Workshop on Advanced Reactors With Innovative Fuels

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Constraining TRU Production in PWRs with a Heterogeneous UO2 – ThO2 Assembly

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Outline

- Introduction
  - Options for Multi-recycling of TRU in PWR
- Description of COTTU concept
  - Calculation Methodology
- Results
- Summary and Conclusions

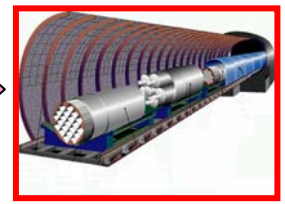
TRU Multi-Recycling

Once – Through Fuel Cycle

Spent fuel

TRU+FP

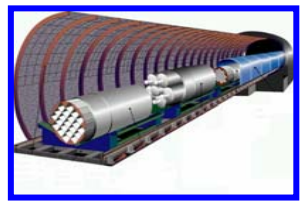
"Expensive" Repository



Multi-Recycling

Short-lived FP

"Cheap" Repository



TRU+LLFP

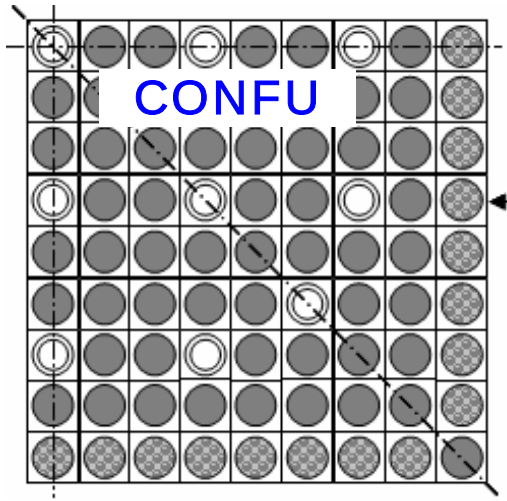
Fuel Fabrication Plant

Fuel Reprocessing Plant

Reprocessing losses

TRU Multi-Recycling Options

- Fertile free fuel
  - CONFU
- Uranium MOX
  - Homogeneous (MIX)
  - Heterogeneous (CORAIL, APA)
- Thorium MOX
  - Homogeneous
  - Heterogeneous (COTTU)



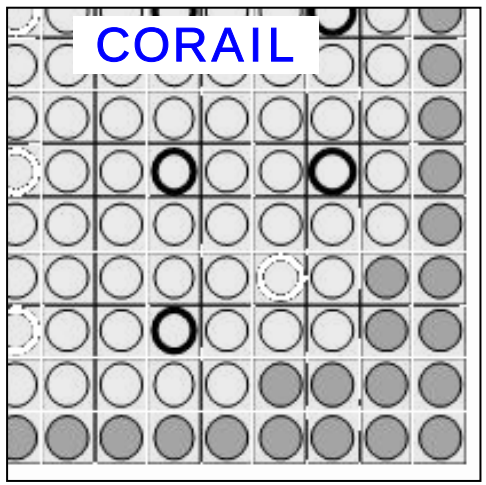
Fertile Free Pins:

70 v/o - Spinel ($MgAl_2O_4$)

