Management of spent nuclear fuel and its waste

Joint Report by the
European Commission's Joint Research Centre and the
European Academies' Science Advisory Council

Presentation by:

Jean-Paul Glatz, Pierre Kockerols,
European Commission, Joint Research Centre

European Academies easac Science Advisory Council

European Commission

EC-JRC

The European Commission Joint Research Centre

is the scientific and technical arm of the European Commission and provides the scientific advice and technical know-how to support a wide range of EU policies.

EASAC

The European Academies' Science Advisory Council

is formed by the national science academies of the EU Member States to enable them to collaborate with each other in providing advice to European policy-makers.

Aim of the report:

To inform policy makers

(in a concise and comprehensive way)

on important issues to take into consideration in developing national programmes for the future management of spent fuel and the waste generated by fuel treatment

European Academies easac Science Advisory Council

European Commission

Context of the report:

European Directive 2011/70/EURATOM

- *establishment of a national policy and framework*
- *establishment of national programmes*
    - *necessity to take related decisions*
- *follow-up the progress of the programme*

European Academies easac Science Advisory Council

European Commission

A national policy in this area is beneficial for:

- ✓ *continuity in technological developments and related investments*
- ✓ *consolidation of knowledge and competence*
- ✓ *facilitation of public dialogue and involvement*

European Academies easac Science Advisory Council

European Commission

Approach for elaboration of the report

elaboration of draft report

1st review by experts

expert meeting
(26 experts)

