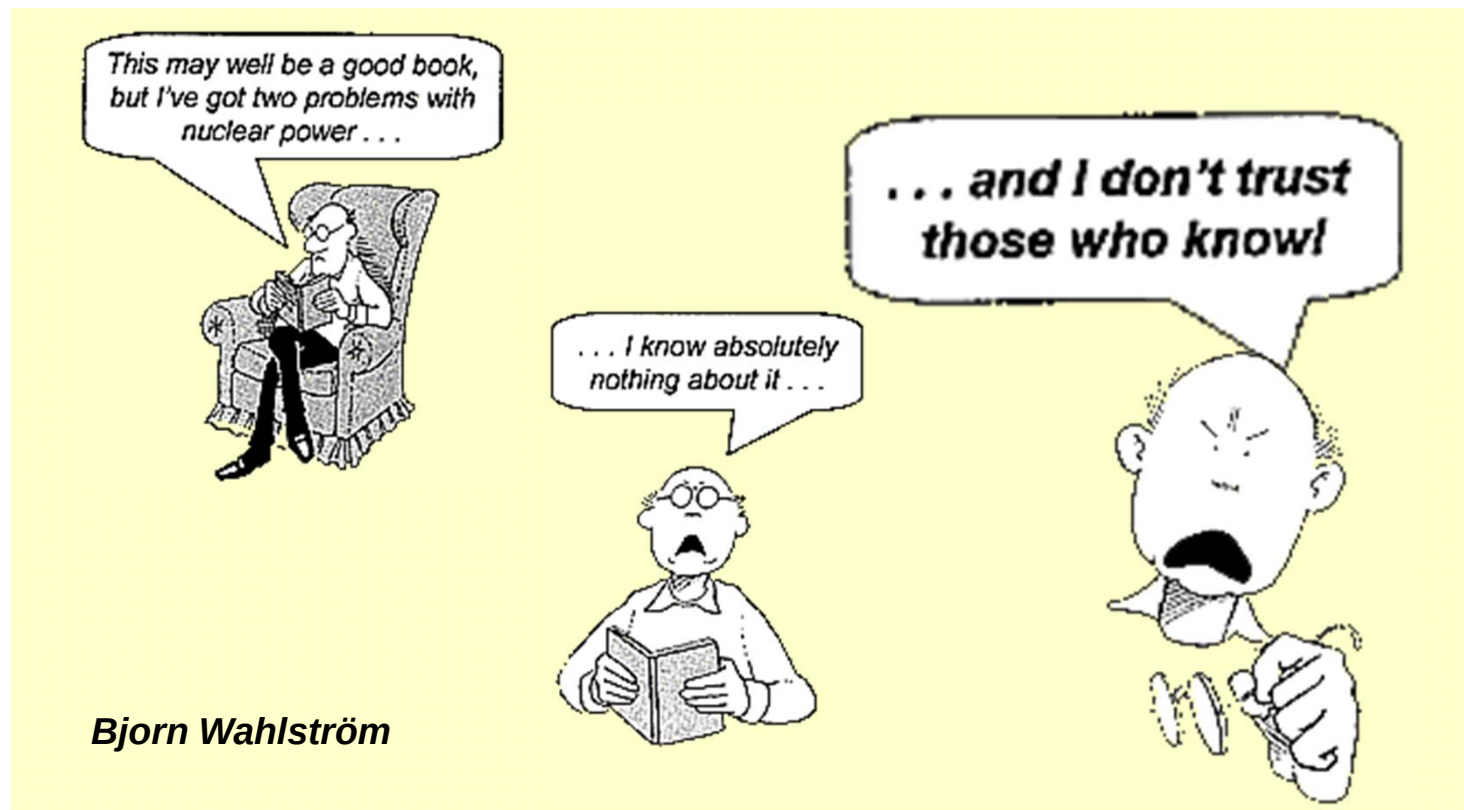


Available Links

- EU Energy research: http://ec.europa.eu/research/energy/index_en.htm
- Euratom Seventh Framework Programme: http://cordis.europa.eu/fp7/euratom/home_en.html
- Information on FP7 and access to programmes and calls: http://cordis.europa.eu/fp7/home_en.html
- Euratom Seventh Framework Programme funded projects http://cordis.europa.eu/fp7/euratom-fission/library_en.html
- **CORDIS publications**
 - ➔ http://cordis.europa.eu/fp6-euratom/library_en.html
 - ➔ http://cordis.europa.eu/fp7/euratom-fission/library_en.html
 - ➔ **Euratom FP6 Research Projects and Training Activities, Volume I-II and III (PDF)**
 - ➔ **Volume I** ftp://ftp.cordis.europa.eu/pub/fp6-euratom/docs/nuclear_fission_eur21228_en.pdf
 - ➔ **Volume II** ftp://ftp.cordis.europa.eu/pub/fp6-euratom/docs/nuclear_fission_eur21229_en.pdf
 - ➔ **Volume III** ftp://ftp.cordis.europa.eu/pub/fp7/docs/euratom-fission_eur22385_en.pdf
 - ➔ **Euratom FP7 Research Projects and Training Activities, Volume I (PDF)**
 - ➔ **Volume I** ftp://ftp.cordis.europa.eu/pub/fp7/docs/fin-266-euratom-web-jun09v02_en.pdf
 - ➔ **Volume II** <http://ec.europa.eu/research/energy/pdf/euratom-fp7-vol-2.pdf>
 - ➔ **Volume III** http://ec.europa.eu/research/energy/euratom/publications/pdf/euratom_fp7_research_&_training_projects_volume_3.pdf
- Research*eu magazine http://ec.europa.eu/research/research-eu/index_en.html
- **Strategic Energy Technolog Plan SET-Plan** http://ec.europa.eu/energy/technology/set_plan/set_plan_en.htm
- FISA 2009 http://cordis.europa.eu/fp7/euratom-fission/fisa2009_en.html
- **Financial Framework 2014 – 2020 “Horizon 2020”**
- http://ec.europa.eu/budget/reform/index_en.htm
- http://ec.europa.eu/budget/biblio/documents/fin_fw1420/fin_fw1420_en.cfm
- http://ec.europa.eu/research/horizon2020/index_en.cfm
- **2013 Symposium on ‘Nuclear Fission research for a low carbon economy’**
 - ➔ <http://www.eesc.europa.eu/?i=portal.en.events-and-activities-symposium-on-nuclear-fission>
- **FISA 2013 and Euradwaste’13** http://cordis.europa.eu/fp7/euratom-fission/fisa-euradwaste-2013_en.html

Low public confidence in the use of nuclear fission energy ?