18 v/o - YSZ

12 v/o - (TRU) O_2

Total 13.2 kg of TRU/assembly

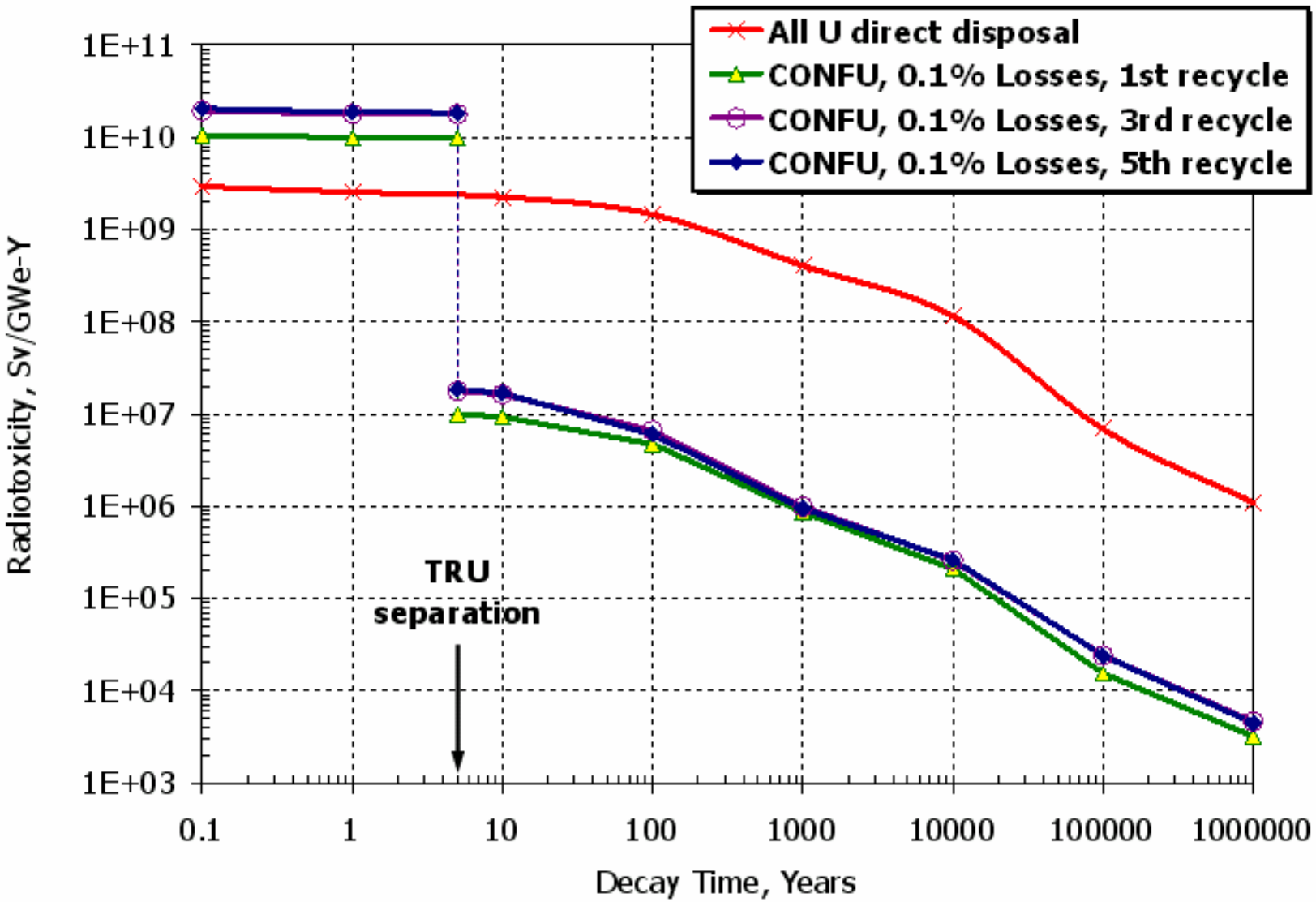


UO_2

MOX

Guide tube

Effect of Complete TRU Recycling



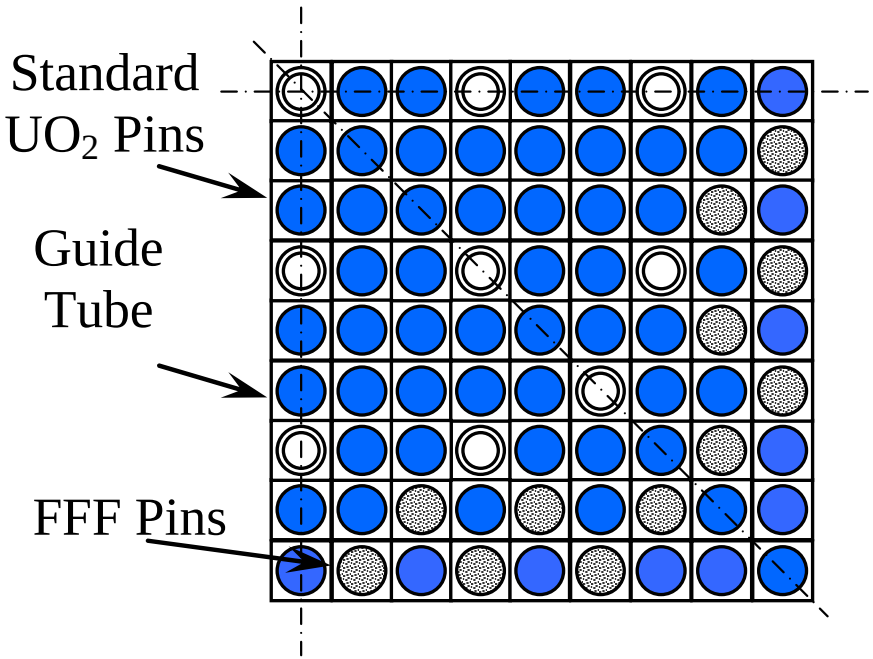
COTTU Assembly Concept

- Combined TRU-ThO_2 and UO_2 Assembly
- Similar to CORAIL and CONFU
- Advantages of using Thorium
  - Existing experience as a fuel
  - Limits TRU generation
  - Efficient TRU destruction
  - Low TRU inventory
  - Some experience with reprocessing
- Drawbacks
  - Reprocessing is more difficult than U-MOX
  - Handling issues due to U232

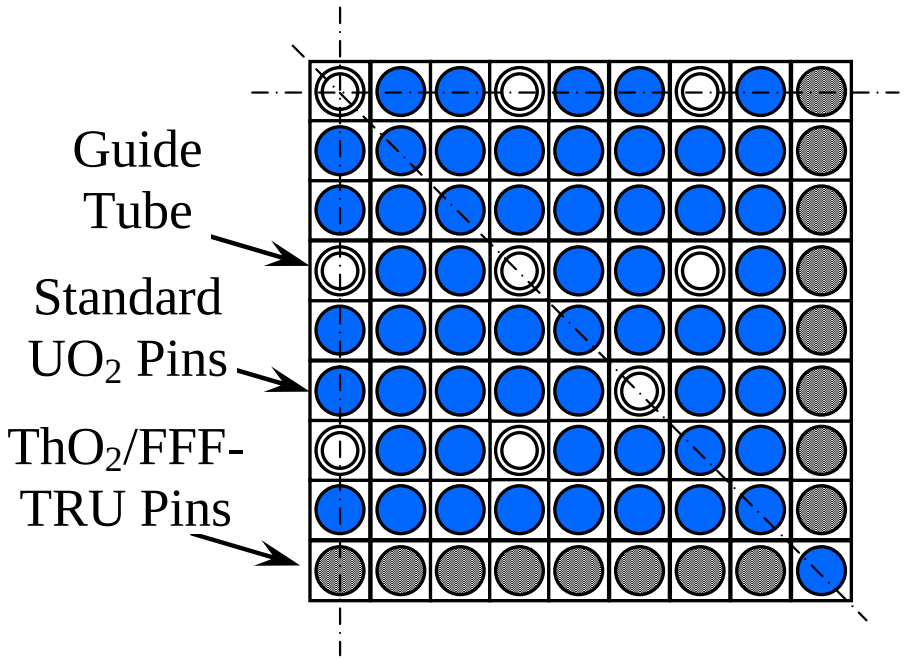
Calculated Cases

- CONFU-1:
  60 FFF-TRU pins per assembly, “small” TRU inventory
- CONFU-2:
  48 FFF-TRU pins per assembly, “large” TRU inventory (equilibrium cycle only)
- COTTU-1:
  60 Th-TRU pins per assembly, 233U recycled together with TRU in Th pins
- COTTU-2:
  60 Th-TRU pins per assembly, 233U recycled separately from TRU in UO2 pins
- UO2:
  Standard Reference UO2 fuel, 4.2% enrichment

