Towards a sustainable nuclear electricity generation

The role of fast reactors

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Question: under which conditions will nuclear energy remain "sustainable" ("durable") in the long term?

"Sustainability" criteria considered

- Depletion rate of natural resources
- Impact on the environment
- Risk factors
- Public acceptance
- Competitivity & energy security

European Commission

Depletion rate of natural resources

Uranium Resources (as of 2007)

Identified (Reasonably Assured + Inferred) Resources (in 1000 tonnes)

	< US $ 40 / kgU	< US $ 80 kgU	< US $ 130 / kgU
World	~ 3 000	~ 4 500	~ 5 500
Australia	1 196	1 216	1 243
Kazakhstan	517	752	817
Russia	84	495	546
South Africa	235	343	423
Canada	352	423	435
USA	NA	99	>> 339
Brazil	140	231	278
Namibia	116	230	275
Niger	34	75	274
Uzbekistan	86	86	111

IAEA

- >60,000 tU extracted each year
- 100 years identified reserves (current reactor fleet)
- 300+ years with speculative resources (<260$/kg)
- Reduced reserves with nuclear expansion (from 2.8 in 2007 to 5 TWh in 2050)
- U reserves x 60 with fast reactors
- Thorium reserves (needs breeding)

Depletion of natural resources in all cases
Pu breeding will increase the resources availability

Impact on the environment

- Negligible greenhouse gases generation
- Small infrastructure footprint (but mining)
- Negligible radiation in the environment in normal operation
- Fuel cycle waste (extraction, enrichment, spent fuel)
- Industrial facilities exist for LLW handling and storage
- HLW (spent fuel, vitrified waste) in geological disposal
- Reduction of HLW volumes (footprint) and radiotoxicity through plutonium recycling, minor actinides transmutation

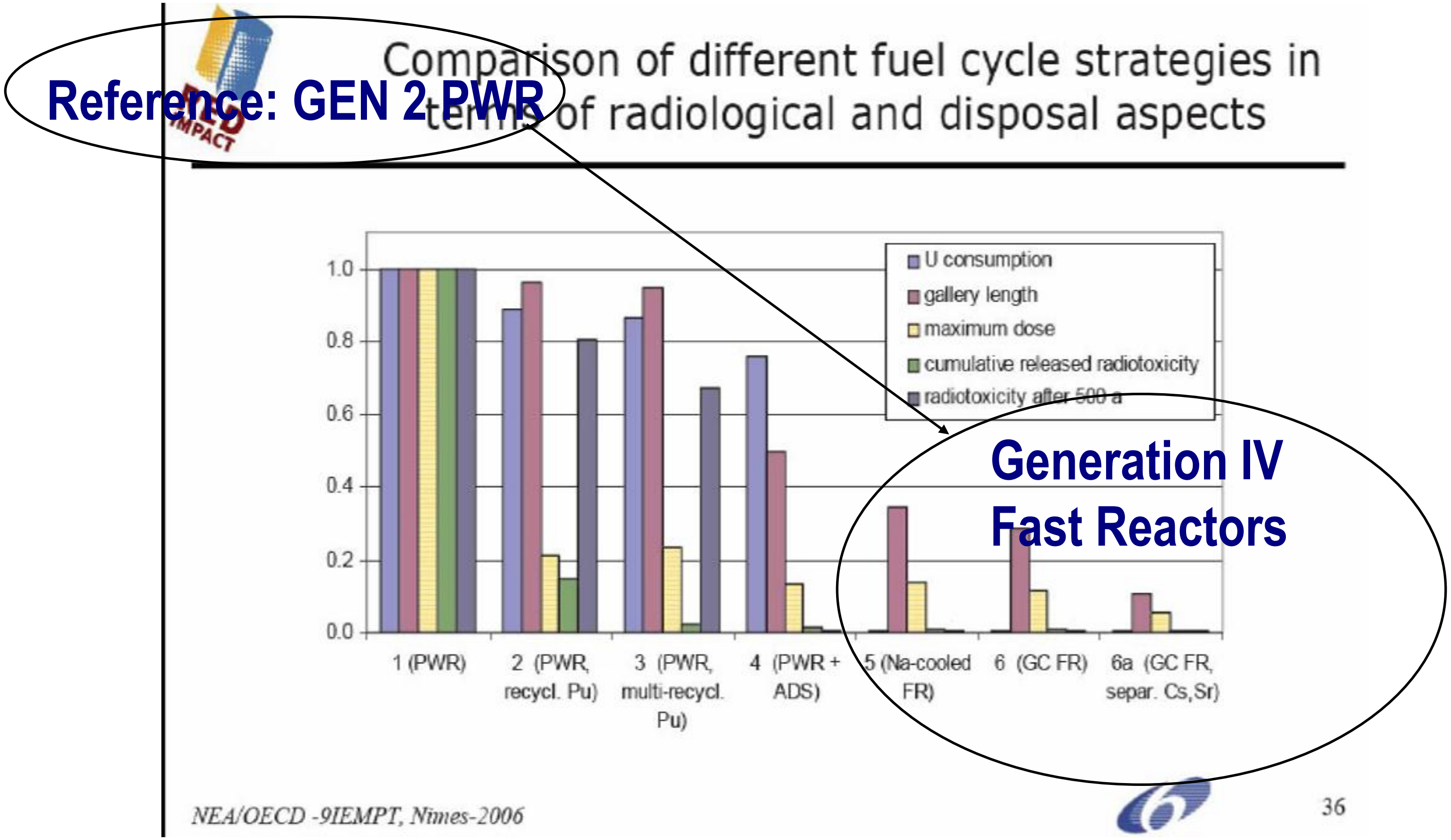
Low impact on the environment in normal operation
HLW geological disposal to be implemented
Fast reactors decrease HLW volumes and radio-toxicity
Specific case of the ADS as actinide burner