re-drafted report

2nd review by experts

final review by EC-JRC and EASAC Academies

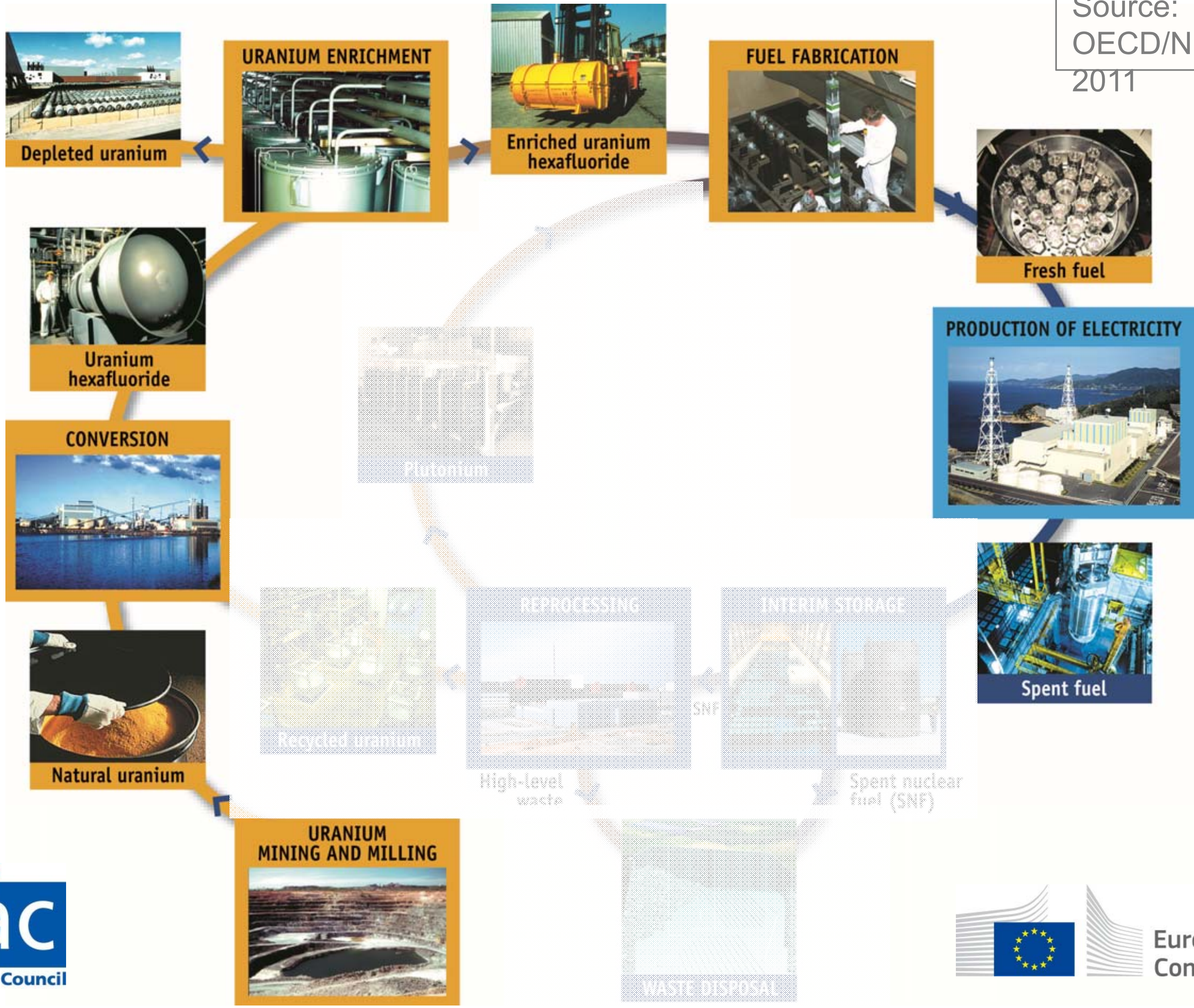
final report

European Academies easac Science Advisory Council

European Commission

Technological Options for Nuclear Fuel

Source: OECD/NEA 2011



European Academies easac Science Advisory Council

European Commission

Technological Options for Nuclear Fuel

OPEN fuel cycle

interim storage

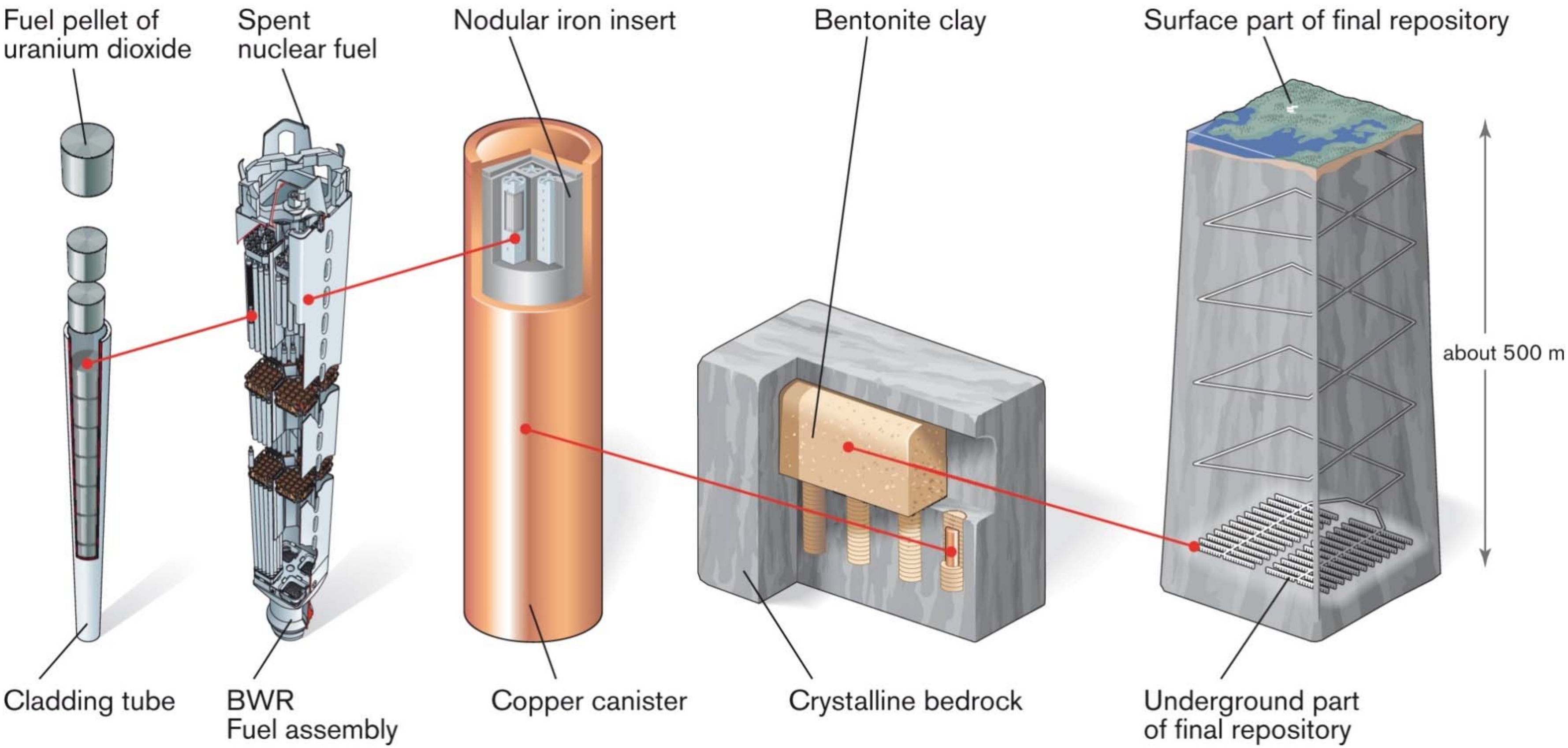
encapsulation

disposal

European Academies easac Science Advisory Council

European Commission

Technological Options for Nuclear Fuel



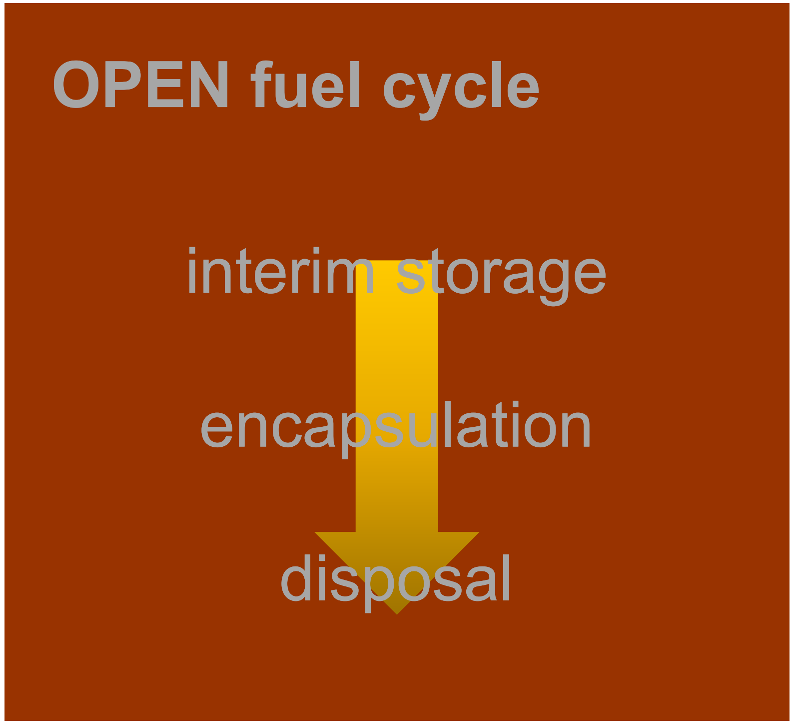
OPEN CYCLE

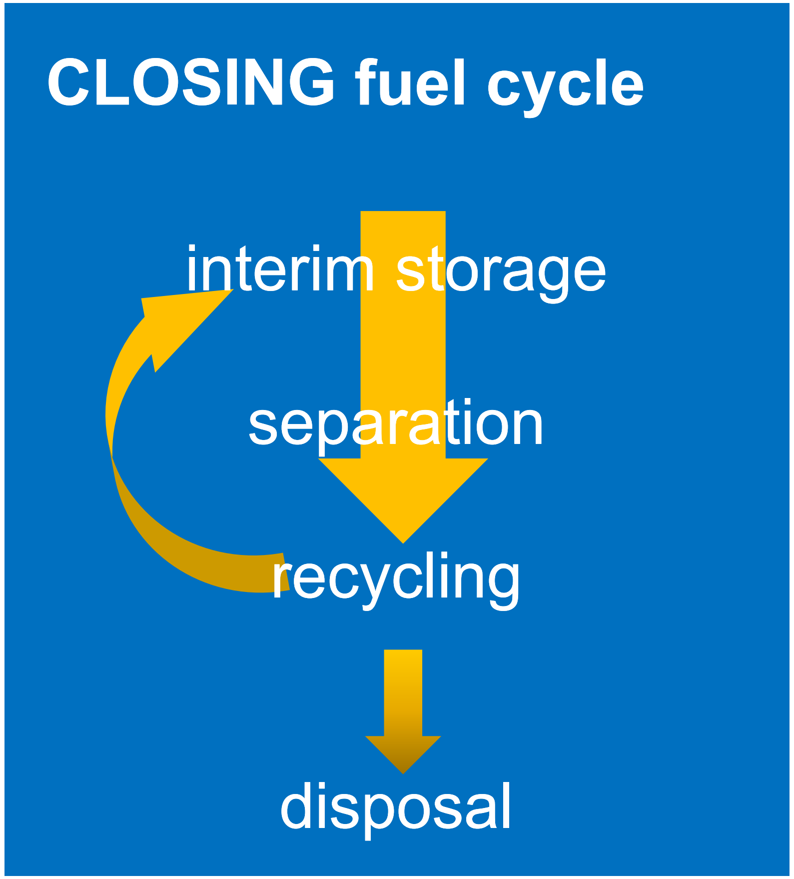
Source: SKB, SE

European Academies easac Science Advisory Council

European Commission

Technological Options for Nuclear Fuel



