BNFL

Current needs in reactor physics arising from nuclear fuel cycle initiatives

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Introduction

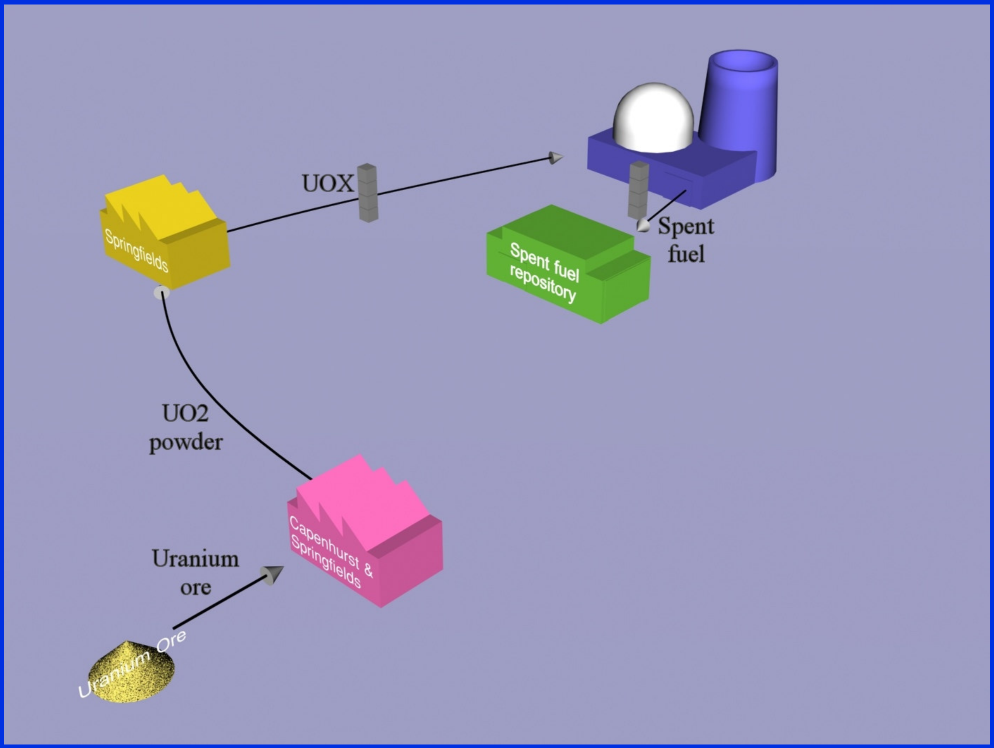
- Personal background

- My message

  Keep a gentle focus on the practicalities of life

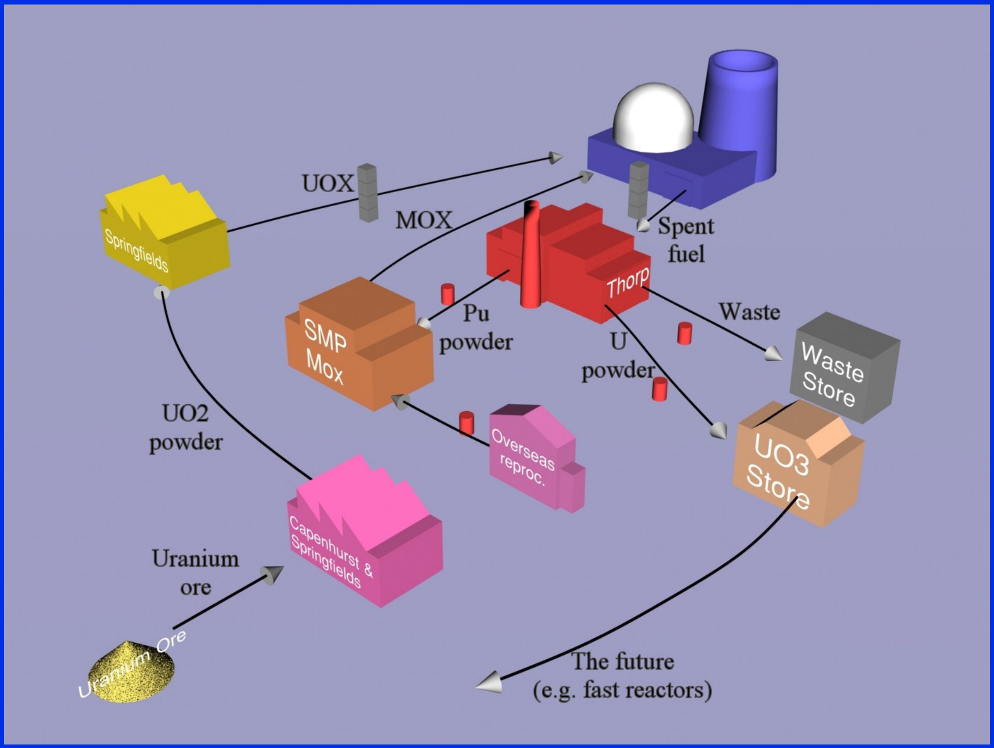
Once-through/open cycle

- Open fuel cycle is effectively the default position today, with > 80% of irradiated fuel currently designated for direct disposal
- This has suited the utilities since the slow down in nuclear growth and with cheap uranium
  - » least resistance path
- Leaves open the possibility of eventual recycle