CONFU and COTTU Assembly Options



CONFU-2



CONFU-1, COTTU-1, COTTU-2

Calculation Methodology

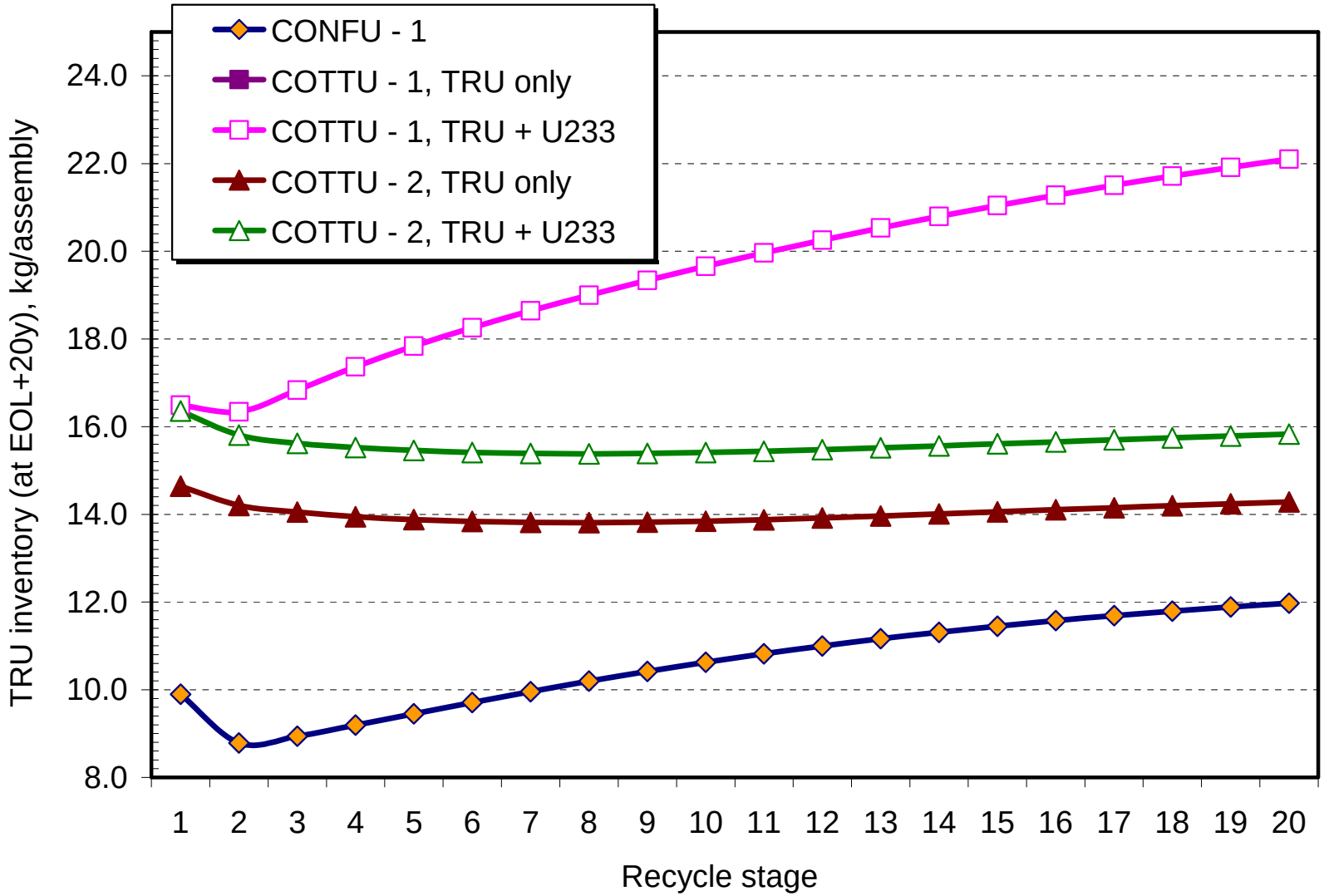
- Typical PWR 17x17 fuel assembly geometry
- Typical PWR operating conditions
- 2-D Assembly level calculations
- CASMO-4 code
- Linear reactivity model, 3% leakage reactivity
- 3-batch core, 18 Months cycle
- 20 years decay time between TRU recycles