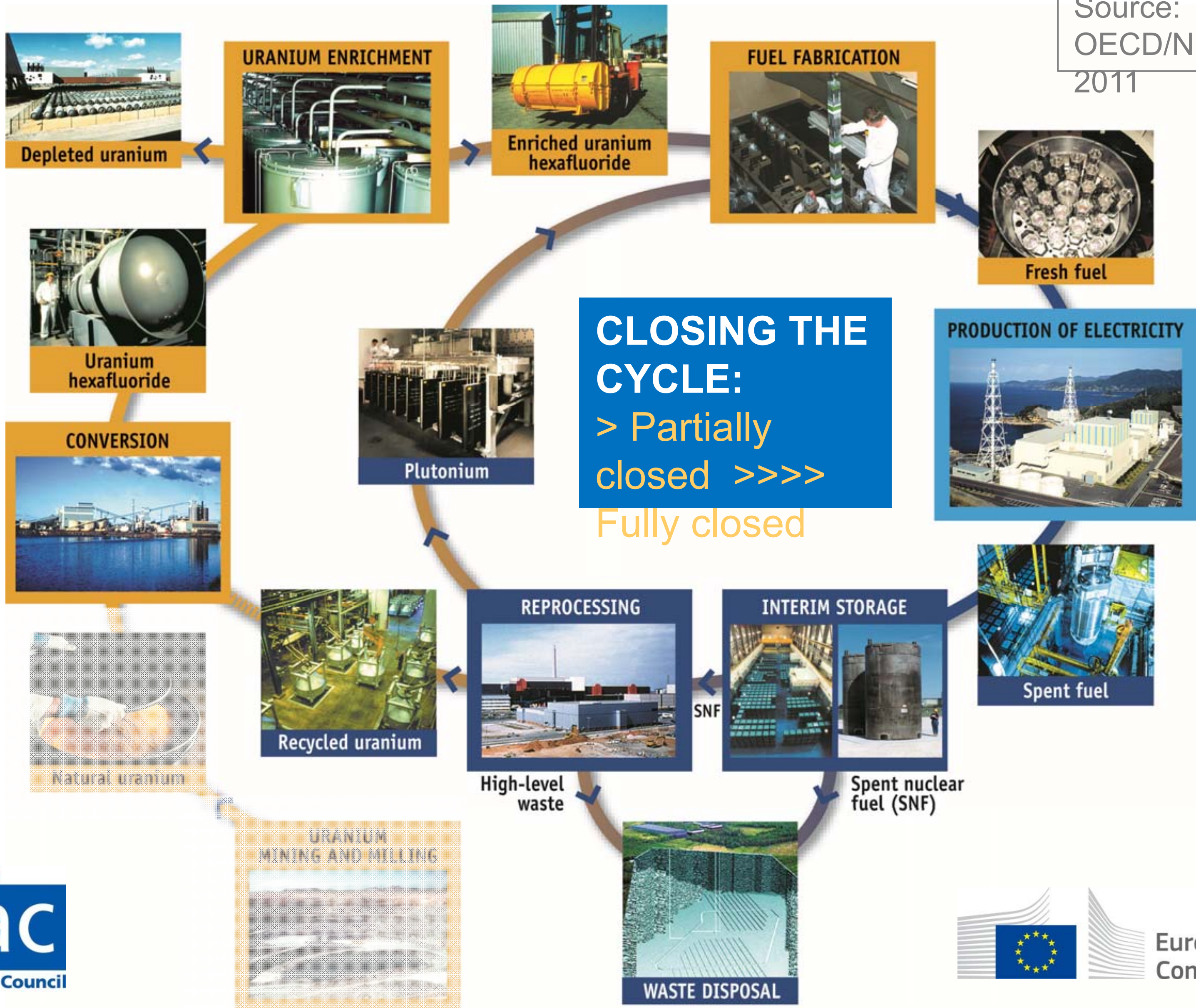


European Academies easac Science Advisory Council

European Commission

Technological Options for Nuclear Fuel

Source: OECD/NEA 2011

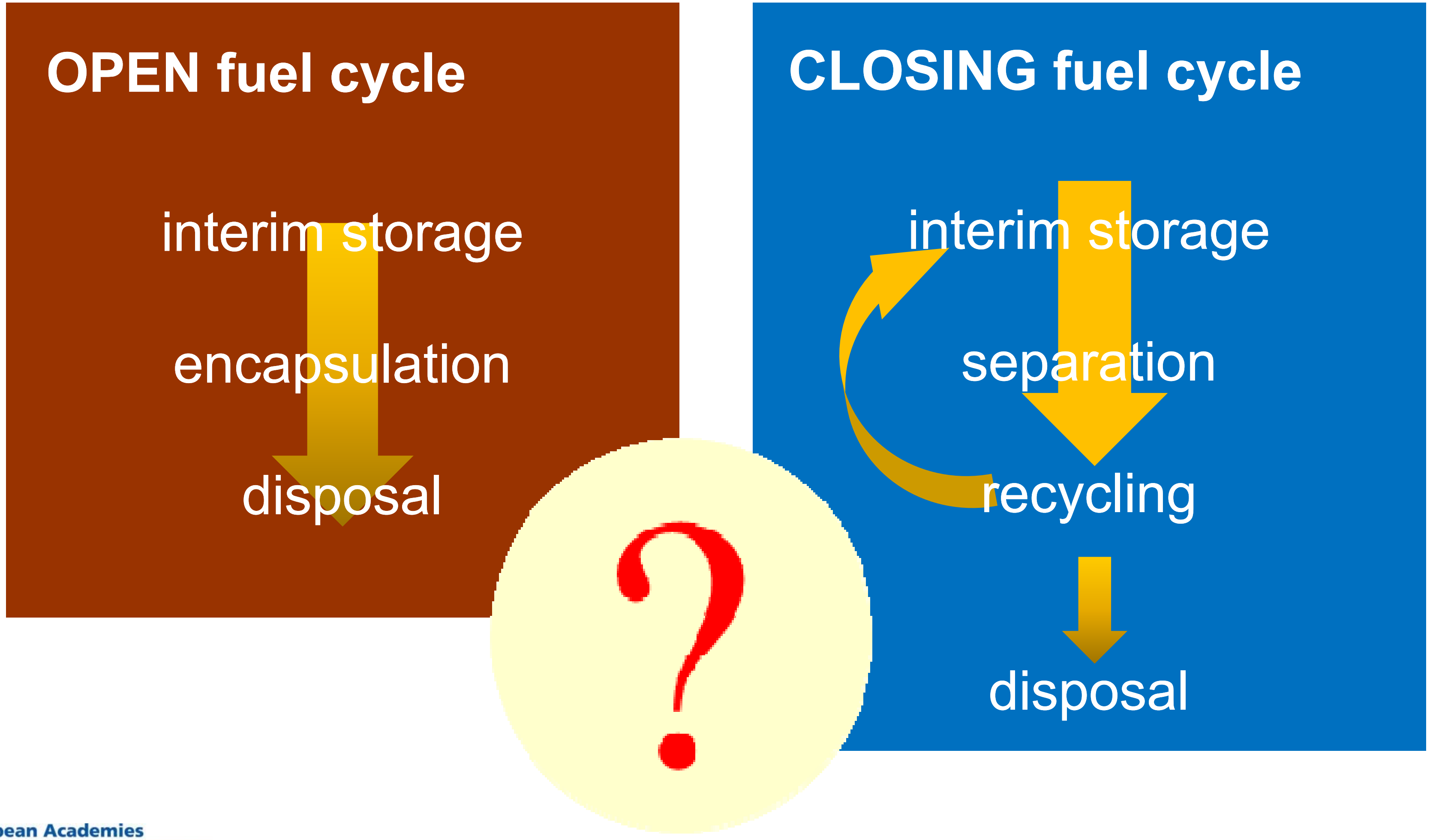


CLOSING THE CYCLE:
> Partially closed >>>> Fully closed

European Academies easac Science Advisory Council

European Commission

Technological Options for Nuclear Fuel



European Academies easac Science Advisory Council

European Commission

Timeframes involved (example of open fuel cycle)

Type of fuel cycle	Phase or activity	Approximate minimum timeframe	*Possible overlap*
	Siting, construction, commissioning of first reactor	**10 years**	*For new programmes: ideally overlapping with disposal programme*
Open fuel cycle	Operation	First reactor: **40-60 years**	*Ideally overlapping with disposal programme*
	Spent fuel storage	**20-60 years** after final removal from core, i.e. last fuel used becoming spent fuel	*Until the last reactor is shut down: overlap with reactor operation*
	Siting and construction of spent fuel repository	**30-40 years**	*Can overlap with reactor operation and spent fuel storage; should at least overlap with end-phase of storage*
	Operation of spent fuel repository	Minimum **30 – 60 years**	
Total estimated timeframe		**Minimum some 100 years**	

European Academies easac Science Advisory Council

European Commission

Decision Factors
in the Fuel Cycle Choice

- 'SUSTAINABILTY' of the option:
    - use of natural resources: uranium consumption
    - complexity and maturity of the fuel handling and treatment technology
    - operation of waste repository
- SAFETY provisions
- nuclear SECURITY and PROLIFERATION resistance
- ECONOMIC factors