Deep Geological Disposal:
Status of European research and implementation projects

		Decision	Location	Operation	Research	Rock type
BE	ONDRAF		ND	ND	HADES-Mol (Clay)	ND
FI	POSIVA	2001	Olkiluoto	2020	Onkalo (Rock)	Cristalline bedrock
FR	ANDRA	2006 (Law)	Not official	2025	Bure (Clay)	Clay (NO)
DE	BFS	ND	ND	ND	Gorleben (Salt)	ND
SU	SKB	2002	Forsmark (2006)	>2020	Aspö Hard Rock	Cristalline bedrock
CH	NAGRA	From 2008	ND	ND	Mont Terri (Clay) Grimsel (Granite)	ND

Source: Company websites, Sept. 2011

Use of Fast Reactors: strong reduction of geological repository volumes and dose, U consumption, waste raditoxicity as compared to the reference LWRs



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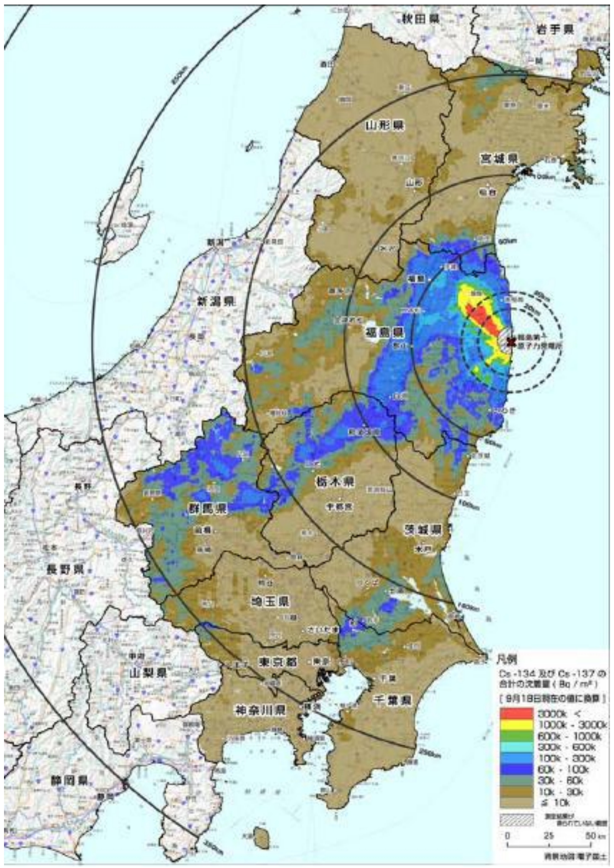
Risk factors (1)