(nuclear power is at a crossroads: options range from a slow decline to a more than doubling of nuclear power in the next 25 years - *World Energy Outlook 2014*)



About communication: 2010 campaign by Belgian Nuclear Forum - "Are you as radioactive as miss Belgium ?"
=> Rock Werchter pop festival (1-4 July 2010, 30 000 attendees, Werchter is located 40 km NE of Brussels)
<https://www.youtube.com/watch?v=5SXGLpNJD9c>

FISA and Euradwaste 2013 conferences



EU2013.LT



European
Commission

**14-17 October 2013
Vilnius, Lithuania**



http://cordis.europa.eu/fp7/euratom-fission/fisa-2013_en.html

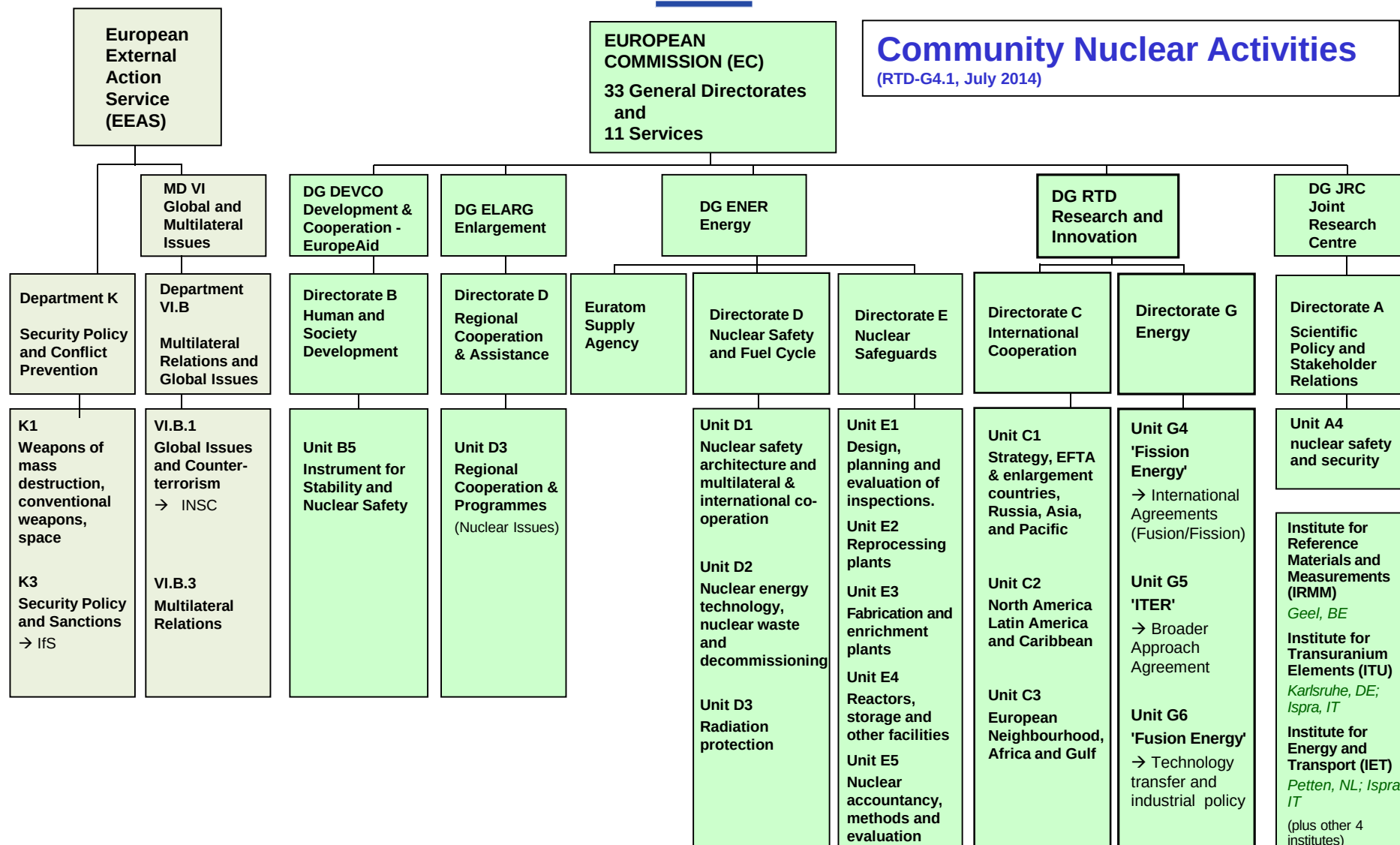


European
Commission

**EUROPEAN
COMMISSION (EC)**
33 General Directorates
and
11 Services

Community Nuclear Activities

(RTD-G4.1, July 2014)



Research &
Innovation



"Euratom Fission Training Schemes" for safety related jobs and functions

Eleven EFTS: ECNET, ENEN III, TRASNUSAFE, CORONA, CINCH II, EUTEMPE-RX, GENTLE, NUSHARE, PETRUS III, ENEN-RU II, ENETRAP-III (1/2)

- ECNET - EU-CHINA Nuclear Education and Training Cooperation: mirror project to be financed by the Chinese Atomic Energy Authority (March 2011 - February 2013)
- ENEN-III Training schemes - Generation III and IV engineering: addressing mainly nuclear systems suppliers and engineering companies (May 2009 – April 2013)
- TRASNUSAFE - Nuclear Safety Culture: addressing mainly the health physics sector (e.g., ALARA principle in industry and medical field) (Nov. 2010 - October 2014)
- CORONA - Regional Center of Competence for VVER Technology and Nuclear Applications: focus on VVER personnel training (December 2011 – November 2014)
- **CINCH-II - Cooperation in education and training In Nuclear Chemistry: focus on the European master's degree in nuclear and radiochemistry (June 2013 – May 2016)**





Eleven EFTS: ECNET, ENEN III, TRASNUSAFE, CORONA, CINCH II, EUTEMPE-RX, GENTLE, NUSHARE, PETRUS III, ENEN-RU II, ENETRAP-III (2/2)