Results

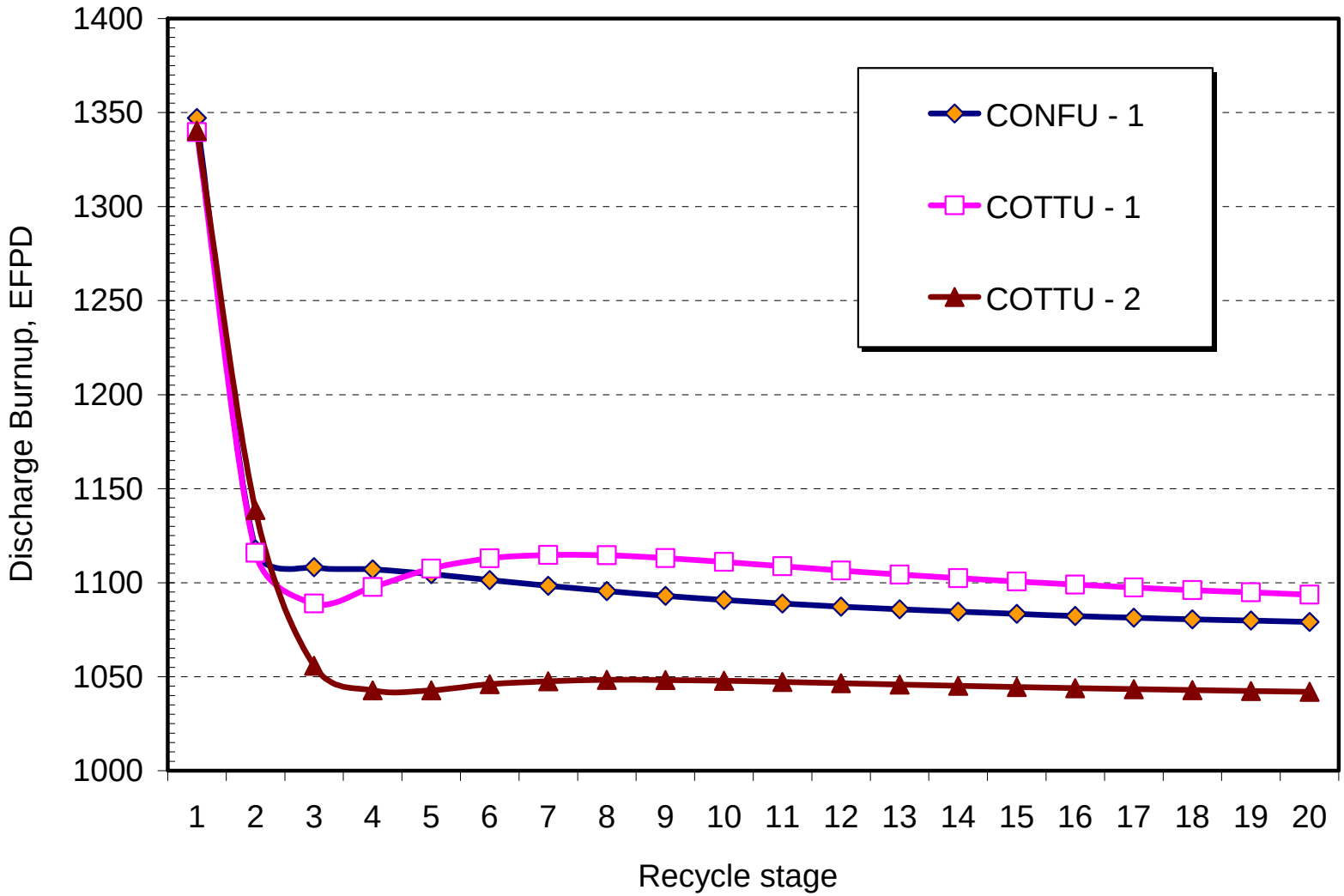
Concepts Comparison

	CONFU-1	CONFU-2	COTTU-1	COTTU-2	Reference UO_2
UO_2 loading, kg/assembly	355	375	355	353	459
UO_2 enrichment, w/o	5	5	5	5	4.2
TRU loading (BOL), kg/assembly	12.5	17.5	23.5	16.0	-
No. of TRU pins per assembly	60	48	60	60	-
TRU pin composition, v/o Matrix:(TRU)O2	89:11	80:20	78:22	87:13	-
Net TRU production, kg/assembly	0.0	- 0.1	- 0.1	0.0	+ 5.7
Discharge assembly burnup, EFPD	1298	1348	1336	1267	1330
Max. assembly pin power peaking factor	1.18	1.21	1.25	1.22	1.06