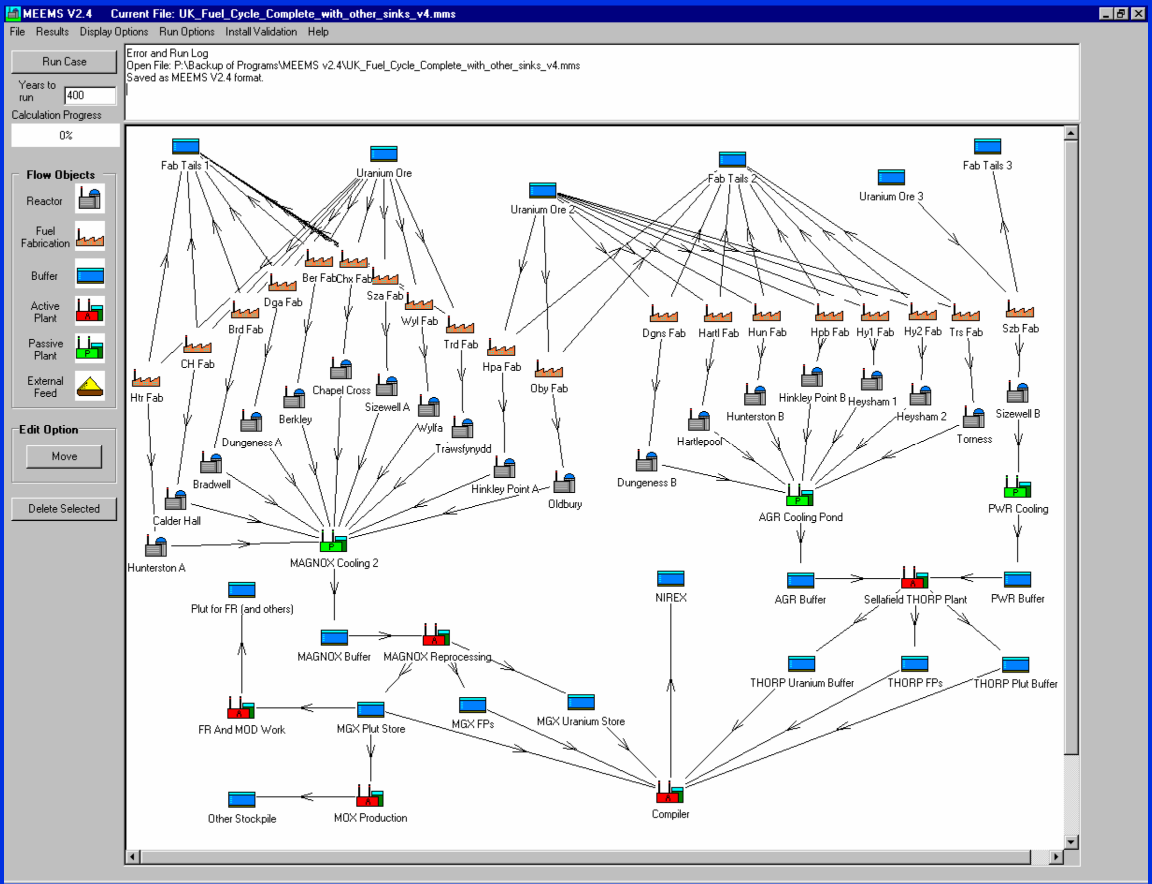


Recycle/closed cycle

- Current reprocessing plants were conceived >30 years ago & intended for an entirely different scenario
- Accumulation of separated Pu can be avoided by thermal MOX recycle
- Historically focus has been recycle of Pu and U
- Possibility also of segregation of Np and Am for transmutation or Cm for interim storage and later recycle
    - » No system has yet demonstrated net Cm destruction



Holistic fuel cycle



UK civil nuclear cycle

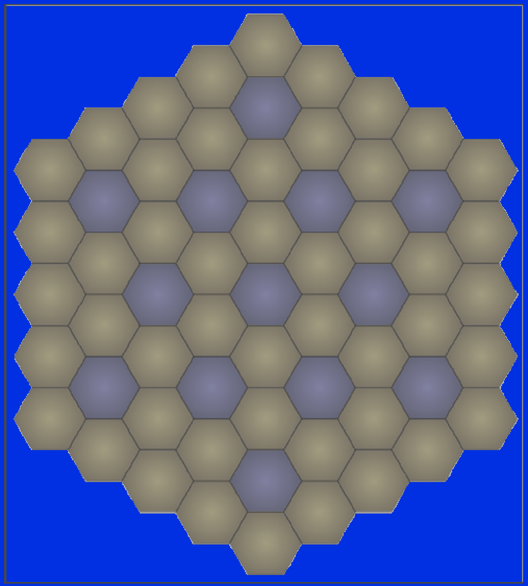
- Important to address the full complexity of actual fuel cycles
- Idealised models have their uses, but also very severe limitations

Current status

- When the current reactors and fuel cycle plants were designed, it was in anticipation of an eventual move to fast reactors
- Due to low uranium prices, fast reactors have not been introduced
- Impact of market deregulation is forcing utilities to concentrate on *short term* competitiveness