European Academies easac Science Advisory Council

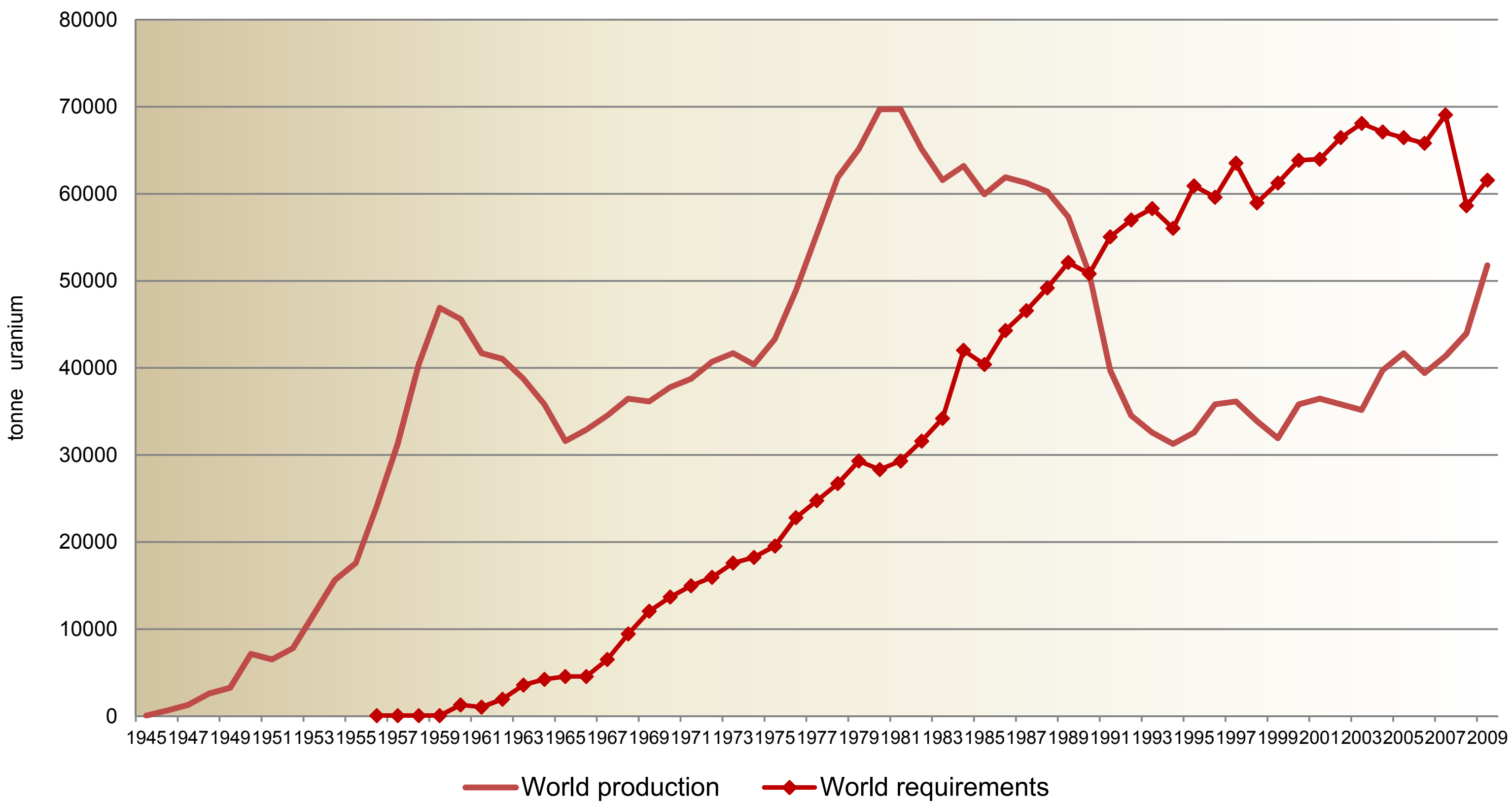
European Commission

Summary - *Sustainability* Issues

SUSTAINABILITY RELATIVE TO AVAILABILITY AND USE OF NATURAL RESOURCES			
	OPEN CYCLE	CLOSING THE CYCLE	
		PARTIALLY CLOSED CYCLE	FULLY CLOSED CYCLE
consumption and availability of uranium	- inefficient use of the uranium; availability for 100 years reactor operation	+ uranium consumption reduced by 10-20% ensuring some longer availability of resources for reactor operation	+ uranium consumption reduced by a factor 50 to 100 ensuring more than 5000 years of reactor operation

Summary - *Sustainability* Issues

evolution world uranium market



Source: OECD/NEA

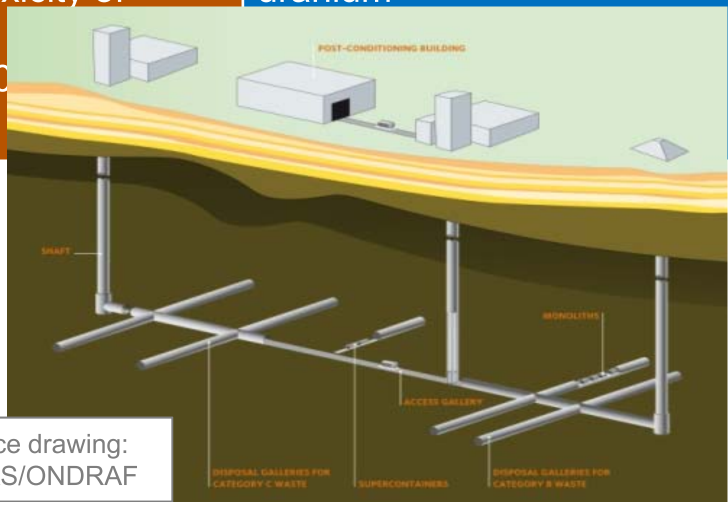
Summary - *Sustainability* Issues

SUSTAINABILITY OF THE SPENT FUEL HANDLING AND TREATMENT PROCESS

	OPEN CYCLE	CLOSING THE CYCLE	
		PARTIALLY CLOSED CYCLE	FULLY CLOSED CYCLE
degree of complexity of techniques	+ relatively 'basic' techniques for interim storage of spent fuel and encapsulation	- more complex techniques for reprocessing, vitrification and fabrication of recycled fuel	- complexity increased by use of fast reactor system
maturity of the techniques, developments required	+ experience with interim storage - developments for long term storage - encapsulation at the design phase	+ experience with reprocessing, vitrification and fabrication of recycled fuel - developments for further reprocessing of spent recycled fuel	- limited experience with fast neutron reactors, reactors in design phase - developments for the spent fuel partitioning and transmutation techniques

Summary - *Sustainability* Issues

SUSTAINABILITY RELATIVE TO WASTE DISPOSAL			
	OPEN CYCLE	**CLOSING THE CYCLE** PARTIALLY CLOSED CYCLE	FULLY CLOSED CYCLE
repository footprint	- repository footprint of few square km	- marginal reduction of the repository footprint	+ reduction of the footprint by 40%, or by 70% in the case of partitioning & transmutation
required longevity of the repository	- very long time scale to reach radiotoxicity of natural (200 00	- very long time scale to reach radiotoxicity of natural uranium	+ reduced time scale to reach radiotoxicity of natural uranium (30 000 years, or 400 years in the case of partitioning & transmutation.)