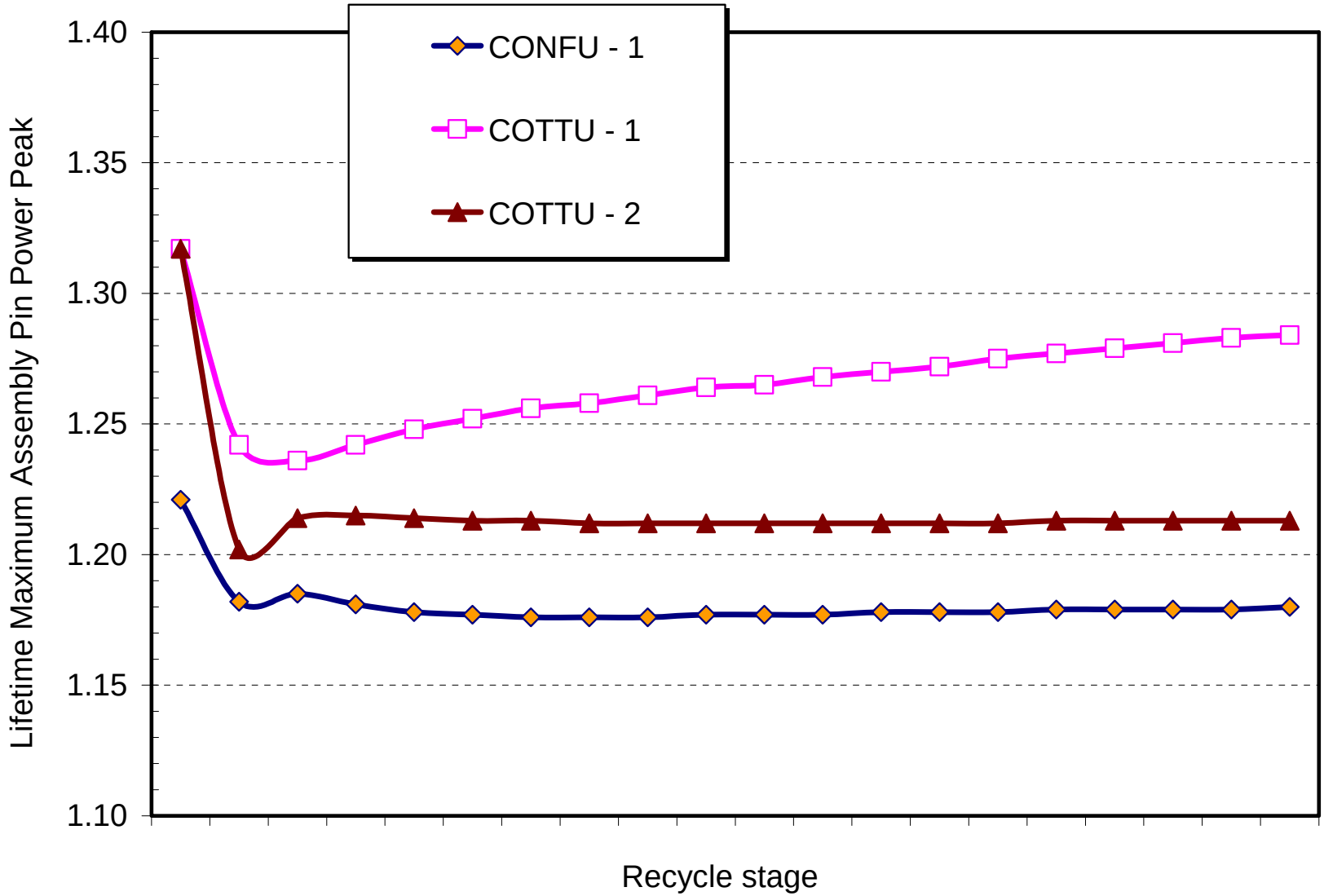
Results: TRU Inventory, kg/assembly



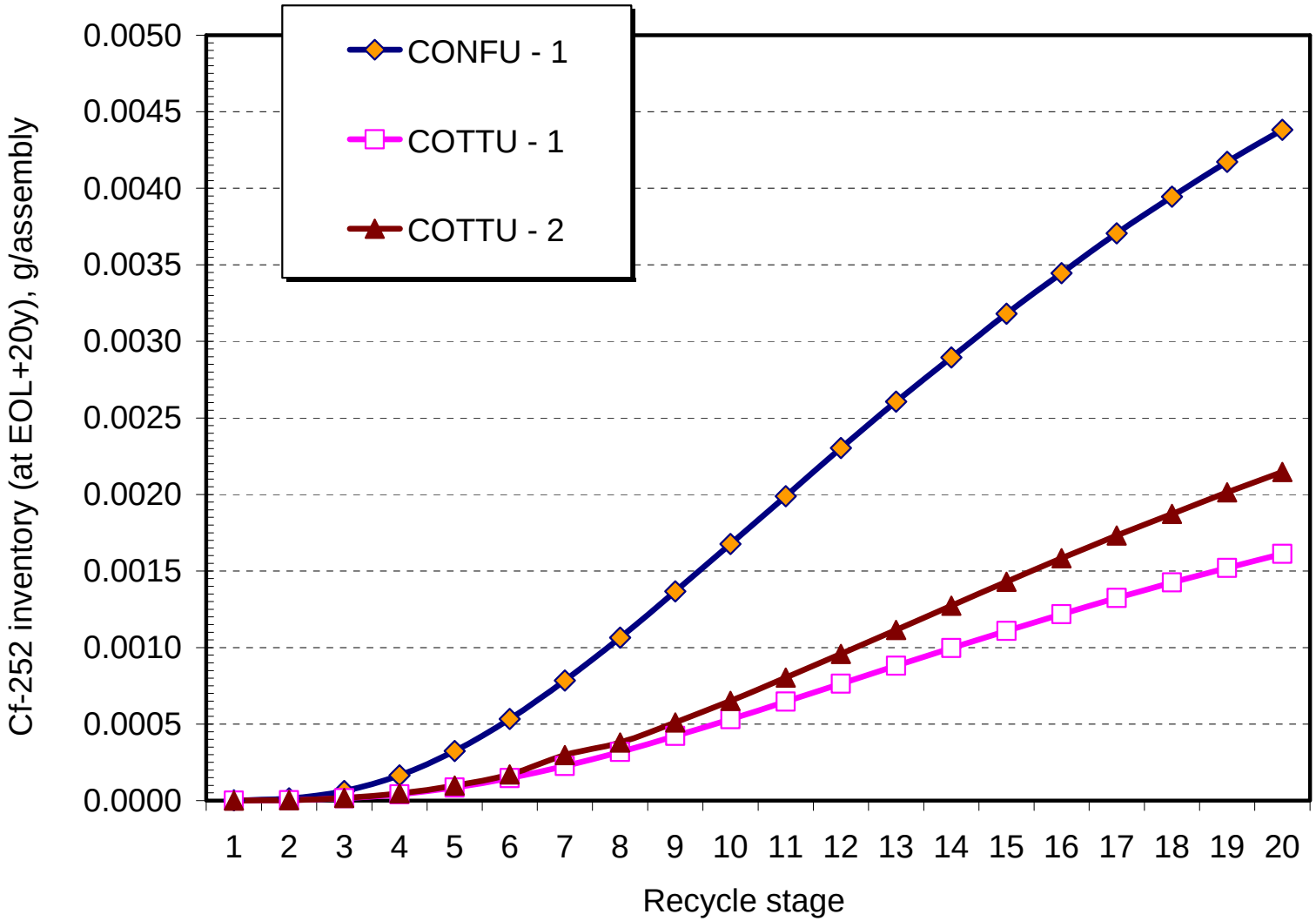
Results: Discharge Burnup



Results: Pin Power Peaking Factors



Results: Cf-252 Inventory, g/assembly



Reactivity Coefficients

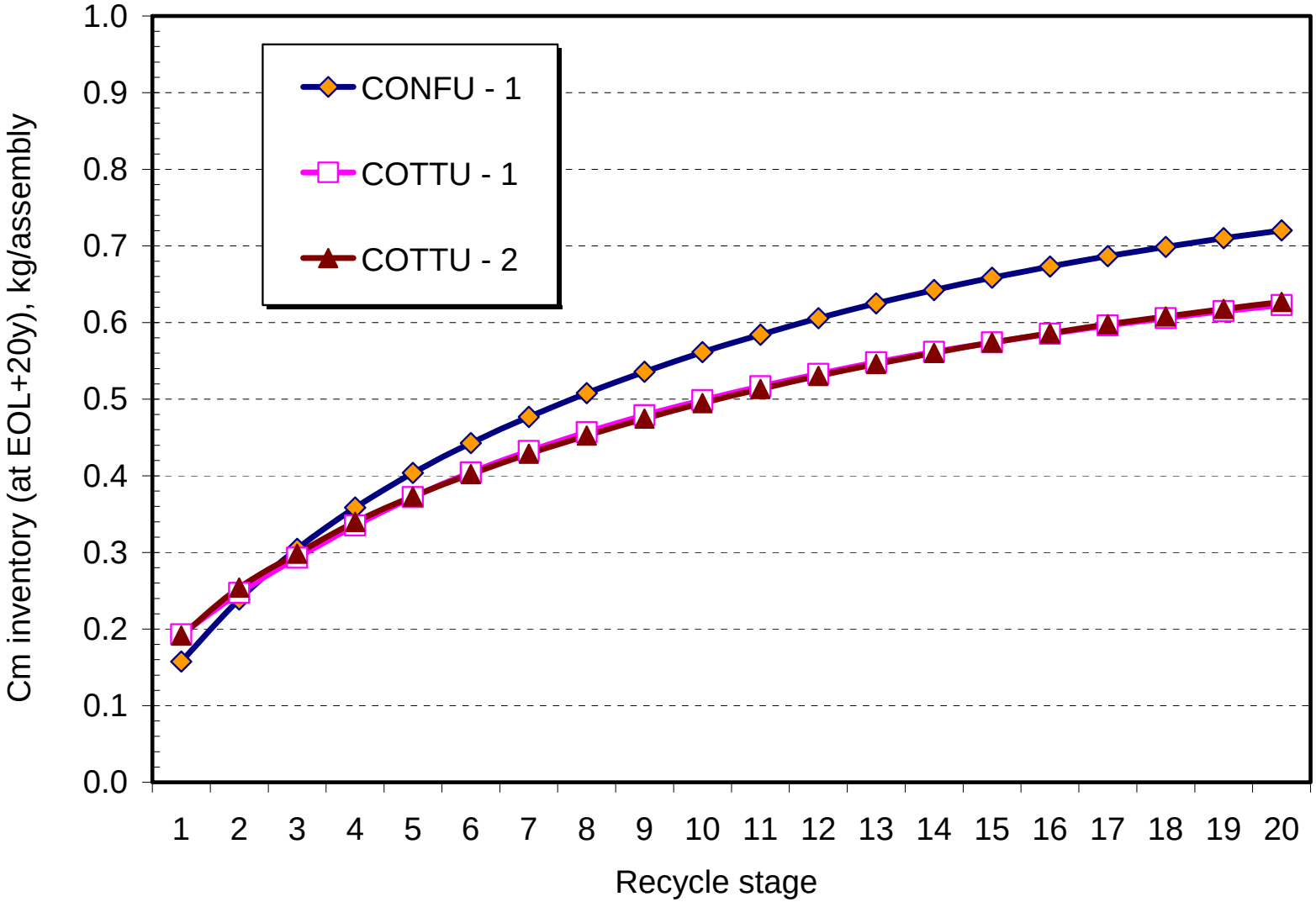
		CONFU-2	COTTU-1	Reference UO_2
Doppler coefficient (BOL), pcm/K	1st recycle	-1.77	-2.14	-2.03
	3rd recycle	-1.99	-2.30	
	15th recycle	-2.00	-2.34	
Moderator Temperature Coefficient (BOL), pcm/K	1st recycle	-17.8	-24.9	-11.26
	3rd recycle	-20.6	-26.8	
	15th recycle	-20.8	-27.0	
Soluble Boron Worth (BOL), pcm/ppm	1st recycle	-4.93	-4.99	-6.11
	3rd recycle	-5.69	-5.30	
	15th recycle	-5.71	-5.42	