  - »doesn’t fit with long term perspective

Changing perspectives

- France, Russia & Japan have never lost sight of the long term and have continued to work towards the commercial development of fast reactors
- Against a background of increasing world energy demand and the pressing need to control CO_2 emissions other countries have acknowledged the need to address long term issues through Gen IV



Phasing

- Short term :
  - » recycling Pu as thermal MOX
- Medium term :
  - » various options available to avoid accumulation of separated plutonium (eg Inert Matrix Fuel)
  - » need to ensure that these options do not have a negative impact and do not preclude future usability (eg in fast reactors)
- Long term :
  - » Gen IV

Pu Management in LWRs - Needs?

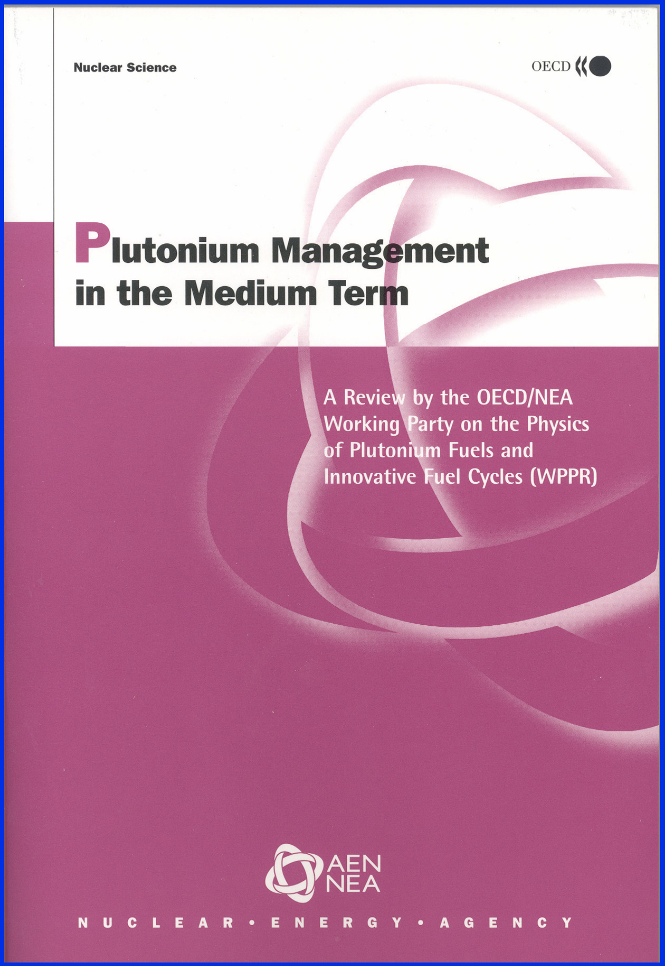
- Partial loading of MOX fuel in PWRs established practice but could be optimised further

