Transmutation of Actinides in CANDU Reactors

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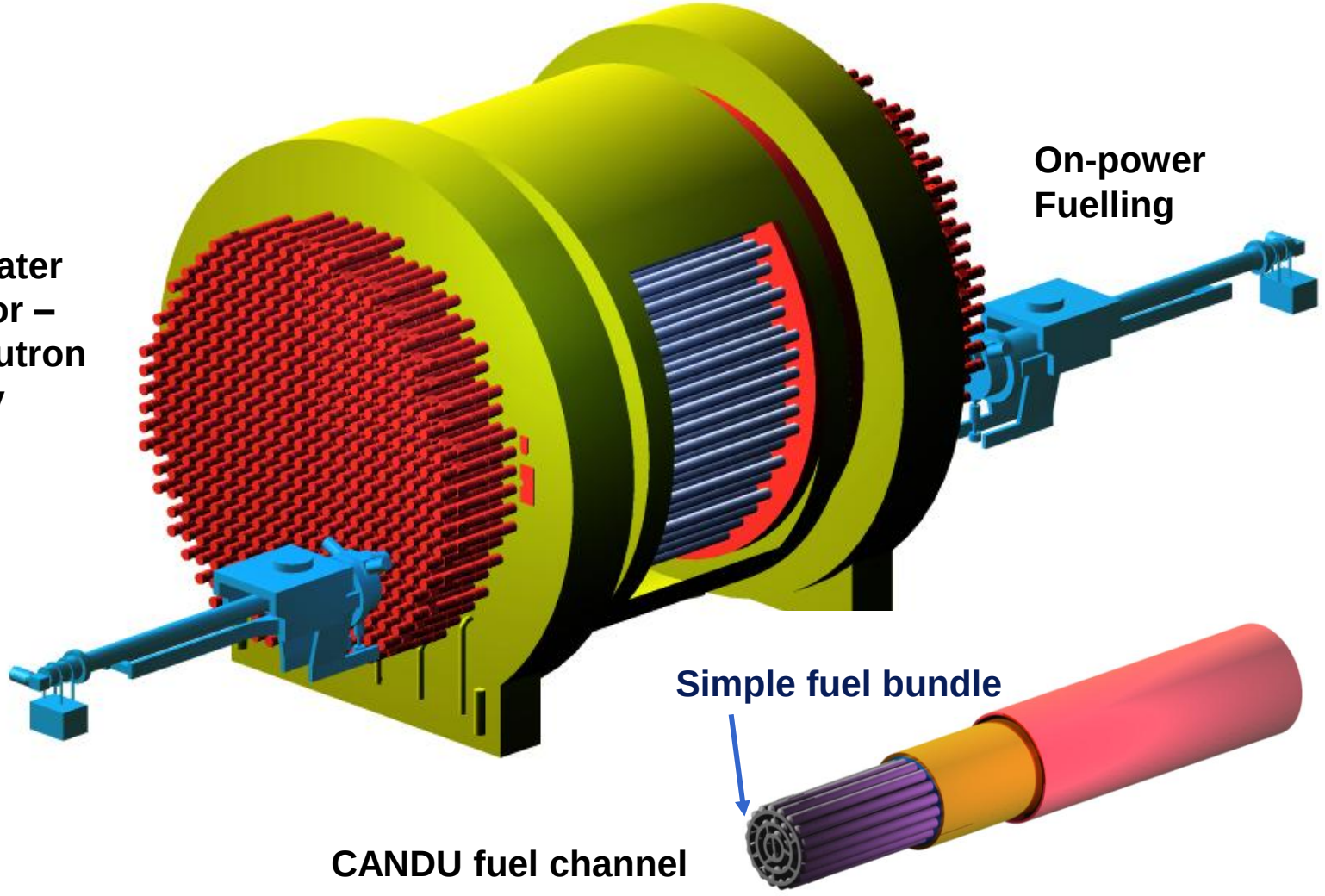
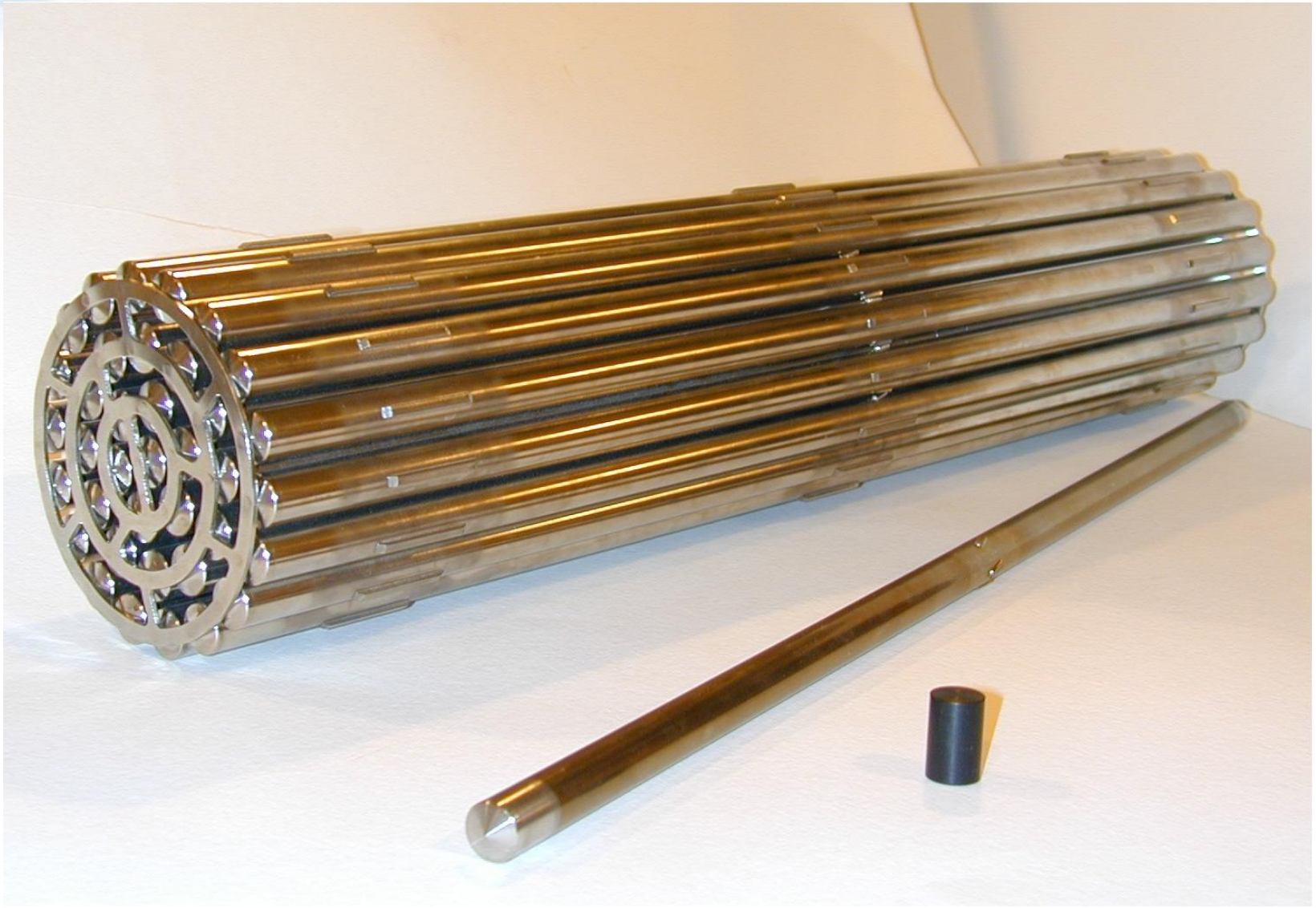
Outline