Summary and Conclusions

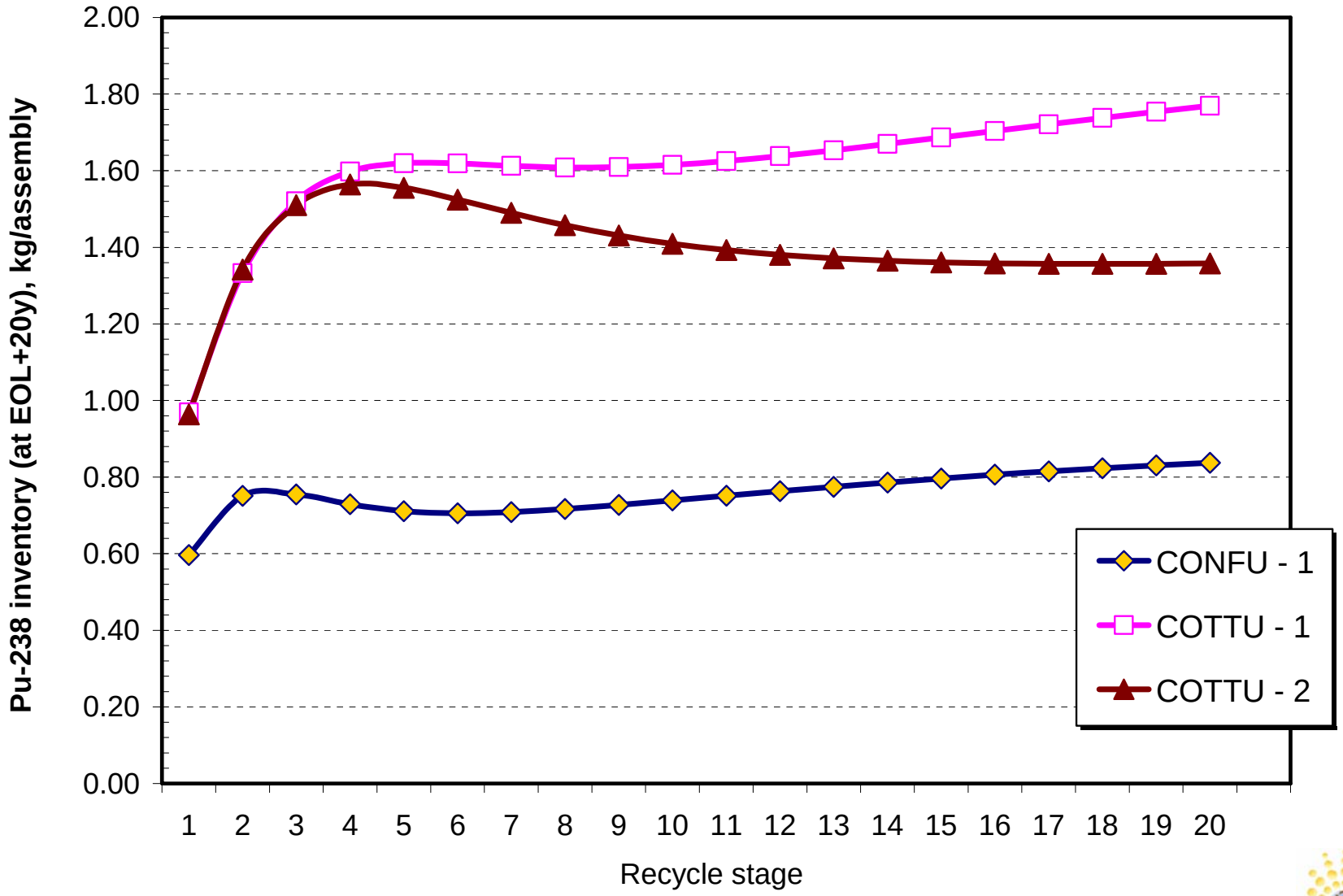
- Zero net TRU production can be achieved with COTTU assembly
- TRU inventory is larger for COTTU than for CONFU due to generation of U233
- Degradation of TRU isotopics requires an increase in UO2 pins enrichment to 5%
- Similar to CONFU, the COTTU concept appears to be practical – reactivity coefficients and power peaking are acceptable
- Cm and Cf252 builds up slower in COTTU than in CONFU
- Recycling U233 in UO2 improves pin power peaking but reduces cycle length
- Existing experience with Th fuel - main advantage over CONFU