Source drawing: NIRAS/ONDRAF (B)

European Academies easac Science Advisory Council

European Commission

Summary
Safety of the fuel cycle and final disposal

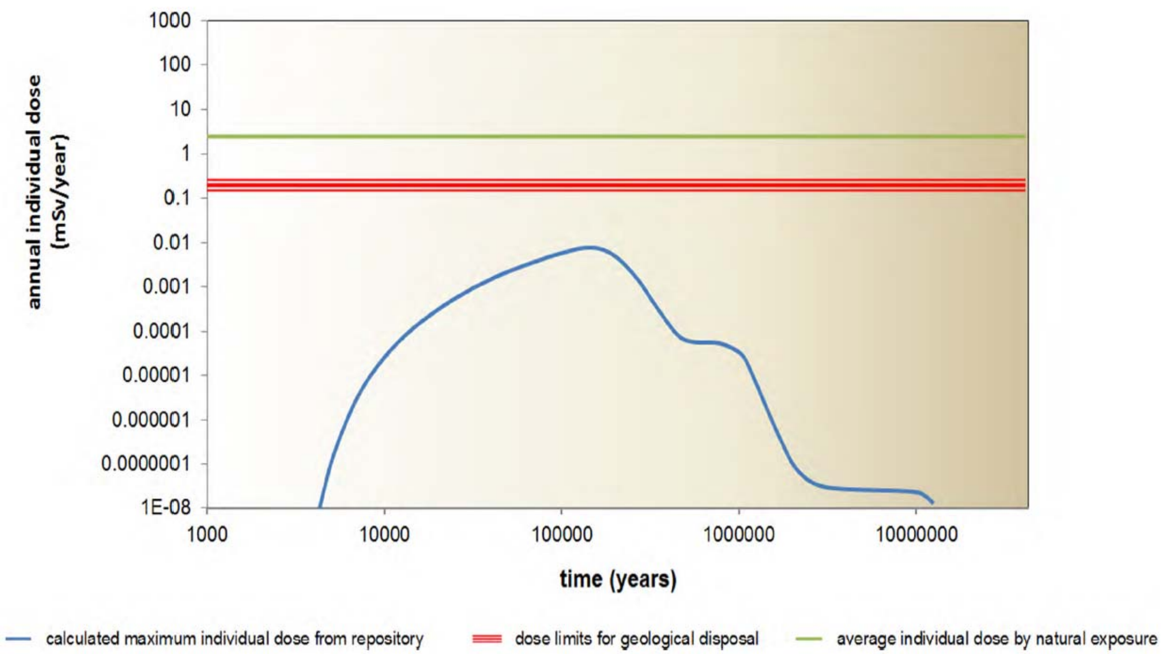
	OPEN CYCLE	FULLY CLOSED CYCLE
Short term : fuel storage and handling	+ fewer handling steps with the spent fuel - uranium extraction and treatment process risks (conventional and radiological)	- more operation and transports of spent fuel and recycling products + no or nearly no uranium extraction and treatment
Long term : fuel geological disposal	- more complicated long term safety o the repository to be guaranteed	+ potential for simpler long term safety of repository

European Academies easac Science Advisory Council

European Commission

Summary
Safety of the fuel cycle and final disposal

disposal: modelling expected radiation exposure in time



- expected exposures due to potential future releases remain fraction (< 1%) of natural exposure of individuals
- no significant difference between open and closed cycle

but

- closed cycle reduces inherent risk would an intrusive or unexpected event occur

Source: NIRAS/ONDRAF, B

European Academies easac Science Advisory Council

European Commission

Summary
Security - Proliferation resistance of the fuel cycle and final disposal

	OPEN CYCLE	FULLY CLOSED CYCLE
Short term: fuel storage and handling	+ no separation of fissile material (plutonium) + fuel is self-protecting + limited number of handling steps	- separation of the fissile material (plutonium) - variety of operations to secure + no or nearly no uranium enrichment required
Long term: fuel geological disposal	- disposed fuel contains fissile material (safeguards required on the repository)	+ no fissile material disposed (no safeguards required on the repository)

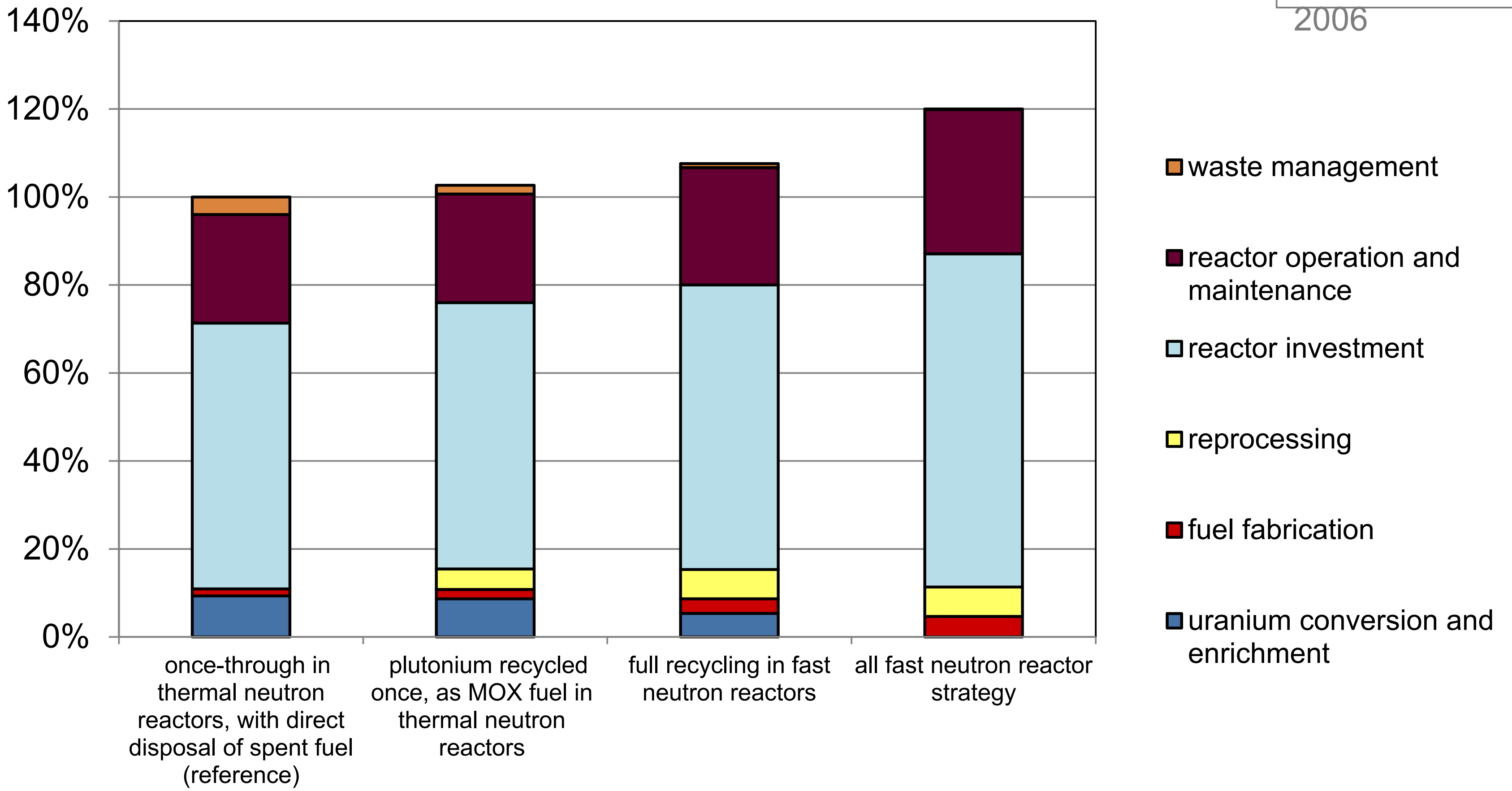
European Academies easac Science Advisory Council