- 100% MOX burners have a number of benefits
  - can avoid the UO_2/MOX power peaking affects and have a single enrichment in the assembly
  - core operation can be optimised around MOX fuel characteristics
    - » slower rate of change of reactivity with burn-up

- How to avoid economic penalty of having to discharge the first batch of MOX assembles with relatively low burn-ups

Plutonium management in evolutionary reactors

- Recent OECD/NEA report has reviewed the technical options in evolutionary reactors
- There are many viable options already available, which could be developed if there is a perceived need
  - » None are irreversible and none do any harm in the interim
- Inert Matrix Fuel options may be very advantageous in the correct context



Pu Management -Initiatives?

- Options must
  - –maintain high standards of safety
  - –should not foreclose options
  - –maintain satisfactory standards of security and safeguards against proliferation
  - –be economically competitive
  - –address waste management issues

Evolution & Revolution

- Evolution
  - » AP600 and AP1000 - Ready for deployment now
    - –No R&D required
- Revolution
  - » PBMR - Commercial deployment from 2010
  - » IRIS (Integral PWR) - Deployment from 2020
  - » GFR - GenIV - Deployment from 2030?
    - –R&D required

Systems perspective

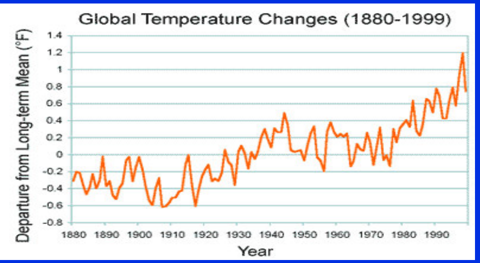
- It is entirely appropriate that Gen IV is emphasising the complete systems
- Fuel manufacturing, spent fuel management & waste management are all aspects that are as important as the reactor engineering