- Introduction to CANDU reactors
- Motivation for transmutation of actinides
- Transmutation of actinides in CANDU
  - Group-extracted TRU in MOX
  - Separated Am/Cm in targets

The CANDU Reactor



37-element bundle



Motivation

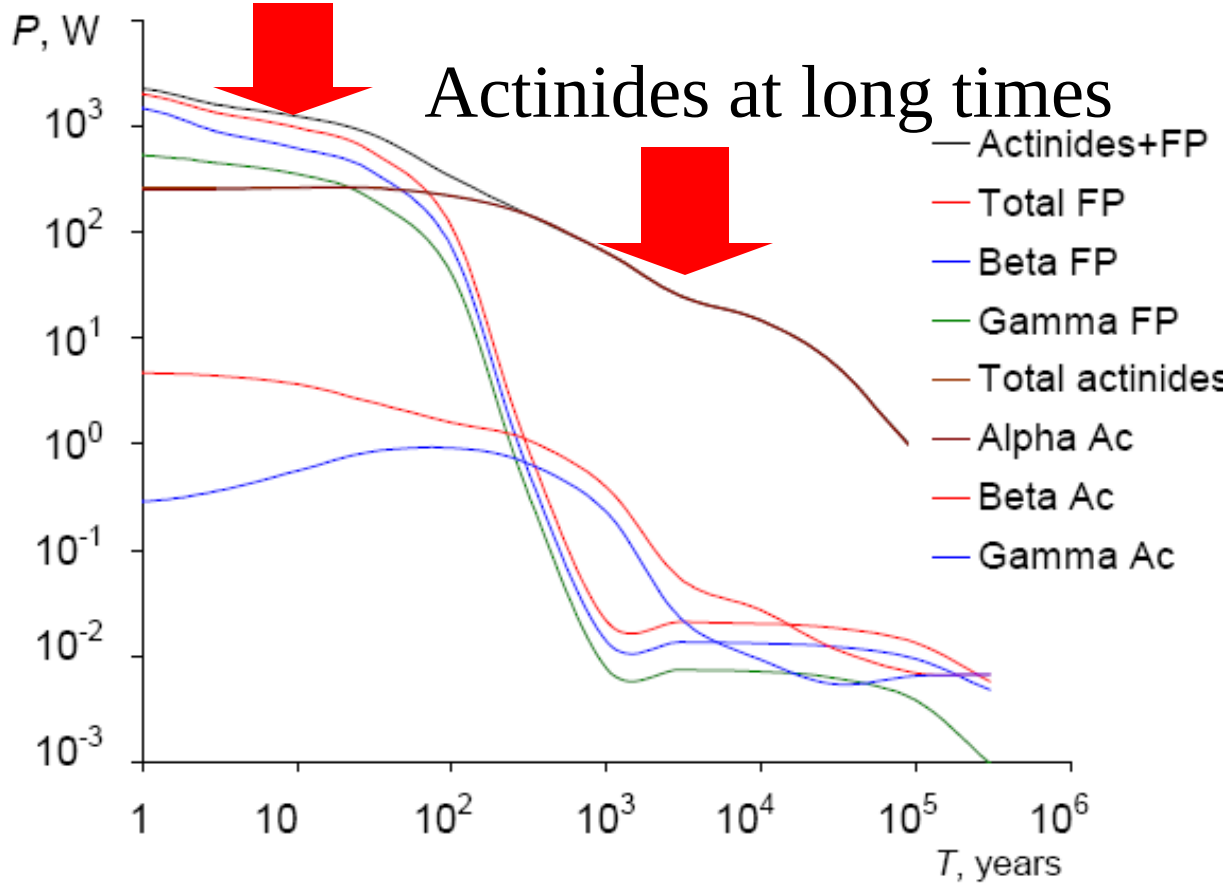
- Increase capacity of long-term geological disposal
- YM final, total cost:

  $96 billion
- Technical capacity limited by decay heat load

What's Contributing to the Heat Load?

FP's at short times

Actinides at long times

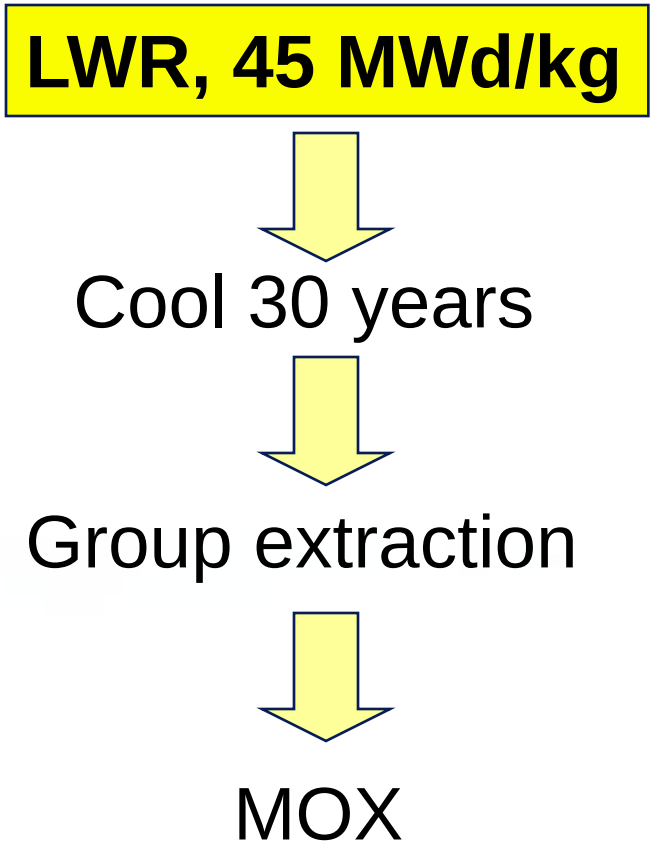


*Data for Russian VVER

Transmutation Scenarios

- Two transmutation scenarios were examined
- Group-extracted TRU in MOX
- Separated Am/Cm in targets