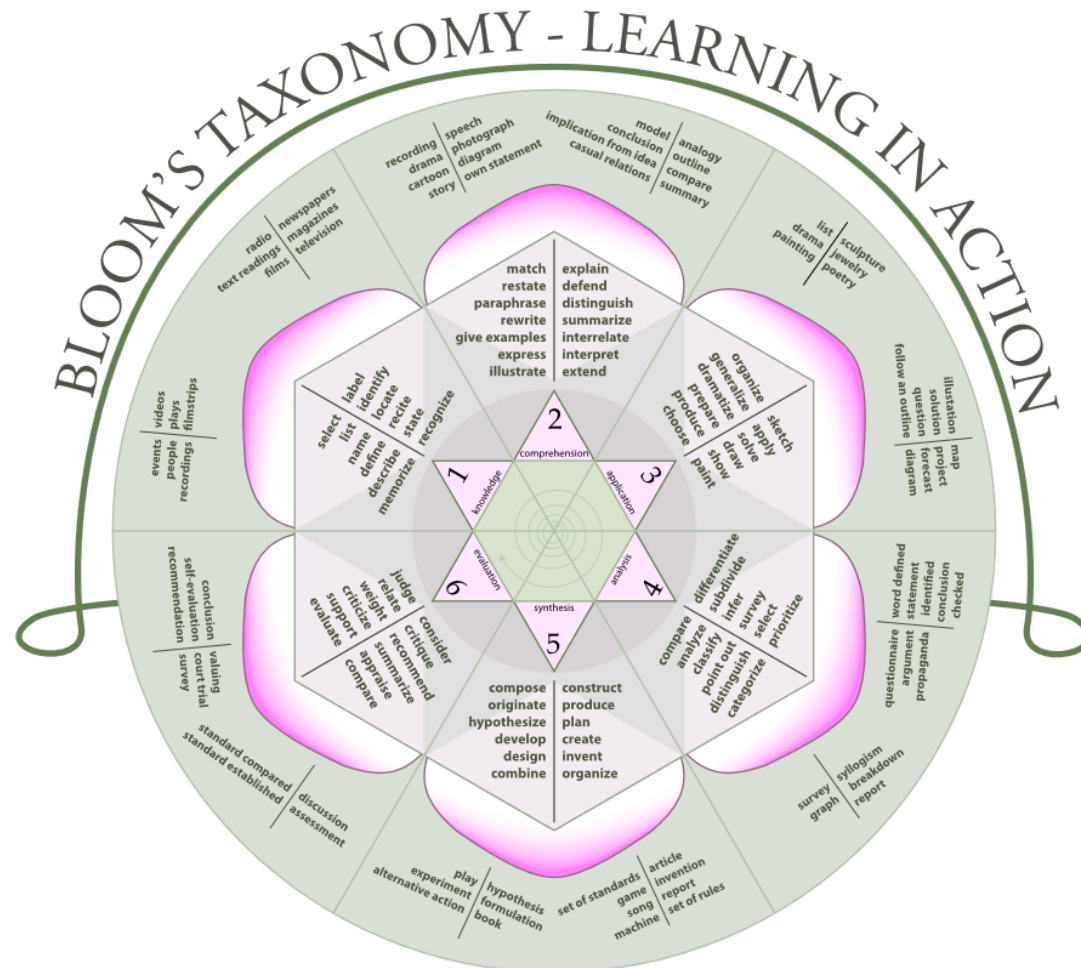
- **EUTEMPE-RX - European Training and Education for Medical Physics Experts in Radiology: focus on Euratom BSS Directive 2013/59 (August 2013 – July 2016)**
- **GENTLE - Graduate and Executive Nuclear Training and Lifelong Education: focus on synergy between industry – academia (January 2013 – December 2016)**
- **NUSHARE – Project for sharing and growing nuclear safety culture competence: focus on policy makers; regulatory authorities; industry (Jan. 2013 – Dec. 2016)**
- **PETRUS III - Program for Education, Training, Research on Underground Storage: addressing mainly the radwaste agencies (September 2013 – August 2015)**
- **ENEN-RU-II- Cooperation with Russia in Nuclear E&T and Knowledge Management: mirror project by ROSATOM and MEPhi (July 2014 – June 2017)**
- **ENETRAP-III - European Network on E&T in Radiological Protection: addressing mainly the nuclear regulatory authorities and TSOs (June 2014 – May 2018).**





European
Commission

**Educational objectives in the cognitive domain
(Learning, Teaching, and Assessing)
(pioneering work of B Bloom (1956) and L W Anderson (2001) in taxonomy)**





EUROPEAN
COMMISSION

Community research

Confucius

- Tell me and I forget
- Show me and I remember
- Involve me and I learn



Technology Goals for Generation-IV Nuclear Energy Systems

Sustainability

1. Generate energy sustainably, and promote long-term availability of nuclear fuel
2. Minimize nuclear waste and reduce the long term stewardship burden

Safety & Reliability

3. Excel in safety and reliability
4. Have a very low likelihood and degree of reactor core damage
5. Eliminate the “technical” need for offsite emergency response

Socio-Economics

6. Have a life cycle cost advantage over other energy sources
7. Have a level of financial risk comparable to other energy projects

Proliferation resistance and Physical protection

8. Be a very unattractive route for diversion or theft of weapons-usable materials, and provide increased physical protection against acts of terrorism

GIF CRITERION NO 1 - SUSTAINABILITY

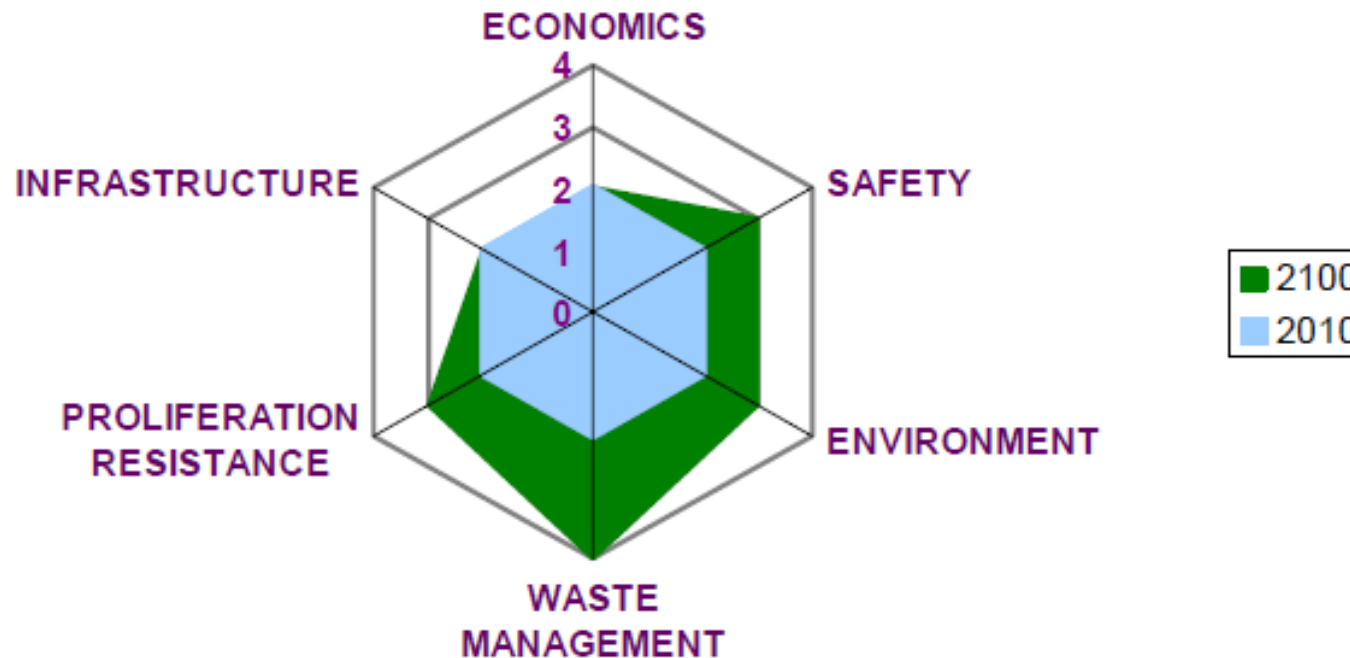
(OPTIMAL NATURAL RESOURCE UTILISATION /U-238 => Pu-239/ + MINIMISE VOLUME, HEAT, RADIO-TOXICITY OF WASTE) (1/2)

- * S-Q1: how to enhance fuel utilisation ? (is Uranium recyclable material or waste ?)
Is Plutonium an asset or a liability ? (breeding of U-238 in FRs => Pu-239)
- * S-Q2: How to minimise volume, heat and toxicity of ultimate radioactive waste ?

IAEA "International Project on Innovative Nuclear Reactors and Fuel Cycles" (INPRO) - "Assessment Methodology for Innovative Nuclear Energy Systems"

- Energy Indicators for Sustainable Development (multi-agency report, 2005)
- General rules for the application of the INPRO method for assessment (2008)
- IAEA INPRO basic principles, user requirements and criteria
 - Economic basic principle
 - Infrastructure basic principle
 - Waste management basic principle
 - Proliferation resistance basic principle
 - Physical protection basic principle
 - Environmental Basic Principle
 - Safety basic principle.