Goals for Gen IV

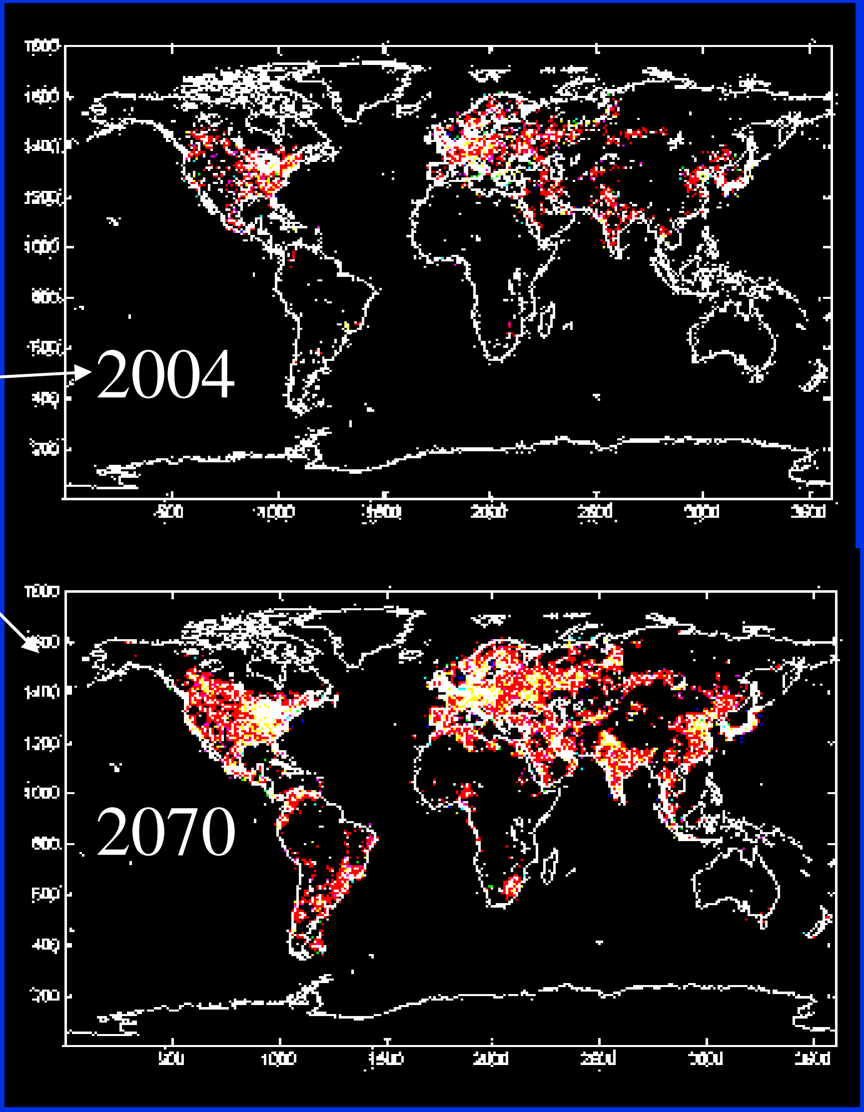
- **Sustainability**
- Improved economics
- Enhanced safety
- Improved reliability
- **Enhanced proliferation resistance**

Sustainability

- Gen IV sustainability goal recognises the context will change
  - »increasing energy demand
  - »climate change imminent ?



  - »need for nuclear contribution in transport sector



Sustainability leads to recycle

- Gen IV has recognised the need for recycle
  - » 5 out of 6 candidate systems involve recycle :

    SFR, LFR, GFR, MSR, SCWR
  - » with recycle as an option for VHTR also

Proliferation Resistance

- Needs to be assessed against the whole fuel cycle
- The assessment depends on a combination of factors, including:
  - –fissile inventory
  - –accessibility
  - –isotopic and chemical form
- Need practical solutions

Key points

- There's more to new designs than just the reactor physics
- Fuel is the one of the key elements of Gen IV :
  - » radical new fuels are required by most of the Gen IV systems (VHTR, GFR, MSR, SCWR) and new fuels essential to fully meet Gen IV goals
  - » fuel development is a very lengthy process and will be one of the main critical path items
  - » new fuels and fuel cycles will necessarily require new recycle technology

Key points

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- Recycle is another key element :
  - » encompasses fuel disassembly, chemical processing, re-fabrication into fuel and waste management
  - » no commercial scale experience exists with molten salt, molten metal or molten chloride reprocessing - critical path item
  - » chemical separation factors are key, especially for minor actinide recycle
  - » recycle plant may need to be co-located with power plant
  - » remote fabrication may be required to meet proliferation resistance goal
  - » waste forms is a particularly difficult area that needs to be borne in mind - especially difficult to evaluate quantitatively without operational experience

Key points

- Benefits of Gen IV must be assessed against *realistic* and *finite* scenarios
    - » theoretical equilibrium scenario models can often lead to misleading conclusions
        - – we must not make exaggerated claims
    - » the whole scenario must be considered

Closing remarks

- The real challenges are not necessarily centred on reactor physics :
  - » they are materials, fuel performance, manufacturing, recycle chemistry, waste management
- Mechanisms will be needed to drive the changes
  - » it will not do to leave things to market forces
- We need to maintain a realistic perspective

The difference between the promise and reality ……

A paper reactor is ….

simple, small, cheap, lightweight, can be built very quickly, very little development is required: it will use off-the-shelf components. It is in the study phase: it is not being built now.

By contrast, a real reactor ….

is complicated, large, heavy, being built now, behind schedule, requires an immense amount of development on apparently trivial items, takes a long time to build because of its engineering problems….

Admiral Rickover

Quoted from Thedore Rockwell's "The Rickover Effect" published 1992

Acknowledgement

A final word of thanks to

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