TRU MOX Scenario



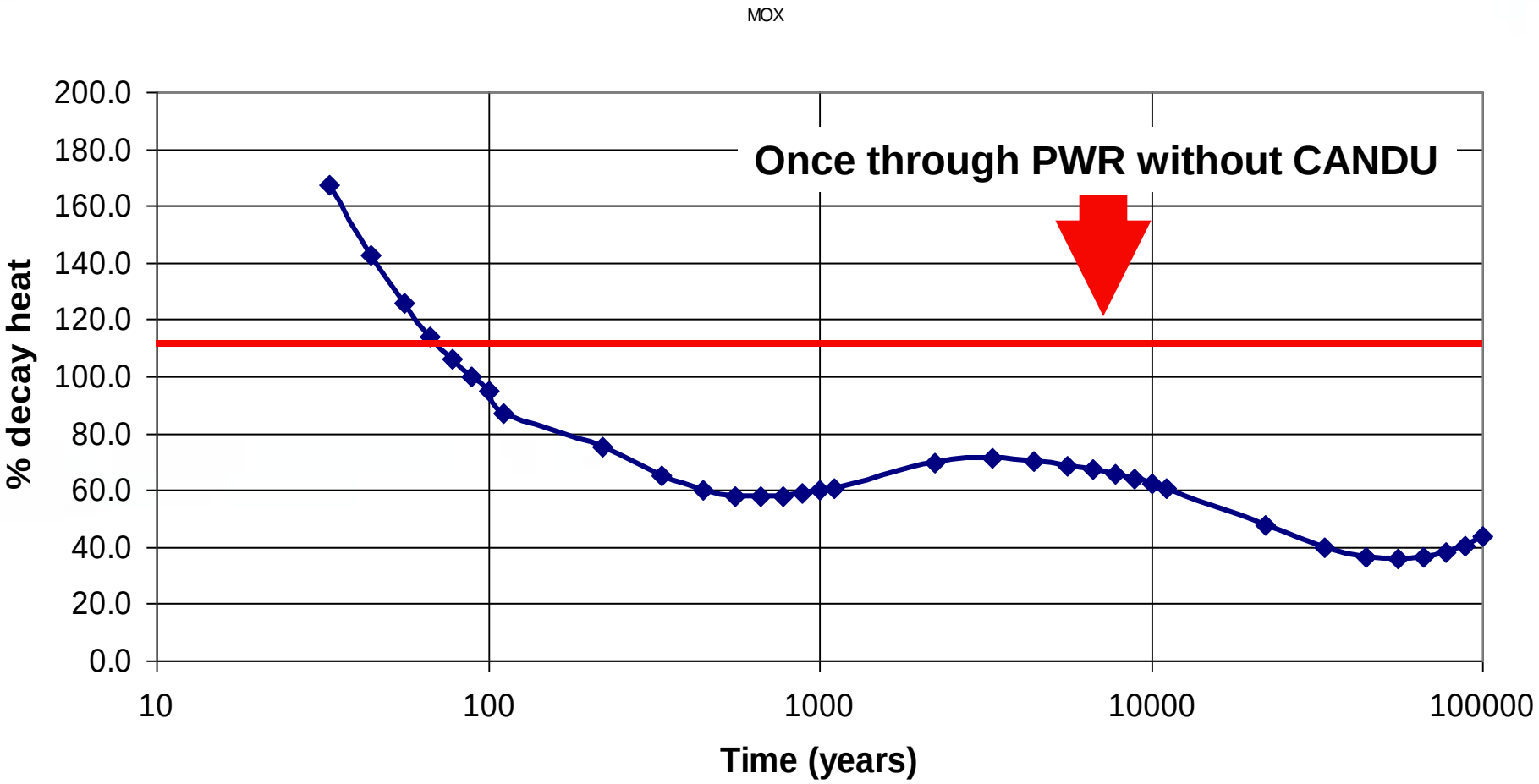
- **WIMS-AECL lattice cell calculations**
- **RFSP full-core calculations**
- **45 MWd/kg exit burnup for MOX**

30 year cooled SNF

	MOX	Initial TRU Compostion, g/kg initial TRU
Initial TRU Content, g/bundle	653	
Initial TRU Content, % by volume	3.3%	
Pu-238	+163	13
Pu-239	-77	563
Pu-240	-1.8	201
Pu-241	+65	30
Pu-242	+176	38
Pu Total	-39	845
Np Total	-52	47
Am-241	-90	100
Am total	-64	108
Cm total	+3700	0.6
Total MA	-45	155
Total TRU	-40	1000

Change in actinide composition (%) at discharge burnup

Decay Heat from Actinides



Nuclide Contribution to Heat Load

Nuclide	Time Frame of Main Contribution to Heat Load	% Difference
Pu-238	Less than 100 years	+163
Cm-244	Less than 100 years	+2641
Am-241	Less than 1000 years	-90
Pu-239	1000-100,000 years	-77
Pu-240	1000-100,000 years	-1.8