Aggregating and consolidating the results of an INPRO assessment (2/2)



Comparison of the capability of two innovative nuclear energy system (INS) operating in France in 2010 (blue) and 2100 (green) in the areas of economics, safety, environment, proliferation resistance, waste management, and infrastructure (The higher the number on the diagram, the better the performance).

Source: IAEA-TECDOC-1575 Rev. 1 / "Guidance for the Application of an Assessment Methodology for Innovative Nuclear Energy Systems" - INPRO Manual — Overview of the Methodology / Volume 1 of 9 of the Final Report of Phase 1 of the International Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO) - November 2008 - http://www-pub.iaea.org/MTCD/publications/PDF/TE_1575_web.pdf



GIF CRITERION NO 2 - SAFETY & RELIABILITY (DETERMINISTIC AND PROBABILISTIC ASSESSMENT METHODS + NUCLEAR SAFETY CULTURE) (1/2)

•SR-Q1: How safe is safe enough ? (integral approach needed)

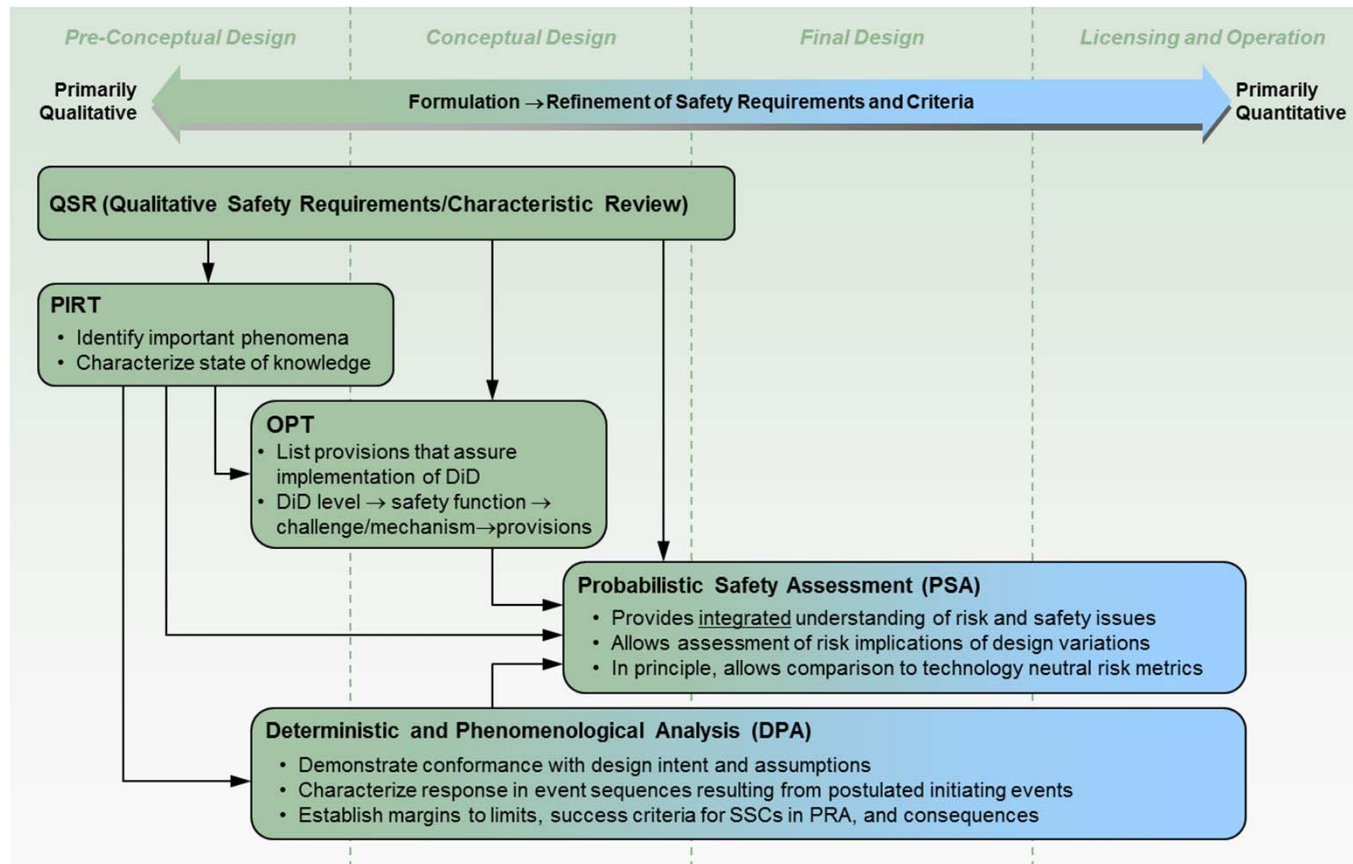
* SR-Q2: What is the impact of managerial and human factors on safety performance ?
(safety culture)

In 2011, the Risk and Safety Working Group (RSWG) of GIF produced a document that describes the methodology, called the "Integrated Safety Assessment Methodology" (ISAM) for use throughout the Gen IV technology development cycle.

This is an advanced method based on an integral Risk Informed approach in which qualitative and quantitative, deterministic and probabilistic insights are made available to support the designer throughout the design process.

The methodology is consistent with existing "Technology-Neutral" guidance documents e.g. produced by IAEA.
("Proposal for a Technology-Neutral Safety Approach for New Reactor Designs" - IAEA TECDOC 1570, 2007)

"An Integrated Safety Assessment Methodology (ISAM) for Generation IV Nuclear Systems", GIF/ Risk and Safety Working Group (RSWG)/2010/002/, June 2011 (2/2)



GIF Portal (public): https://www.gen-4.org/gif/jcms/c_9260/public

ISAM Report 2011: https://www.gen-4.org/gif/upload/docs/application/pdf/2013-09/gif_rsgw_2010_2_isamrev1_finalforeg17june2011.pdf



GIF CRITERION NO 3 - SOCIO-ECONOMICS (TOTAL SOCIAL COSTS OF ENERGY + PUBLIC ENGAGEMENT IN DECISION MAKING)

- **SE-Q1: How to evaluate the total social costs of energy technologies ?**
= private (capital + O&M + fuel) + external (system effects + accidents + avoided CO2)
- **SE-Q2: How to improve public engagement in decision making**
(energy governance = openness, participation, accountability, effectiveness, etc) ?

In 2007, the Economics Modeling Working Group (EMWG) of GIF accepted to produce a credible methodology to assess, compare, and eventually select future nuclear energy systems, taking into account a robust evaluation of their economic viability.