European Commission

Economic factors

Relative cost estimates for alternative types of fuel cycles

Source: OECD/NEA 2006



Involving Stakeholders in decision-making

Source: SKB

- Involvement is indispensable from an early stage
- Aim of:
  - broadening decision-making basis
  - constructive contribution from stakeholders
- Two phases to consider for public involvement:
  1) at the defining of policy and programme
  2) at the siting of the facilities for spent fuel and radioactive waste management
- *If managed well* ➢➢ *more robust decisions*

European Academies easac Science Advisory Council

European Commission

Decision 'Milestones' and Consequences

Decision to implement a Nuclear Energy programme

- ✓ *Fuel management policy needed*
- ✓ *Spent fuel interim storage capacity needed*
- ✓ *Participation in development of suitable fuel cycle options*
- ✓ *Geological disposal will be needed*
- ✓ *Funding scheme*

Decision 'Milestones' and Consequences

Decision to implement a Nuclear Energy programme

Decision not to reprocess and to directly Dispose of Spent Fuel

- ✓ *Long term storage capacity needed*
- ✓ *Encapsulation process needed*
- ✓ *Adequate geological disposal needed*

Decision to Reprocess and Recycle Spent Fuel

- ✓ *Contracts for reprocessing and MOX*
- ✓ *Fuel fabrication needed*
- ✓ *Interim storage for high level waste and spent MOX fuel*
- ✓ *Participation in development of fast neutron reactor*

European Academies easac Science Advisory Council

European Commission

Decision 'Milestones' and Consequences

Decision to implement a Nuclear Energy programme

Decision not to reprocess and to directly Dispose of Spent Fuel

Decision to Reprocess and Recycle Spent Fuel

Decision to implement Fast neutron Reactors

- ✓ *Dedicated system for recycling needed*
- ✓ *Geological disposal needed, mainly limited to high level waste*

Decision 'Milestones' and Consequences

Decision to implement a Nuclear Energy programme

Decision not to reprocess and to directly Dispose of Spent Fuel

Decision to Reprocess and Recycle Spent Fuel

Decision to implement Fast neutron Reactors

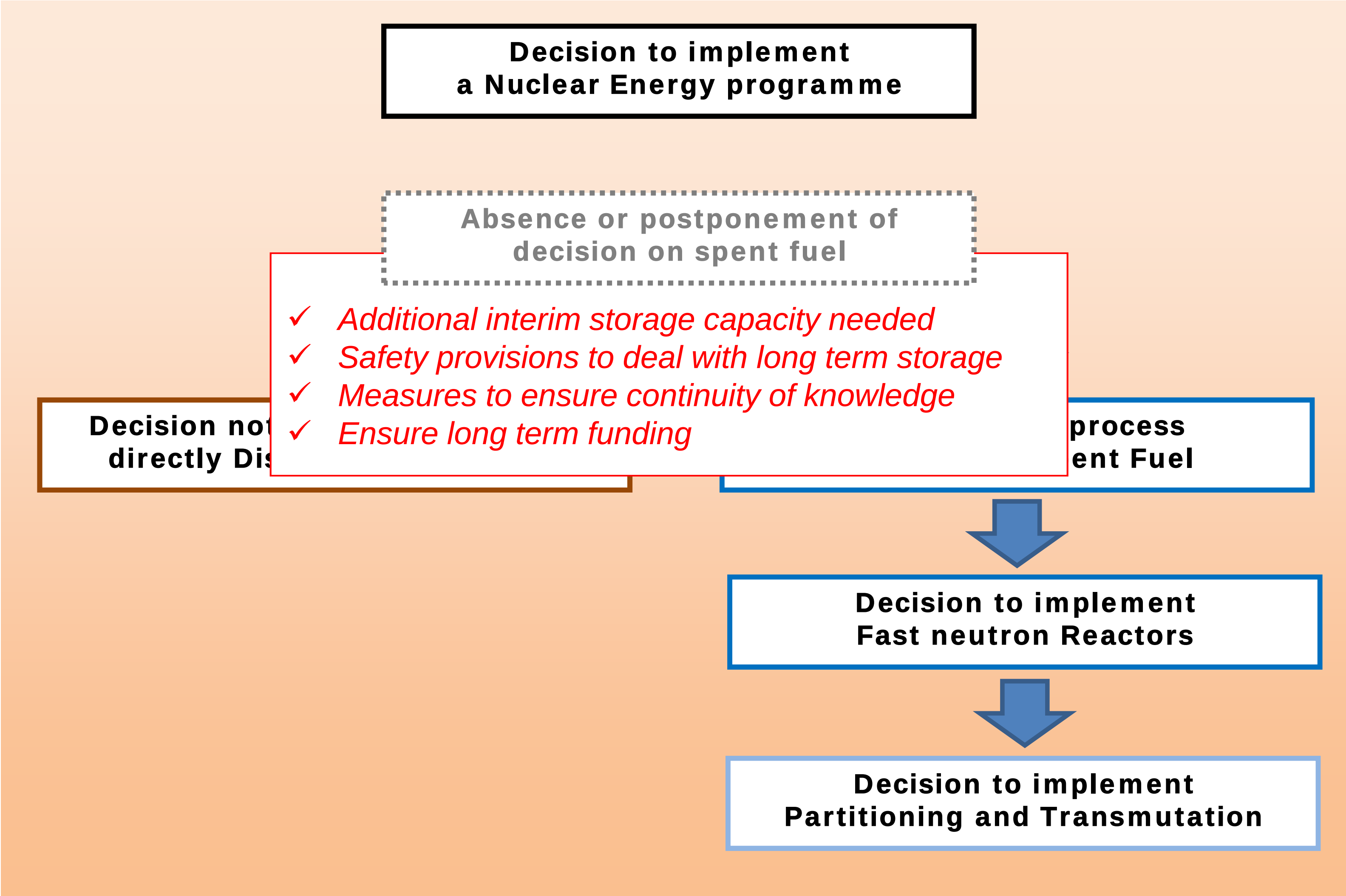
Decision to implement Partitioning and Transmutation