Full-Core Calculation

Input fuel composition

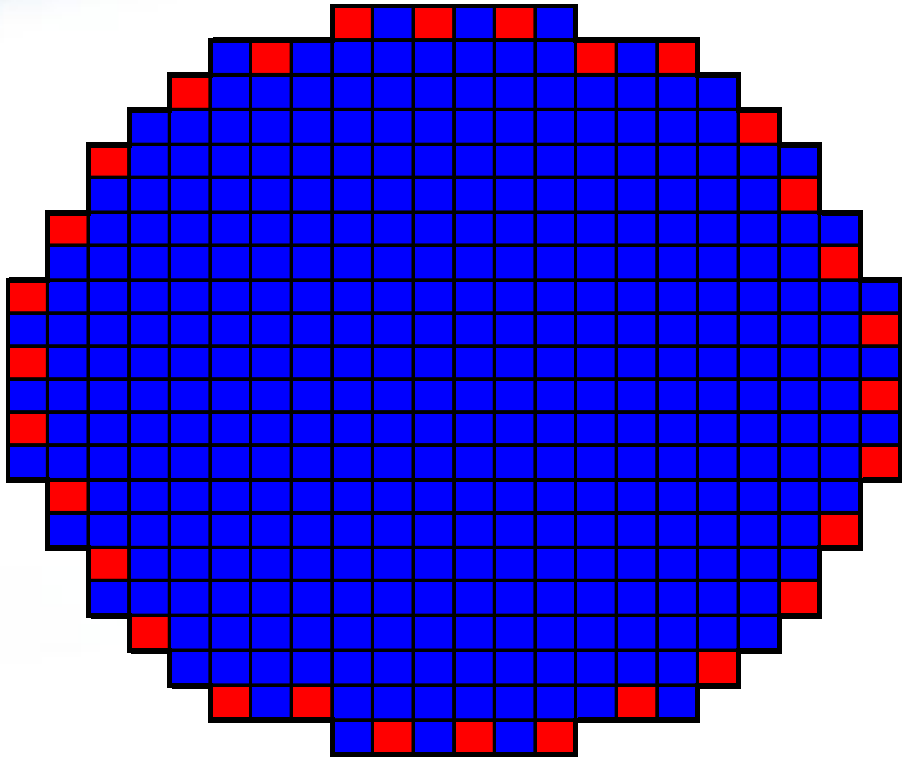
Lattice cell calculation: WIMS

Cross-sections, Depletion

Full-Core Calculation: RFSP

Full-core Parameters, Dwell Time, Burnup

Am and Cm Target Channels



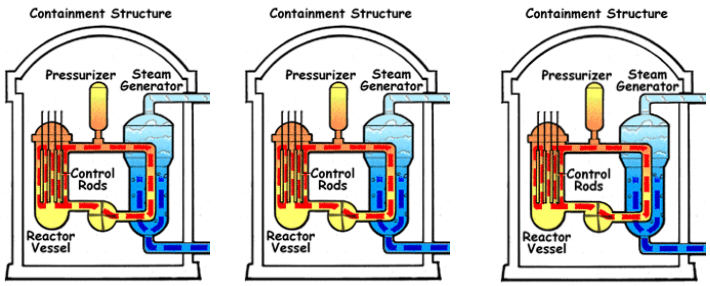
- 30 target channels

Am and Cm in IMF

0.9% Fissile RU

Important Criteria

- **Support ratio**



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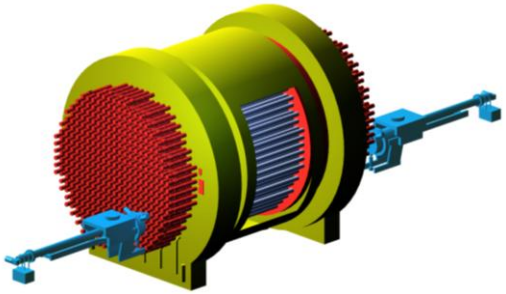
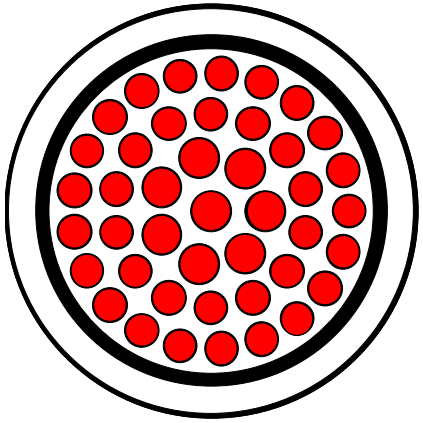