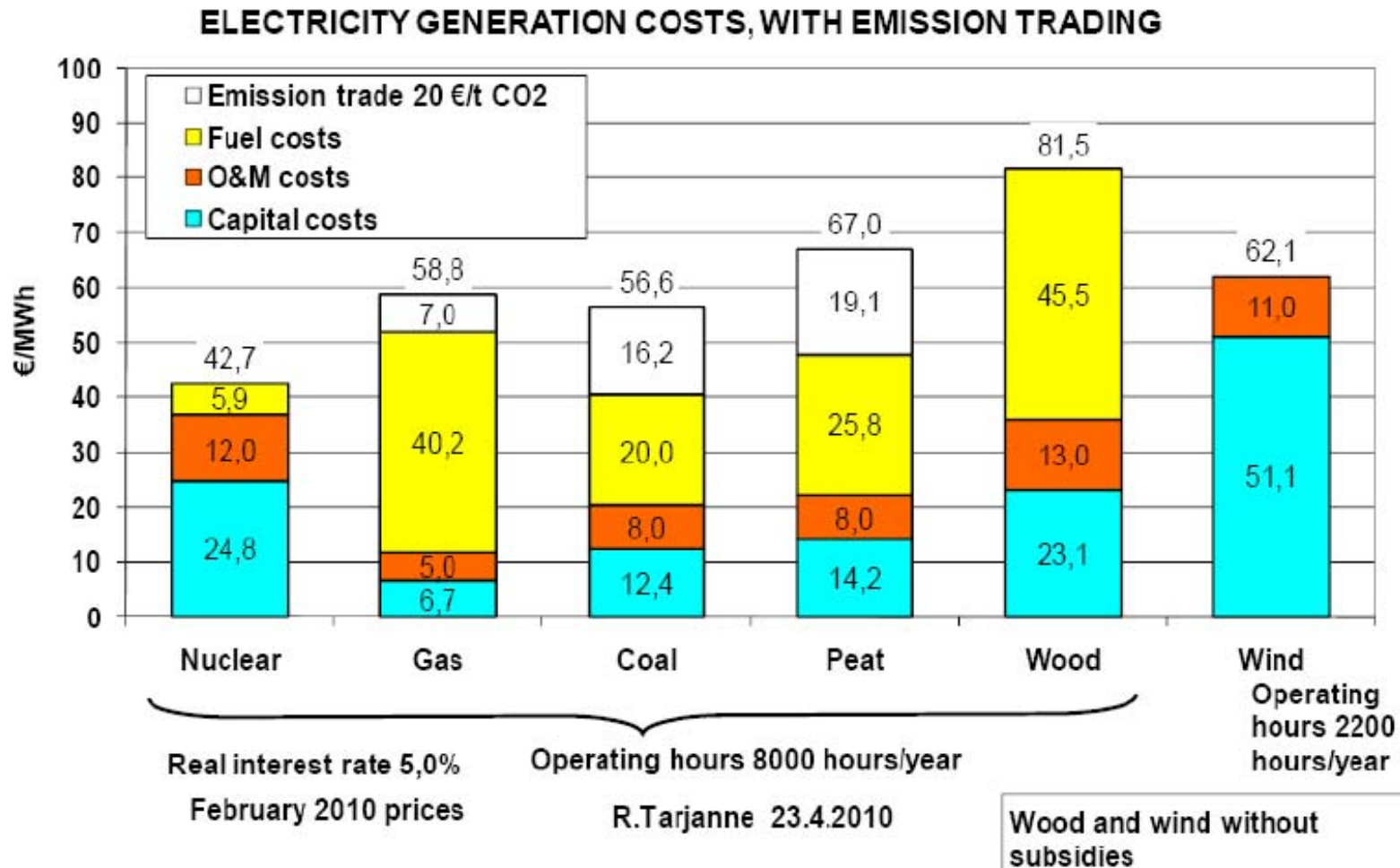
They issued "Cost Estimating Guidelines for Generation IV Nuclear Energy Systems" for economic optimization during the viability and performance phases of the Generation IV project.

Several existing nuclear-economic models were upgraded and then integrated in an integrated nuclear energy economic model (INEEM) and a software tool called G4Econs has been developed to provide a global economic assessment .

This document discusses the development of all relevant life cycle costs for Generation IV systems, including the planning, research, development, demonstration (including prototype), deployment and commercial stages.

Electricity generation costs with emission price of 20 EUR / t CO₂ (2/2)

NB: “nuclear” refers to the nth of a kind (NOAK) [different from first of a kind (FOAK)]





GIF CRITERION NO 4 - PROLIFERATION RESISTANCE AND PHYSICAL PROTECTION

- **PR-Q1: Is the nuclear proliferation risk over-estimated ?**
(weapons of mass destruction: Chemical, Biological, Radiological and Nuclear /CBRN/ threats)

- * **PR-Q2: How to combat radiological terrorism ? (related to “small weapons”)**

In 2011, the Proliferation Resistance and Physical Protection (PR&PP) Working Group of GIF, prepared a document that describes the "Evaluation methodology for PR&PP of Generation IV nuclear energy systems" (NESs) - Rev. 6 (GIF/PRPPWG/2011/003).

For a proposed nuclear energy systems (NES) design, the methodology defines a set of challenges, analyses system response to these challenges, and assesses outcomes. The results are intended for three types of users: system designers, program policy makers, and external stakeholders.

Definitions (GIF PR&PP)

"Proliferation resistance" is that characteristic of an NES that impedes the diversion or undeclared production of nuclear material or misuse of technology by the Host State seeking to acquire nuclear weapons or other nuclear explosive devices.. (IAEA)

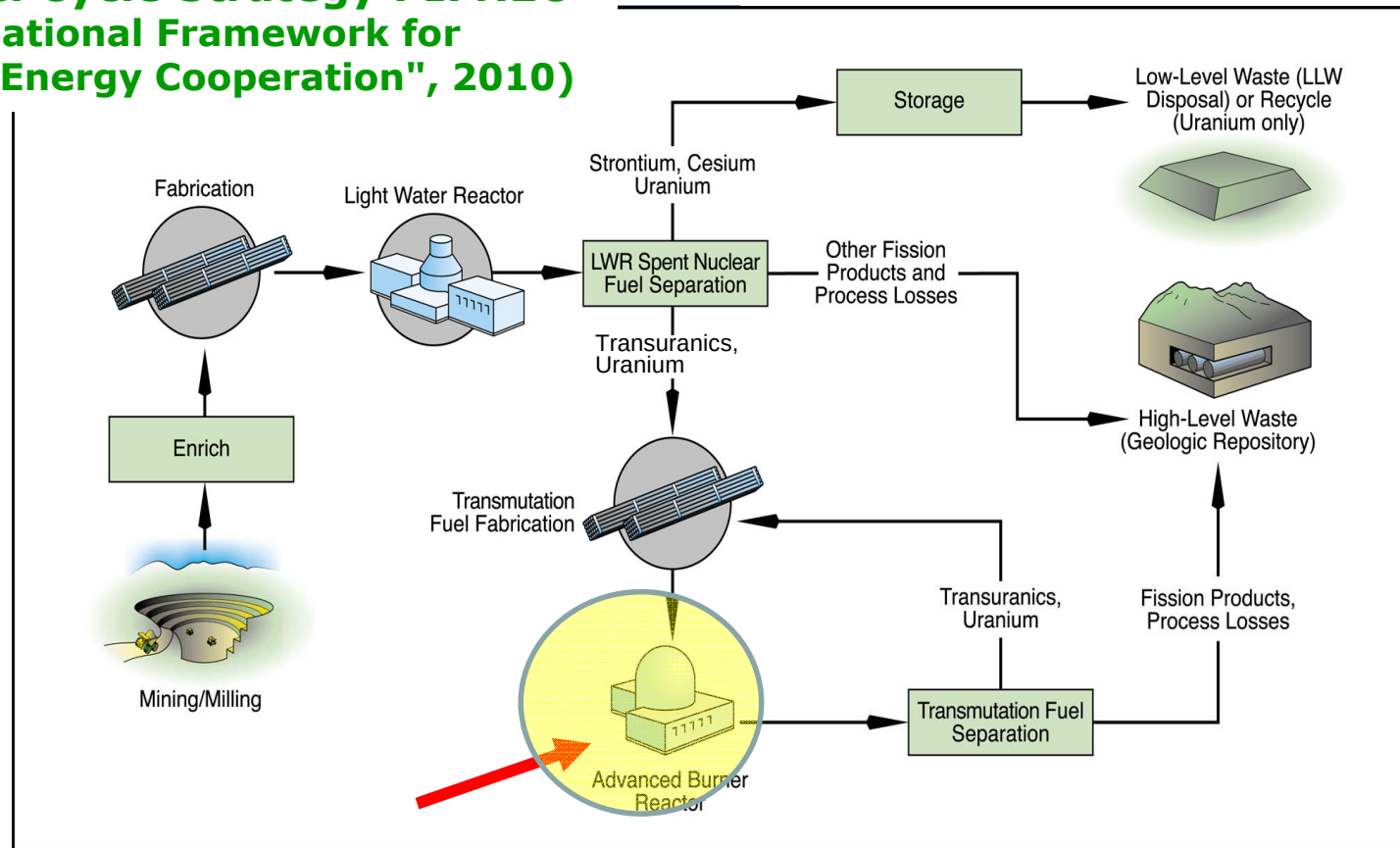
"Physical protection (robustness)" is that characteristic of an NES that impedes the theft of materials suitable for nuclear explosives or radiation dispersal devices (RDDs) and the sabotage of facilities and transportation by sub-national entities and other non-Host State adversaries."