- ✓ *Dedicated system for partitioning needed*
- ✓ *Simple geological disposal needed, limited to residual high level waste*

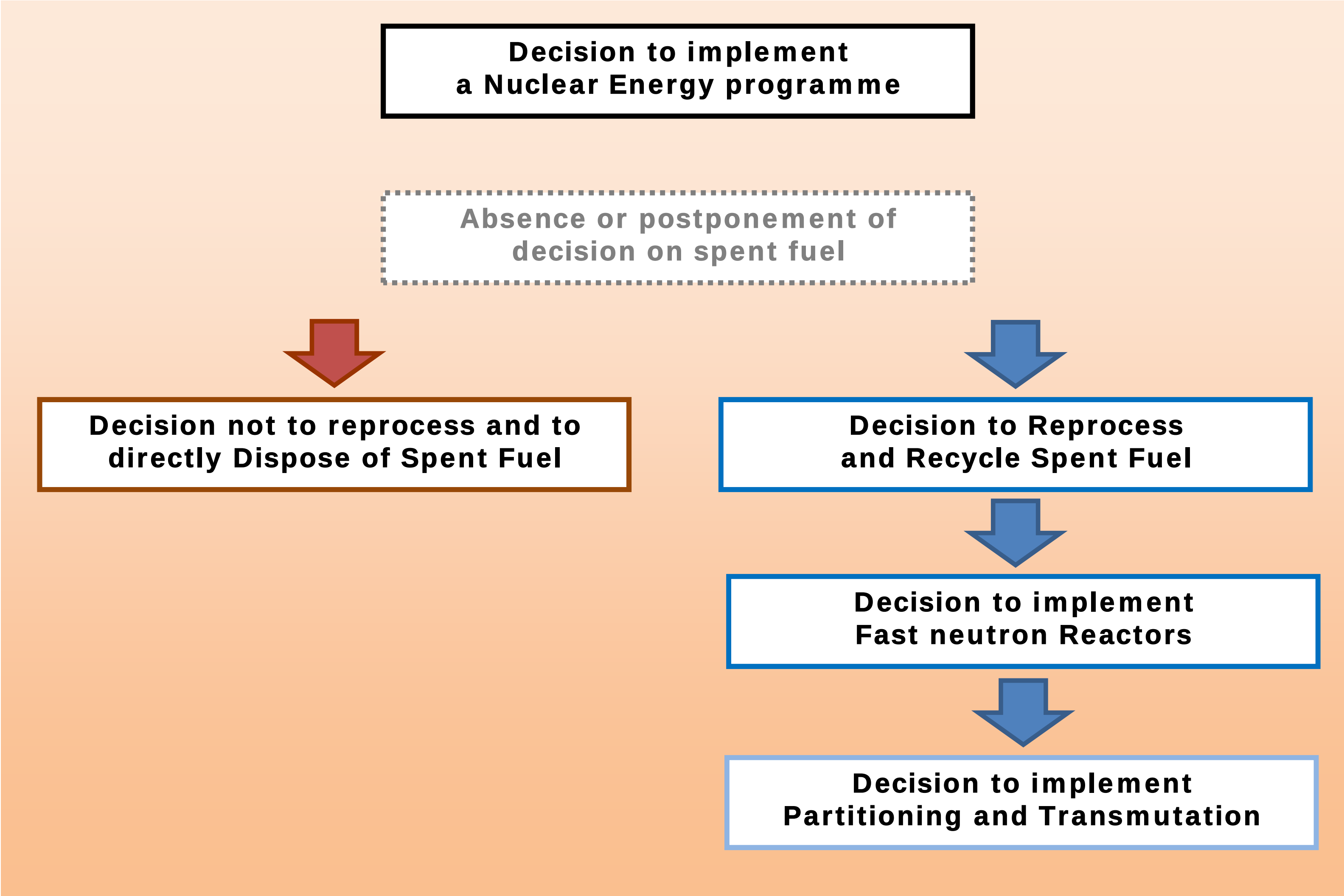
European Academies easac Science Advisory Council

European Commission

Decision 'Milestones' and Consequences



Decision 'Milestones' and Consequences



European Academies easac Science Advisory Council

European Commission

Concluding considerations

- Need for a spent fuel management *policy*
- Policy should take into account:
  - to generate *robust technical solutions*, but keeping *alternatives* available
  - *cooperation on research* in both open and closed cycles
  - further work on *national or regional solutions for geological disposal*, which is essential and urgent
  - attention for *education and training*, value of initiatives at EU level
- Policy must ensure *public involvement and communication* in the decision-making steps

European Academies easac Science Advisory Council

European Commission


Thank you for
your attention