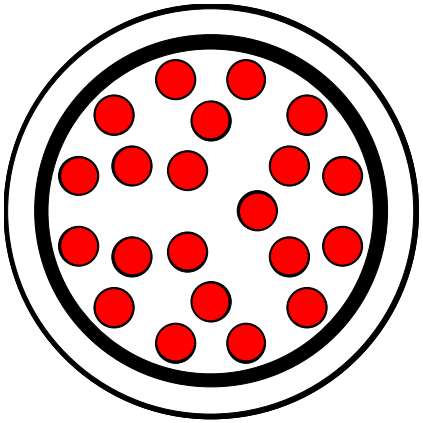
- **% transmutation**

- **Residence time**

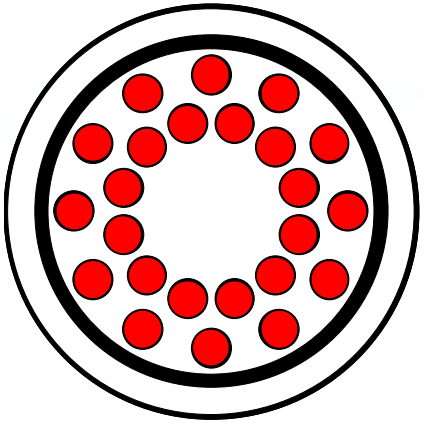
Fuel Bundle Designs



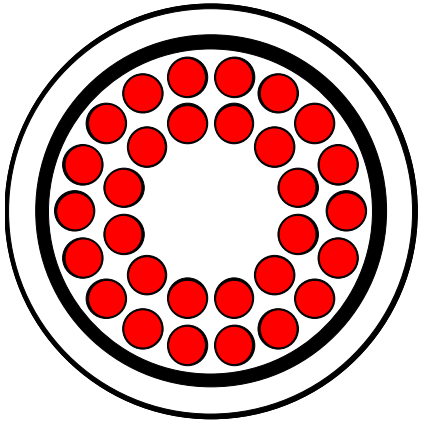
CANFLEX 43 elements



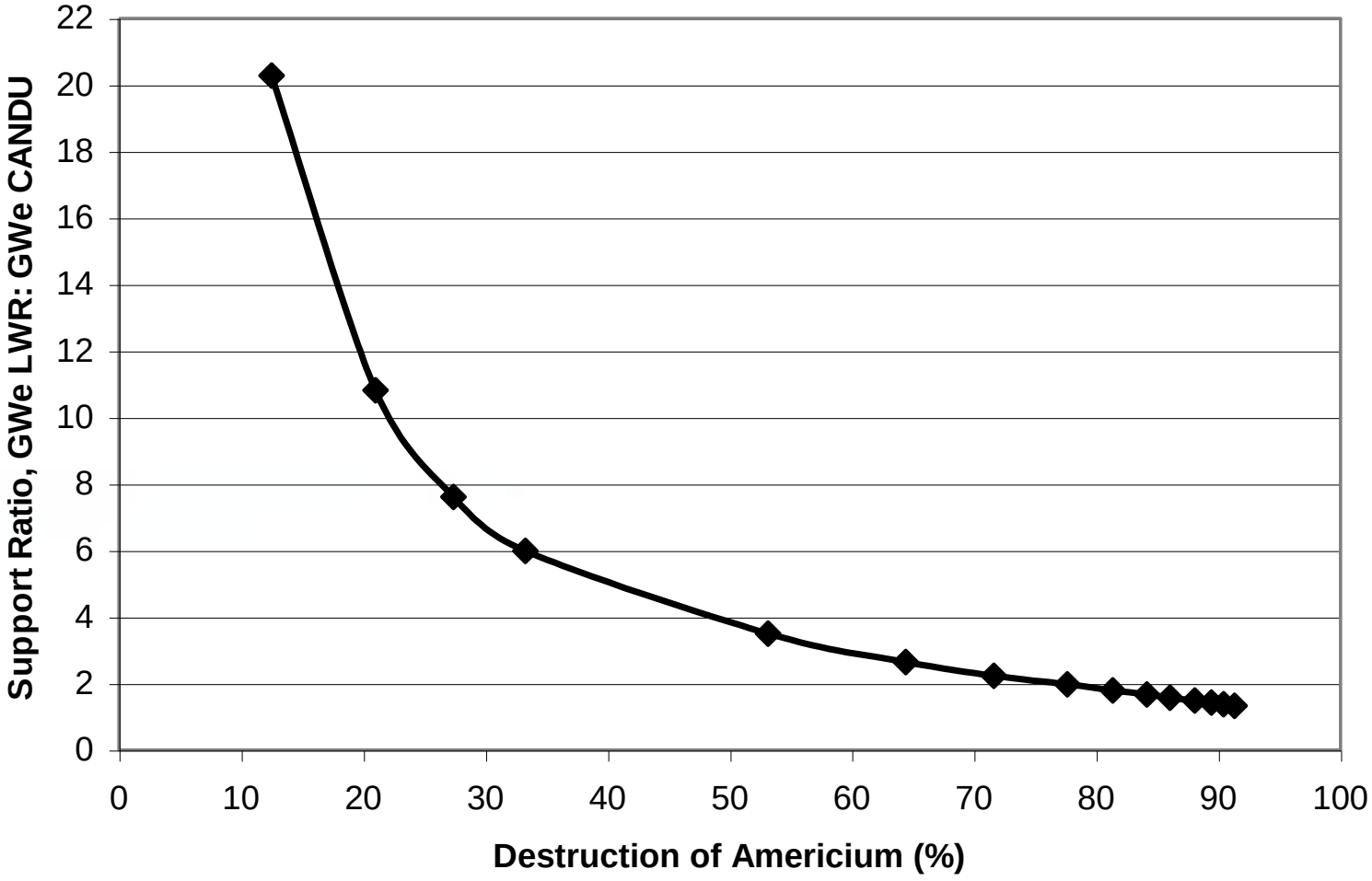
21 elements

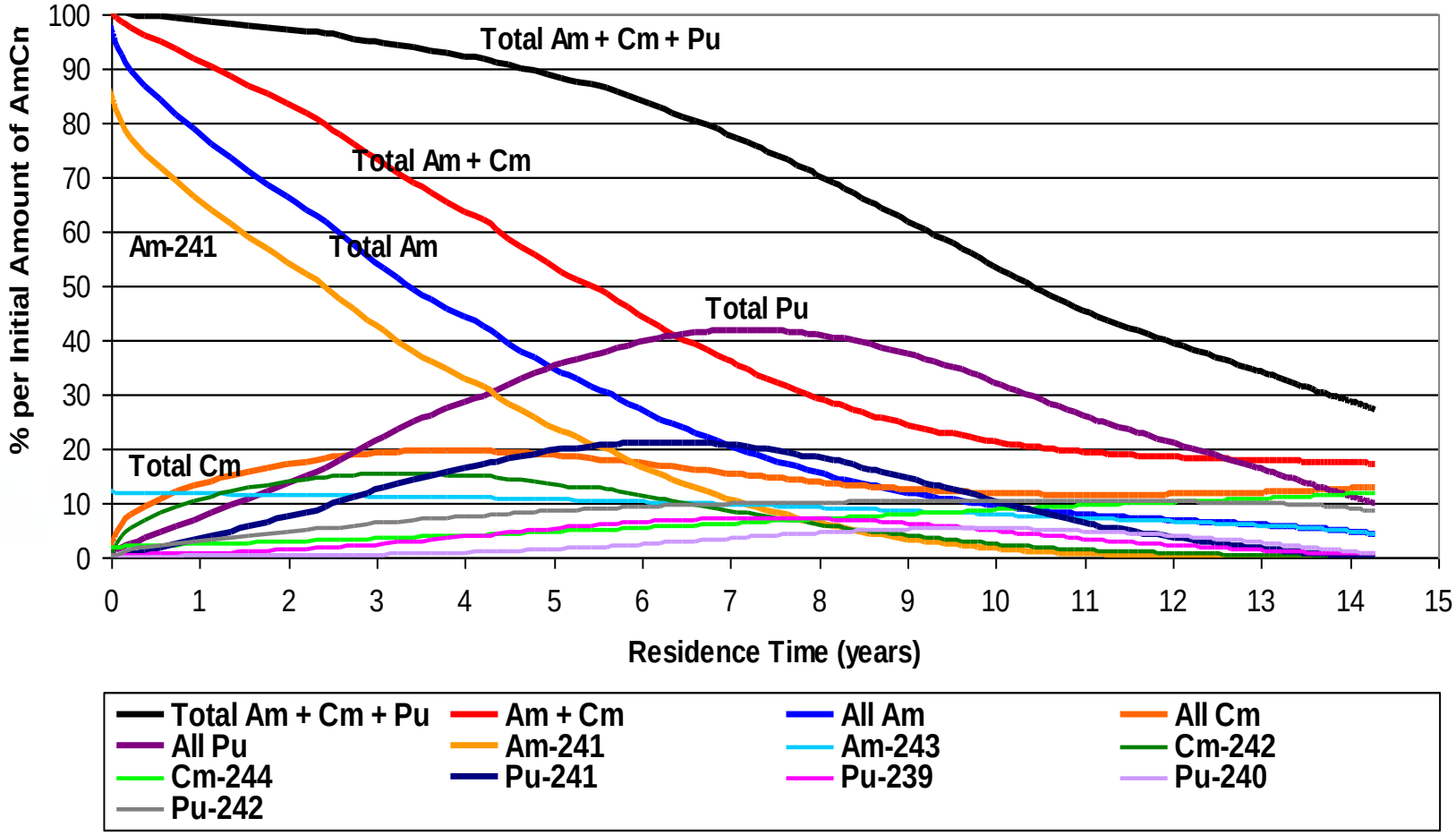


24 elements



30 elements


Support Ratio, GWe LWR: GWe CANDU
22
20
18
16
14
12
10
8
6
4
2
0
0
10
20
30
40
50
60
70
80
90
100
Destruction of Americium (%)


% per Initial Amount of AmCm
100
90
80
70
60
50
40
30
20
10
0
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
Residence Time (years)
Total Am + Cm + Pu
Total Am + Cm
Am-241
Total Am
Total Pu
Total Cm
Total Am + Cm + Pu
Am + Cm
All Am
All Cm
All Pu
Am-241
Am-243
Cm-242
Cm-244
Pu-241
Pu-239
Pu-240
Pu-242

Results

	Input kg/CANDU	Exit kg/CANDU	% Change
Am	373	112	-70
Cm	9	68	+700
Total Am + Cm	382	180	-53

- 21-element bundle
- 26% initial concentration
- Support ratio 2.5 GWe LWR : 1 GWe CANDU
- Residence time for AmCm = 5.7 years