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European
Commission

Closed Fuel Cycle Strategy : IFNEC ("International Framework for Nuclear Energy Cooperation", 2010)



- **33 Participant countries:** Argentina; Armenia; Australia; Bahrain; Bulgaria; Canada; China; Estonia; France; Germany; Ghana; Hungary; Italy; Japan; Jordan; Kazakhstan; Kenya; Republic of Korea; Kuwait; Lithuania; Morocco; Netherlands; Niger; Oman; Poland; Romania; Russian Federation; Senegal; Slovenia; Ukraine; United Arab Emirates (U.A.E.); United Kingdom; U.S.A.
- **4 Observer Organizations:** IAEA, GIF, Euratom, OECD-NEA
- **31 Observer countries:** Algeria, Bahrain, Bangladesh, Belgium, Brazil, Chile, Czech Republic, Egypt, Finland, Georgia, Greece, Indonesia, Latvia, Malaysia, Mexico, Mongolia, Nigeria, Philippines, Qatar, Saudi Arabia, Singapore, Slovakia, South Africa, Spain, Sweden, Switzerland, Tanzania, Tunisia, Turkey, Uganda, Vietnam





European Sustainable Nuclear Industrial Initiative

Four ESNII projects:

ASTRID (sodium), MYRRHA (lead-bismuth), ALFRED (lead), ALLEGRO (helium)

"The European Sustainable Nuclear Industrial Initiative, ESNII, is one pillar of the SNETP, a platform dedicated to nuclear energy technologies. ESNII is devoted to fast neutron reactors with closed fuel cycles, which represent a sustainable version of nuclear energy systems thanks to a better use of the uranium resource through plutonium breeding and recycling.

Presently, ESNII includes the study of three types of technologies that could lead to future industrial deployment: sodium-cooled fast reactors (SFR), lead-cooled fast reactors (LFR), and gas-cooled fast reactors (GFR), thanks to different domestic projects of construction of demonstration plants promoted by some European countries: ASTRID a SFR in France, ALFRED a LFR in Romania, and ALLEGRO a GFR in central Europe (Czech Republic, Slovakia, Hungary, Poland). "

Source: "ESNII in the context of Generation IV: ESNII+, SARGEN_IV, CP-ESFR, LEADER, GoFastR", by Pascal Anzieu 1, Carole Wahide 1, Daniel Blanc 2, Alfredo Vasile 1, Alessandro Alemberti 3, Christian Poette 1 (1 CEA; DEN, France, 2 IRSN, France; 3 Ansaldo Nucleare, Italy)

FISA 2013 - 8th European conference on Euratom research and training in reactor systems - 14-17 October 2013 - Vilnius, Lithuania - Co-organised by the European Commission and the Lithuanian Presidency of the EU

- http://cordis.europa.eu/fp7/euratom-fission/fisa-2013_en.html



European Industrial Initiatives (EIIs) Implementation Plans

The SET-Plan High Level Steering Group asked all European Industrial Initiatives (EIIs) to develop an Implementation Plan. The implementation plans cover the first 3-year period 2013-2015 and are revised every year, thus becoming rolling programmes. These documents therefore outline the actions that should be launched in the first phase of the Technology Roadmap. Further to that, it provides an indication of relevant key performance indicators (KPIs), an analysis of the EU added value of each project as well as an indication of relevant budgets and available funding schemes (EU or national).

The following elements are included in the EII Implementation Plans:

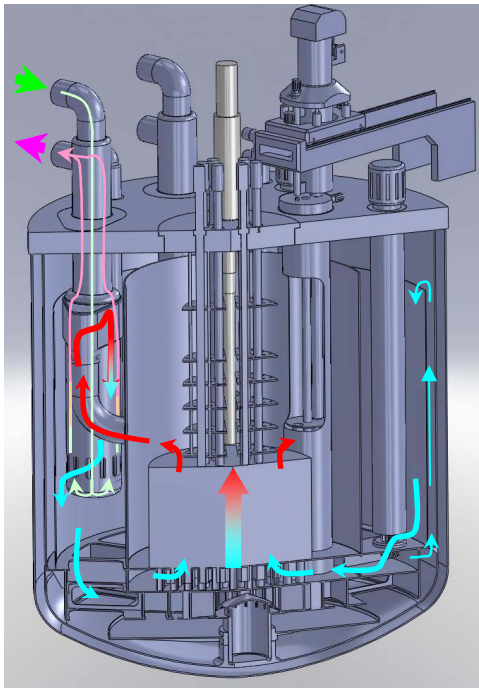
- Taking into account the present technology, and projects financed by the EU and Member States, identify the priority actions to move towards the objective / milestone;
- Estimate the budgets, the European added-value of the actions and the risk involved by the different actions;
- Identify the existing available public and private financial sources;
- Identify the needed actors and potential countries to finance the actions;
- Define Key Performance Indicators;
- Estimate the contribution of the identified priority actions towards the 2020 objectives/milestones;
- Identify possible links with joint programmes of the EERA.