Fukushima area: Ground Surface Deposition of Cs-134 and Cs-137 (Bq/m2) at Sep. 18, 2011



Reactor and fuel cycle safety

- Very low accident probability with severe consequences
- Pollution of the environment in case of accident
- Safety measures and criteria re-evaluation after Fukushima
- Continuous safety improvements: external releases must be excluded
- Highest standards required internationally

Highest safety criteria required (LWRs and FRs)

Risk factors (2)

MOX Plant in construction (Savannah River)

Proliferation resistance and physical protection

- International control system in place (enrichment, reprocessing)
- Protection of infrastructures at national level, from design phase on
- Weapon-grade HEU and Pu reduction programmes

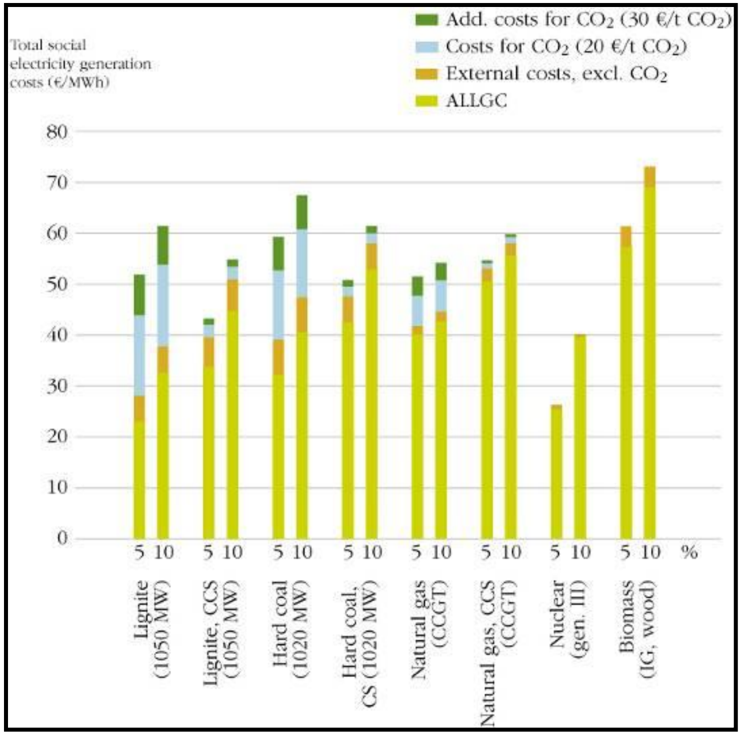
Improving PRPP through controls and design measures
Fast reactors: U enrichment vs Pu cycle
Proliferation risks mitigated by minor actinides

Public acceptance

- In todays democraties, public acceptance is a main prerequisite for nuclear development
- Since a zero-risk industry does not exist, the risks and benefits should be explained and balanced
- Full transparency helps (re-)gaining confidence; however, transparency and honesty should also be expressed by opponents
- Importance of international cooperations (IAEA); indeed nuclear power plants are distributed worldwide and boarders are ineffective against contamination!
- Role of education

No sustainability without public acceptance

Competitivity and energy security



- Nuclear energy is competitive
- But investment risks are high and need to be controlable (rules must be clear)
- Low kWh cost dependence on fuel price (as compared with fossile fuels)
- Broad international distribution of uranium supplies

Nuclear energy will remain competitive. This statement remains to be demonstrated for fast reactors and their fuel cycle

The way towards sustainability

1. Resources: very sustainable (durable), mainly with fast reactors (FR>LWR)

2. Impact on the environment: low in normal operation; geological disposal to be implemented; HLW volumes and radio-toxicity reduction with fast reactors (FR>LWR)

3. Risks factors and public acceptance: nuclear will be sustainable only if major risks to the public (external release) are excluded (LWR=FR?)

4. Competitiveness: nuclear will remain sustainable. The possible advantage of FR over LWR remains to be demonstrated (FR<LWR?)