Full-Core Calculation

Input fuel composition

Lattice cell calculation: WIMS*

Cross-sections, Depletion

Full-Core Calculation: RFSP

Full-core Parameters, Dwell Time, Burnup

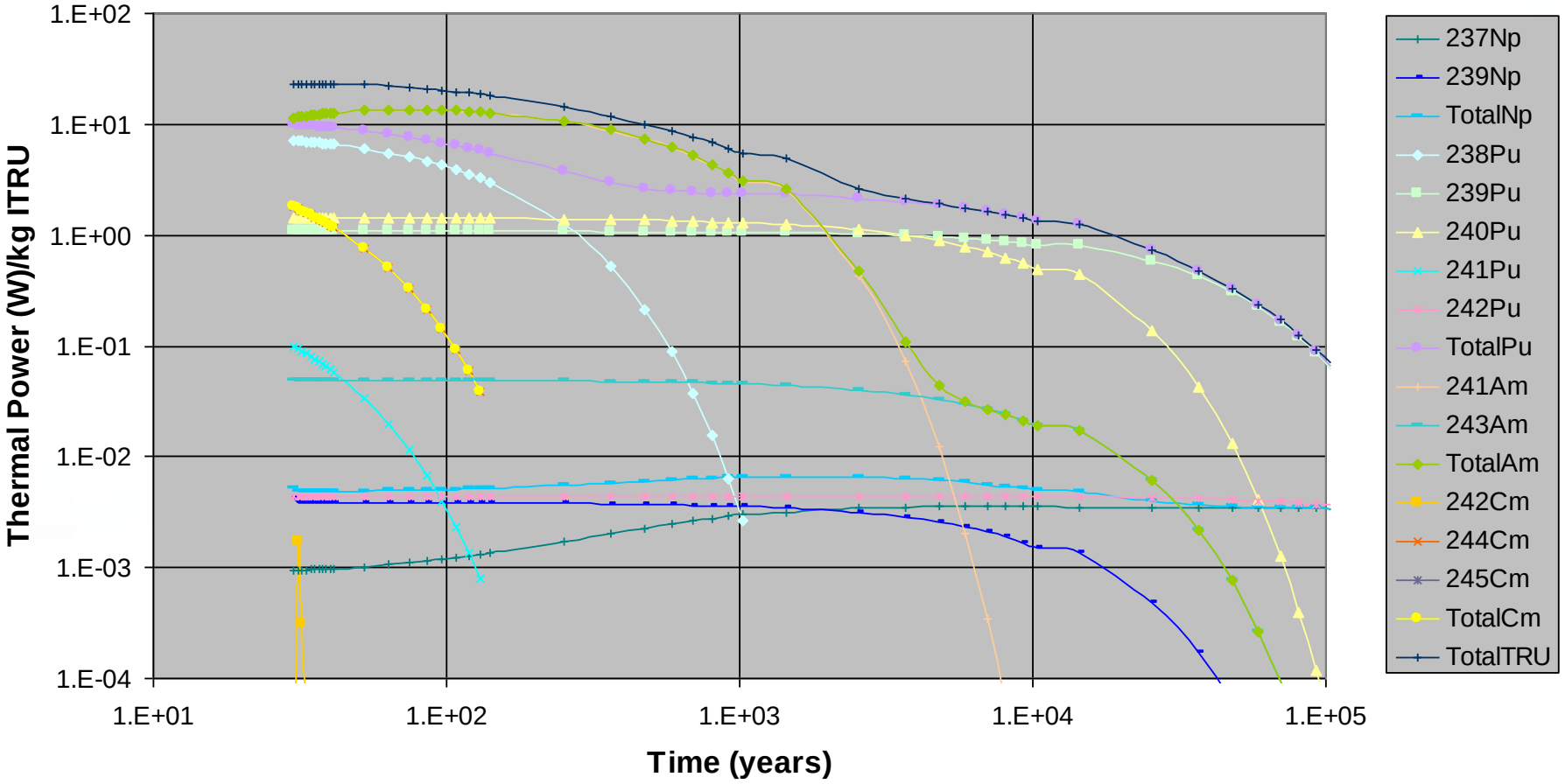
* Calculations done with a developmental version of WIMS-AECL

Summary

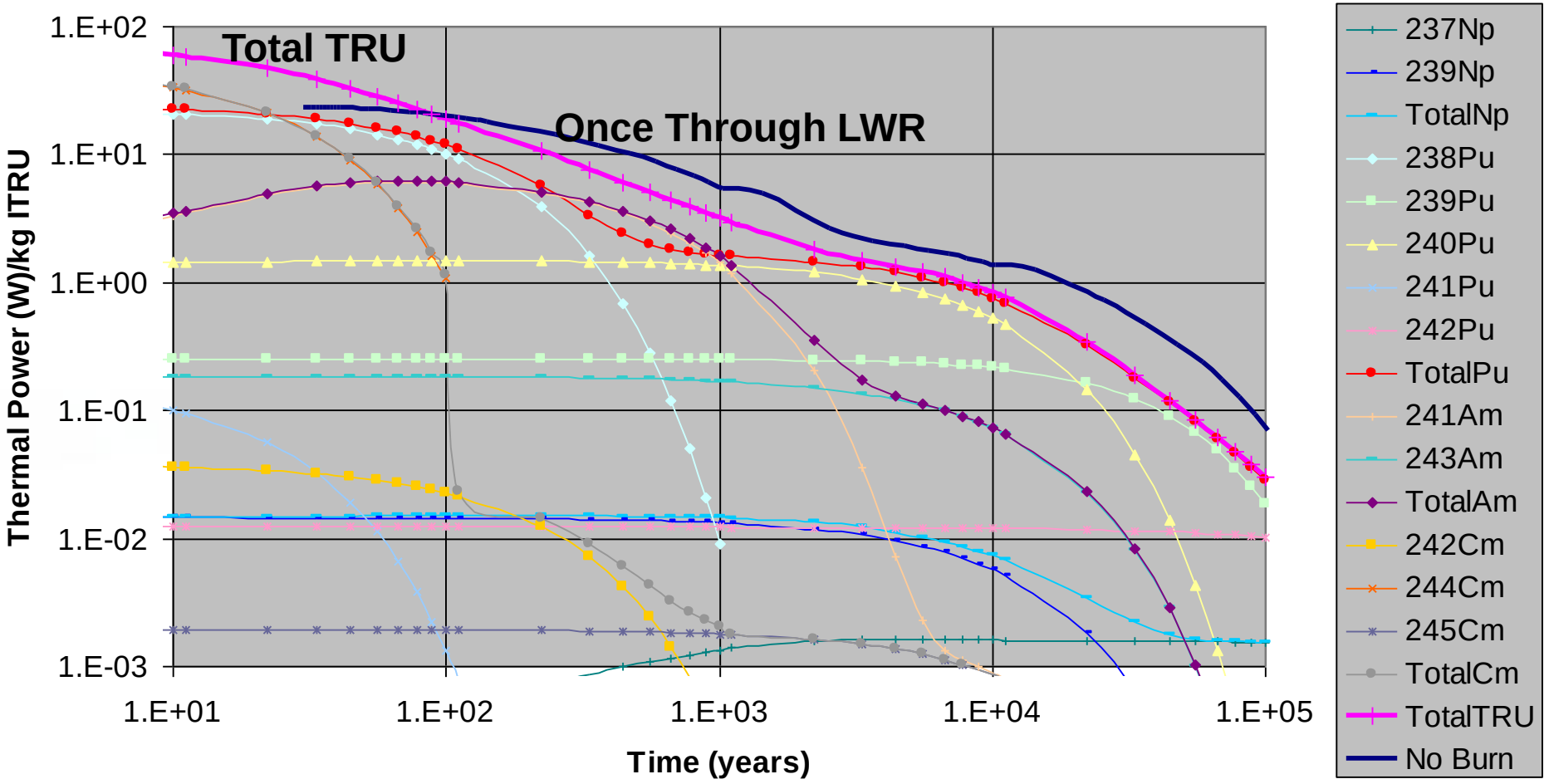
- CANDU reactors have unique features which allow them to effectively transmute transuranics
- TRU in MOX
  - We can burn 40% of TRU
  - Reduce heat load by 40% at 1000 y
- Am/Cm targets
  - We burn 70% of Am (53% or Am+Cm)
  - Reduce heat load by 70% at 1000 y
- Provide a significant increase in geological repository capacity.
- Full-core calculations indicate that both fuel cycles are feasible