Source <http://setis.ec.europa.eu/set-plan-implementation/european-industrial-initiatives-eiis/eii-implementation-plans>

ESNII-1 : ASTRID Project (1/2)



Advanced Sodium Technological Reactor for Industrial Demonstration (600 MWe)



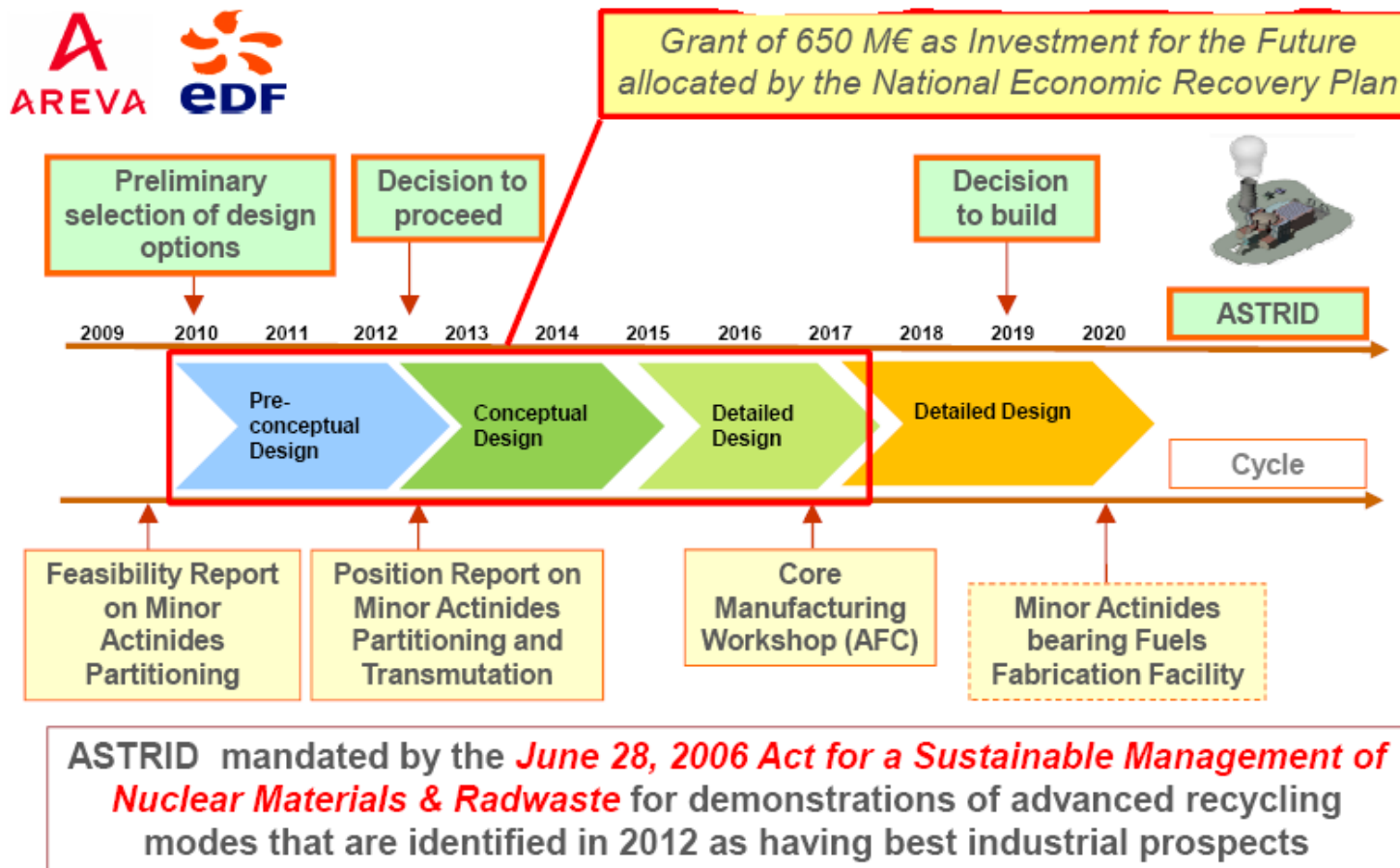
Pre-conceptual study by AREVA

- French government (CEA) led project : national loan 650 M€
- Industry participation
 - ➔ EDF operations feedback from previous reactors, utility requirements and design, safety
 - ➔ AREVA : from pre-conceptual to detailed design studies for the Nuclear Steam Supply System
 - ➔ Other industrial partners are invited by CEA
- Current project phase
 - ➔ design choices to move from pre-conceptual design to conceptual design coupled to ongoing R&D and
 - ➔ discuss with the regulator the safety orientations (2012)
 - ➔ FP7 support (CP-ESFR) with important contribution from industrial partners

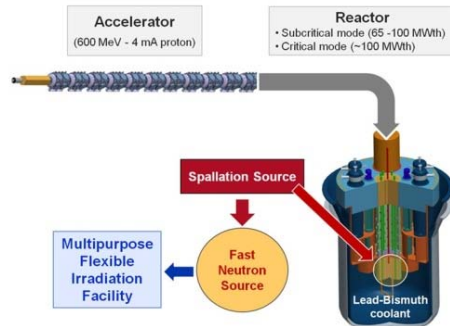
ESNII-1 : ASTRID Project (2/2)



TIME LINE FOR THE NEXT GENERATION SODIUM FAST REACTOR



ESNII-2: MYRRHA Project (1/2)



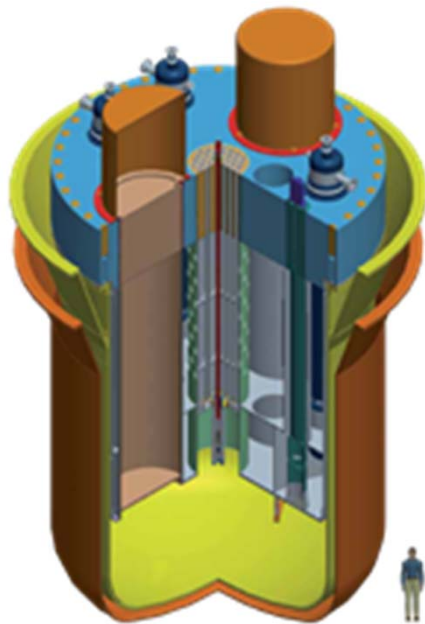
LFR Lead-Bi cooled Fast Reactor (*Multipurpose hYbrid Research Reactor for High-Tech Applications*)

Develop a LFR system with equal safety and competitiveness, and with comparable uranium utilisation and reduction of waste burden, to SFR

Design and obtain a license for the construction of a European Technology Pilot Plan (ETPP) in the range 50-100 MWth, with full operation in 2023;

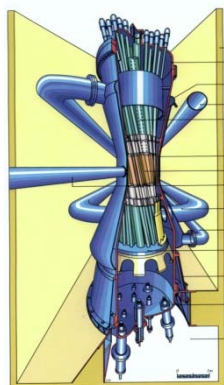
MYRRHA will be:

- **A hybrid system combining a high energy proton linear accelerator and a lead-alloy cooled fast spectrum irradiation facility**
- Unique large facility in the world for demonstration of the accelerator driven system **(ADS) → R&D in spent fuel partitioning & transmutation**
- Site selected (Mol, Belgium)
- FP7 support (CDT, MAX, FREYA, MAXSIMA, etc) with important contribution from industrial partners



Pre-conceptual study

ESNII-2: MYRRHA Project (2/2)



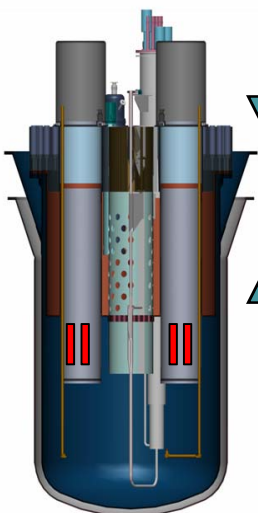
1962

BR2

Material
Testing Reactor
(fission)