AECL
EACL

30 year cooled—No Burn



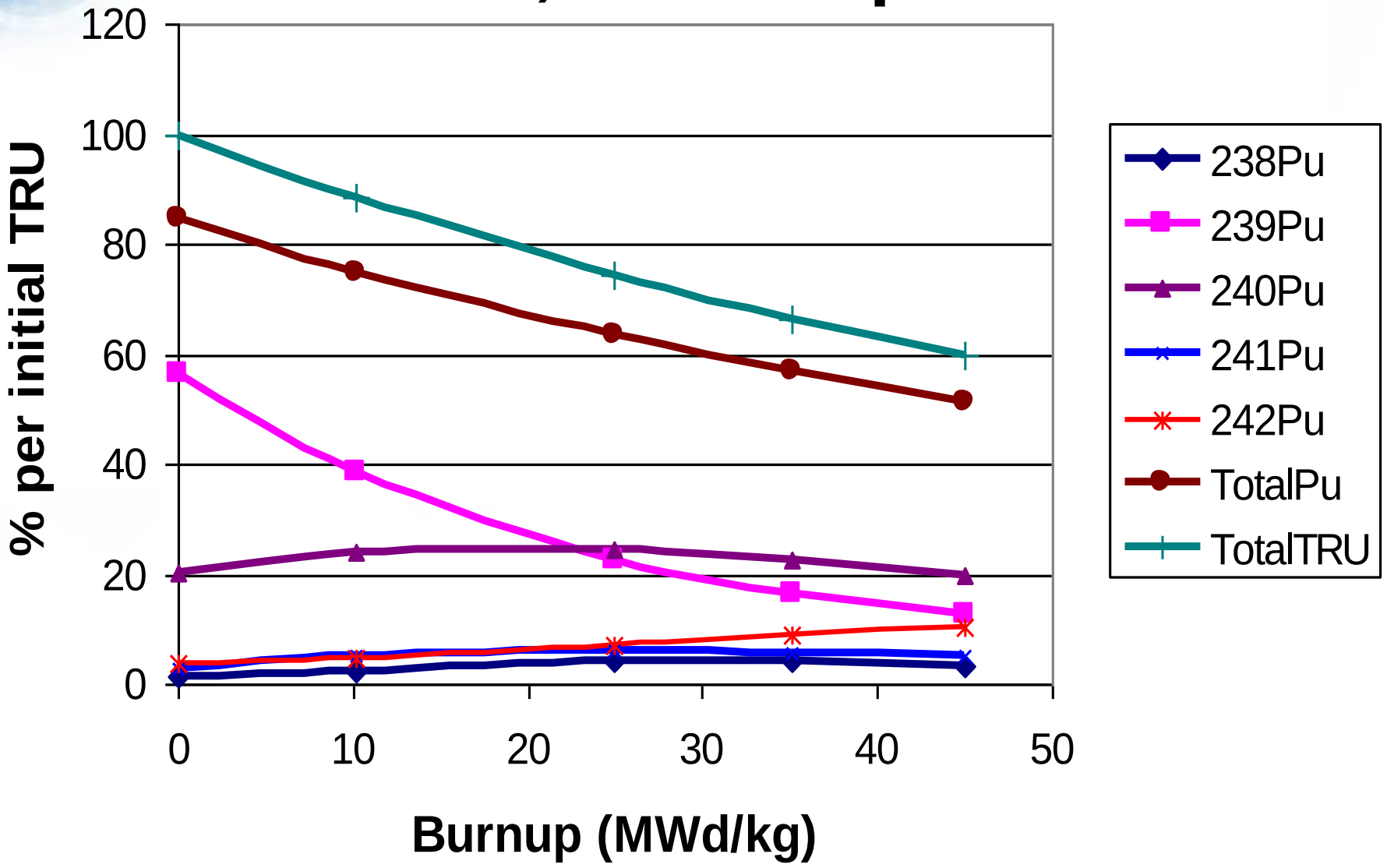
Decay Heat from Actinides, MOX



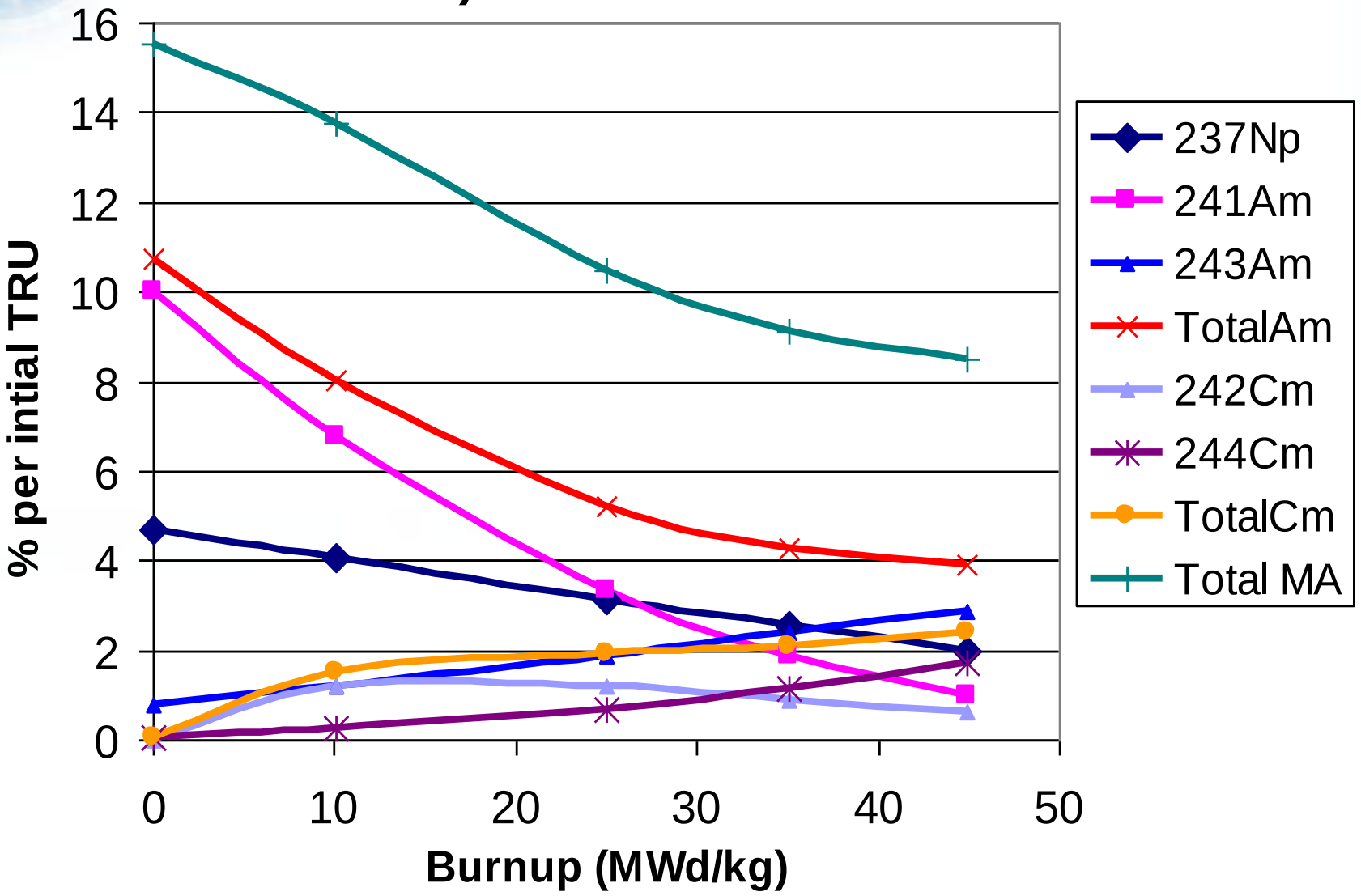
The Calculation

- **WIMS-AECL used to calculate neutron fluxes**
- **ORIGEN-S used for the depletion calculation**
- **MOX: burned to 45 GWd/t**
- **Assumed 3% neutron leakage**