Fuel testing
For LWR
& GEN II/GEN III

Irradiation Services:
- Medical RI
- Silicium doping
- Others



2020

MYRRHA

Fast Neutron
Material
Testing Reactor
(fission + fusion)

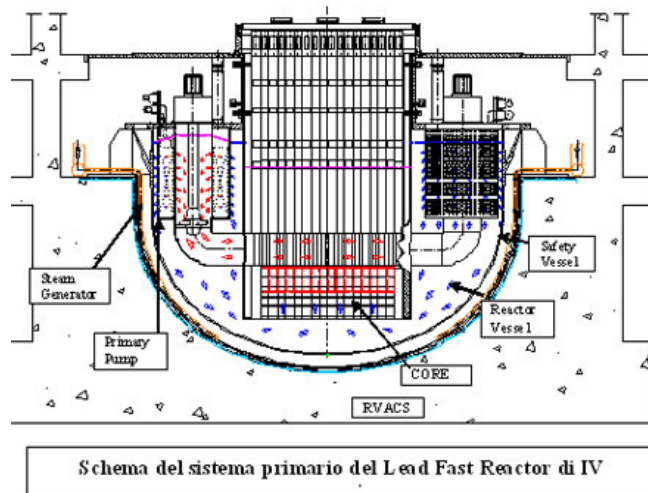
ADS-Demo
+
P&T testing
(Partitioning &
Transmutation)

Fuel testing
For LFR GEN IV

Irradiation Services:
- Medical RI
- Silicium doping
- Others

LFR GEN IV technology demonstration

Advanced Lead cooled Fast Reactor (LFR)



Pre-conceptual study

FP7 support (LEADER, ARCADIA)
with important contribution from
industrial partners (ANSALDO)

- Design and obtain a license for the construction between 2015 and 2025 of a LFR Demonstrator ALFRED, with a power around 100 MWe that will allow connection to the grid;

- Demonstrate safety and waste minimisation performance by operational feedback and prepare the design and construction of an LFR Prototype of the order of 600MWe

- 2011 Central European ALFRED Hosting: Romanian proposal (to be built at ICN's facility in Mioveni, near Pitesti in southern Romania)

=> Long-term plan of ALFRED includes 2phases:

- First step (2015-2020): experimental infrastructures, experiments and design with a strong effort in technology development.

- Second step (2020-25): construction of ALFRED (the unit could start operating in 2026).



ALFRED - Advanced Lead Fast Reactor European Demonstrator

A consortium has been formally set up in December 2013 for the construction of a demonstration lead-cooled fast reactor in Romania.

The conceptual design of the Alfred reactor and the integrated project were led by Ansaldo Nucleare under Euratom FP-7.

A memorandum of technical cooperation (MoA) has been signed between Italy's National Agency for New Technologies, Energy and the Environment (ENEA) and Ansaldo Nucleare, as well as Romania's Nuclear Research Institute (Institutul de Cercetari Nucleare, RATEN-ICN), to implement construction of Alfred.

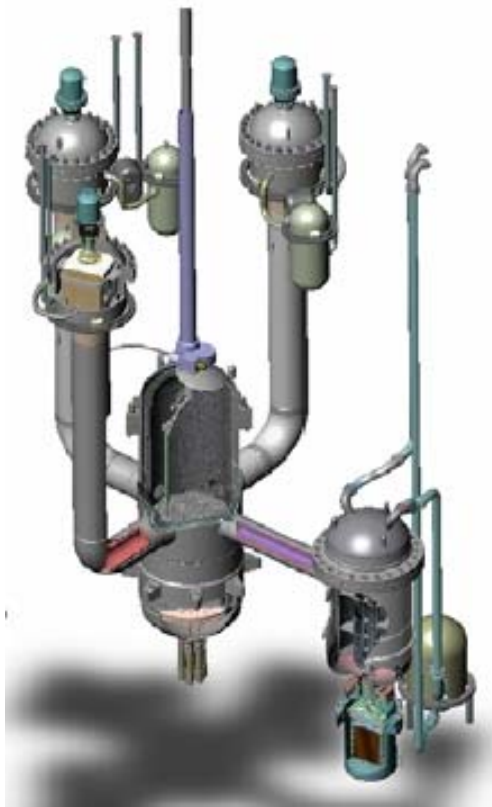
The group is known as the "Fostering Alfred Construction" (Falcon) consortium and has recently acquired in November 2014 a new partner, the CV-REZ research center located close to Prague (Czech Republic). The consortium aims to obtain finance for the reactor through EU funds allocated to R&D infrastructure in new member states administered by the European Investment Bank (Reformed Cohesion policy).

The reference cost of the construction is put at 1.0 billion while technology developments, experimental facilities and associated work has been preliminary evaluated at about half a billion.

ESNII-4: ALLEGRO (1/2)



GFR Advanced Gas cooled Fast Reactor



Pre-conceptual study

Longer term alternative technology of fast spectrum reactors for sustainability

- *Able to deliver high temperature heat for industrial processes (H₂ production)*
- *After an R&D program to consolidate preconceptual design options, ALLEGRO demonstrator (10-75 MWt) to be launched in 2015*
- *2010 Central European ALLEGRO Consortium: Czech Republic, Slovakia, Hungary*
- *Ongoing process for Site selection and site permit (Eastern Europe)*

- FP7 support (GoFASTR, ALLIANCE) with important contribution from industrial partners



ALLEGRO demonstrator with helium gas (prepared by V4G4 Centre of Excellence composed of Slovak Republic, Czech Republic, Hungary and Poland)

The ALLEGRO project started in 2010 by signing a MoU by UJV, VUJE and AEKI/EK, with an essential support of CEA (NCBJ joined in 2012): the aim is to start licensing, construction and operational phases

- The new legal entity “V4G4 Centre of Excellence” (*Visegrad 4 countries for Generation 4 reactors*) was introduced to the public at the Hungarian Academy of Sciences on July 18, 2013
- New strategy for ALLEGRO reactor since April 2014: e.g. reduce ALLEGRO power from 75 MWth to circa 10 MWth and find optimum core configuration; increase main blowers inertia ; as a consequence of potential fuel supply difficulties, use UO2 pellets in AIM1 cladding instead of MOX pellets.

Within the ALLEGRO project the tasks and responsibilities are shared as follows:

- *Hungary (MTA Centre for Energy Research /MTA EK/ www.energia.mta.hu) will investigate the closed fuel cycle - safety related activities will be financed from a new National Nuclear Energy Research Program*
- *the Czech party (ÚJV Řež, a.s. / www.ujv.cz) for testing high-temperature gas technologies*
- *the Slovakian party (VUJE, a. s. / www.vuje.sk) for planning and security testing - the preparatory works for designing and establishing a non-nuclear mock-up of ALLEGRO are financed in 2014-2015*
- *the Polish party (NCBJ / www.ncbj.gov.pl) will be responsible for the material testing.*

The overall long-term plan of ALLEGRO includes four phases:

- Preliminary phase (2010 - 2013): creation of the V4G4 Centre of Excellence
- Preparatory phase (2013-2018): creation of the ALLEGRO consortium
- Licensing and construction phase (2018 - 2027): unit could start operating in 2027
- Operation phase (2028 – 2040)