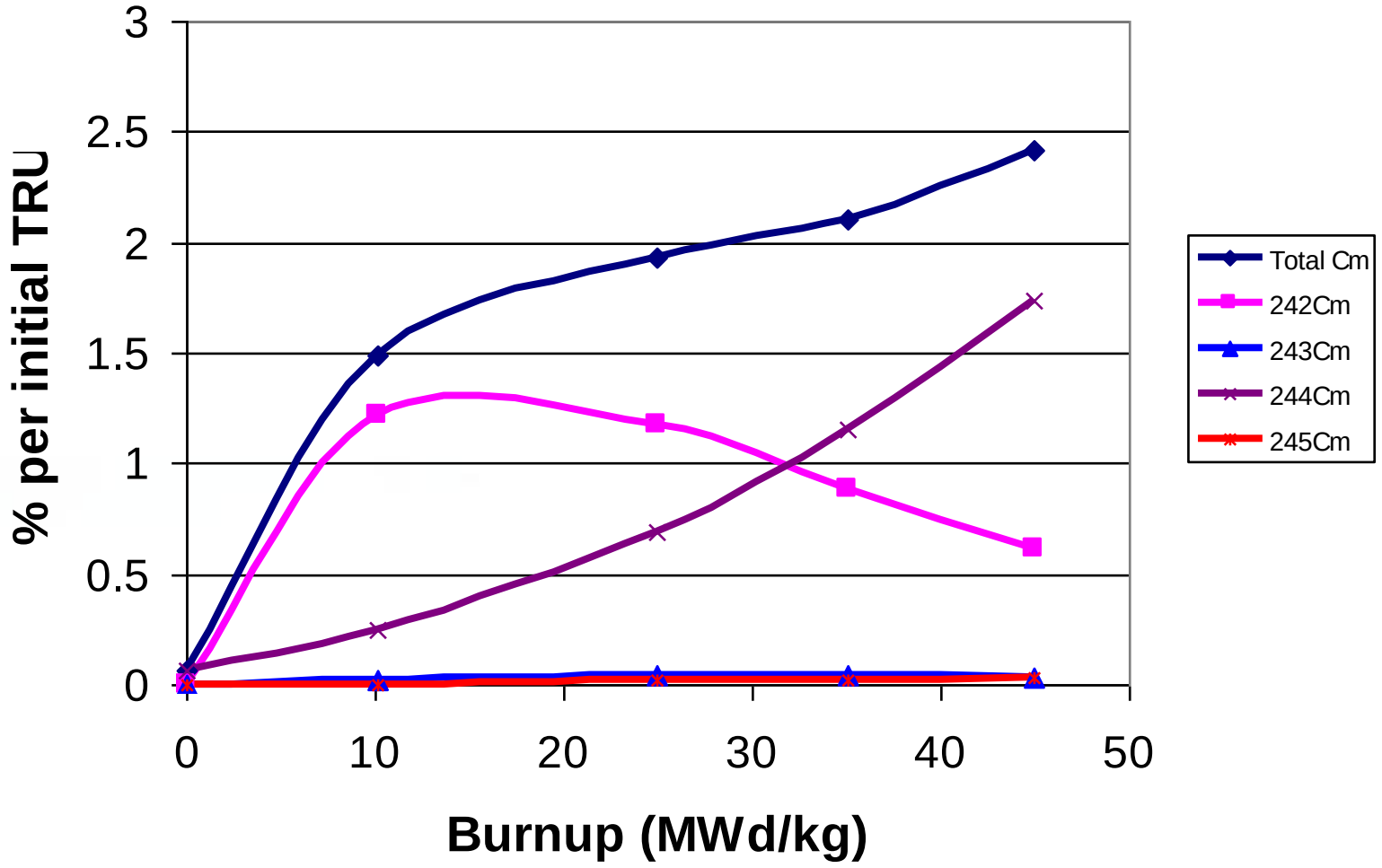
MOX, Pu Isotopes



MOX, Minor Actinides

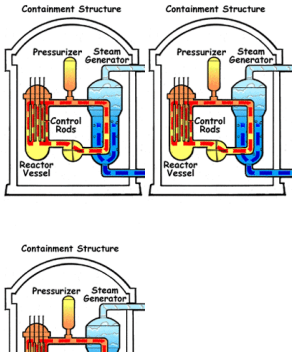


Group Extracted TRU MOX, Cm



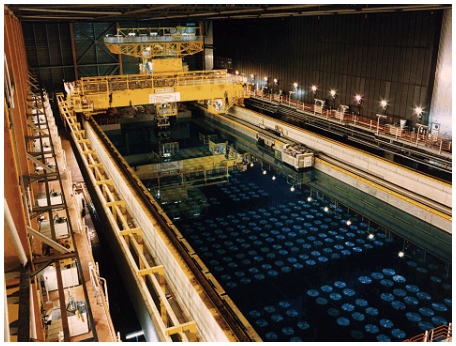
Am Mass Flow

2.5 GWe LWR

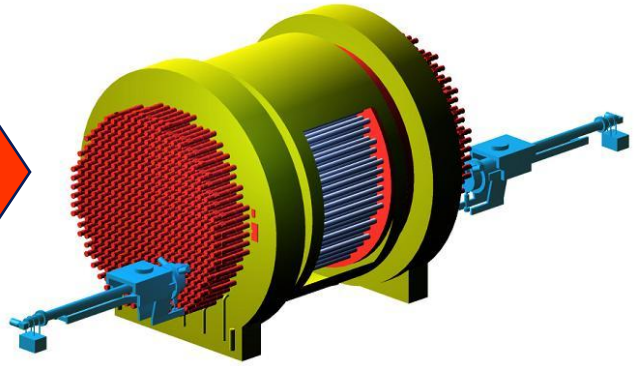


21 kg/year

Decay for 30 years
Separate Am, Cm



90 kg/year



27 kg/year

63 kg/year destroyed

Full-Core Results

	Time-Average	Refueling Ripple	NU Fuel
Max Channel Power (kW)	6600	7100	7300
Max. Bundle Power (kW)	790	845	935

- Avg. burnup for RU is 12.2 MWd/kg
- 3.7 channels/day, 11 bundles/day

For 30 year cooled TRU in MOX At Mid-Burn