BACKUP SLIDES

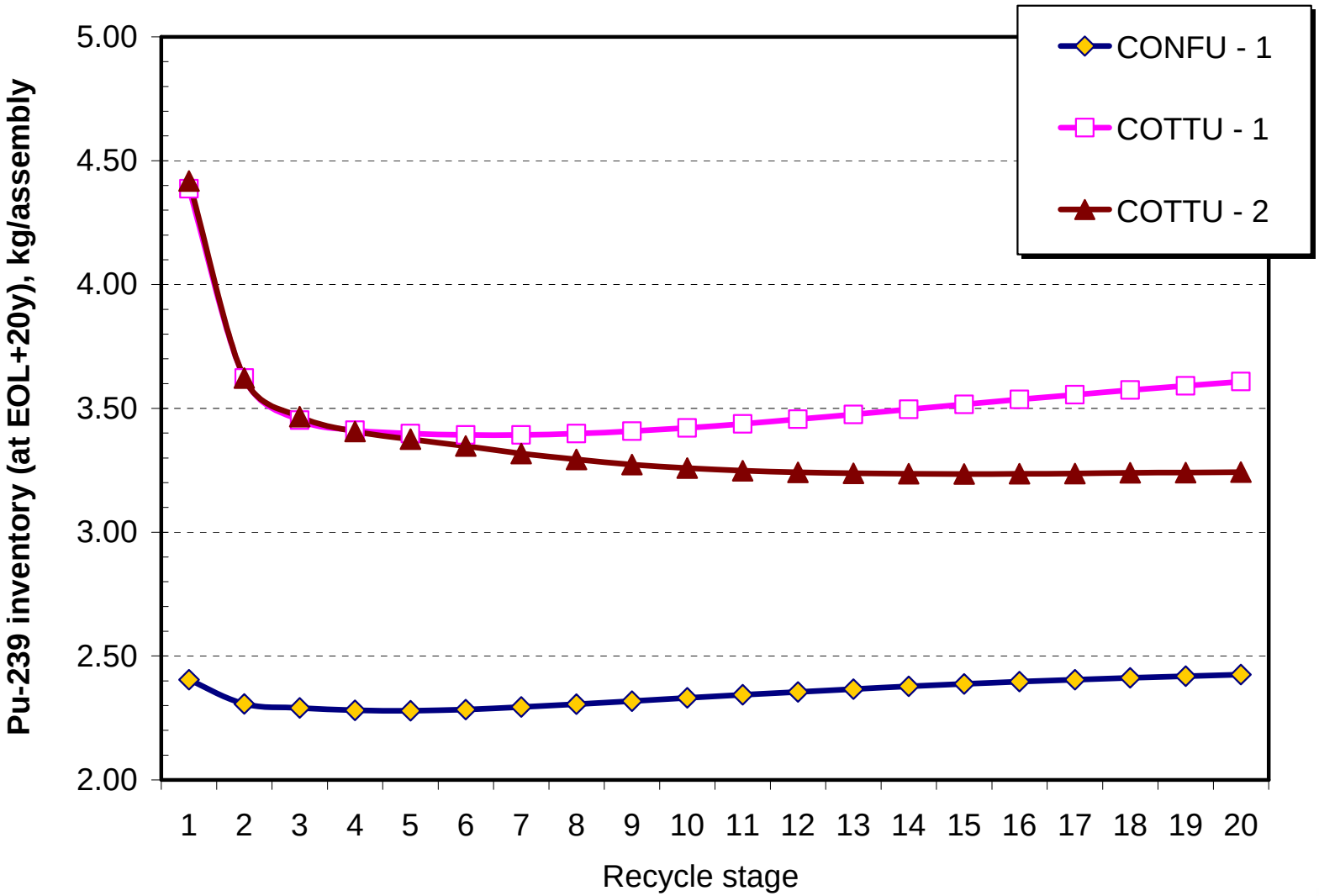
Cm Inventory



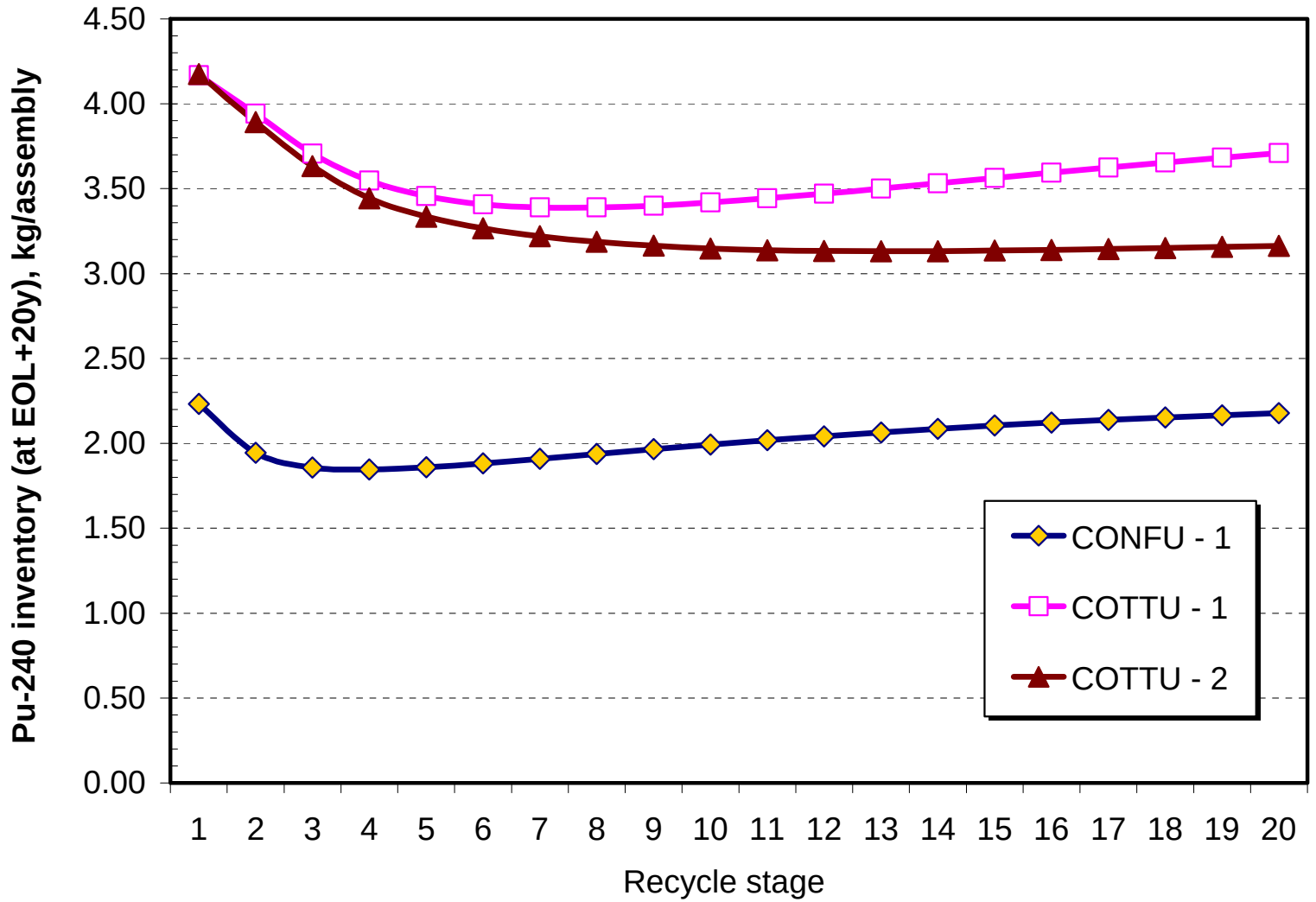
Pu-238 Inventory



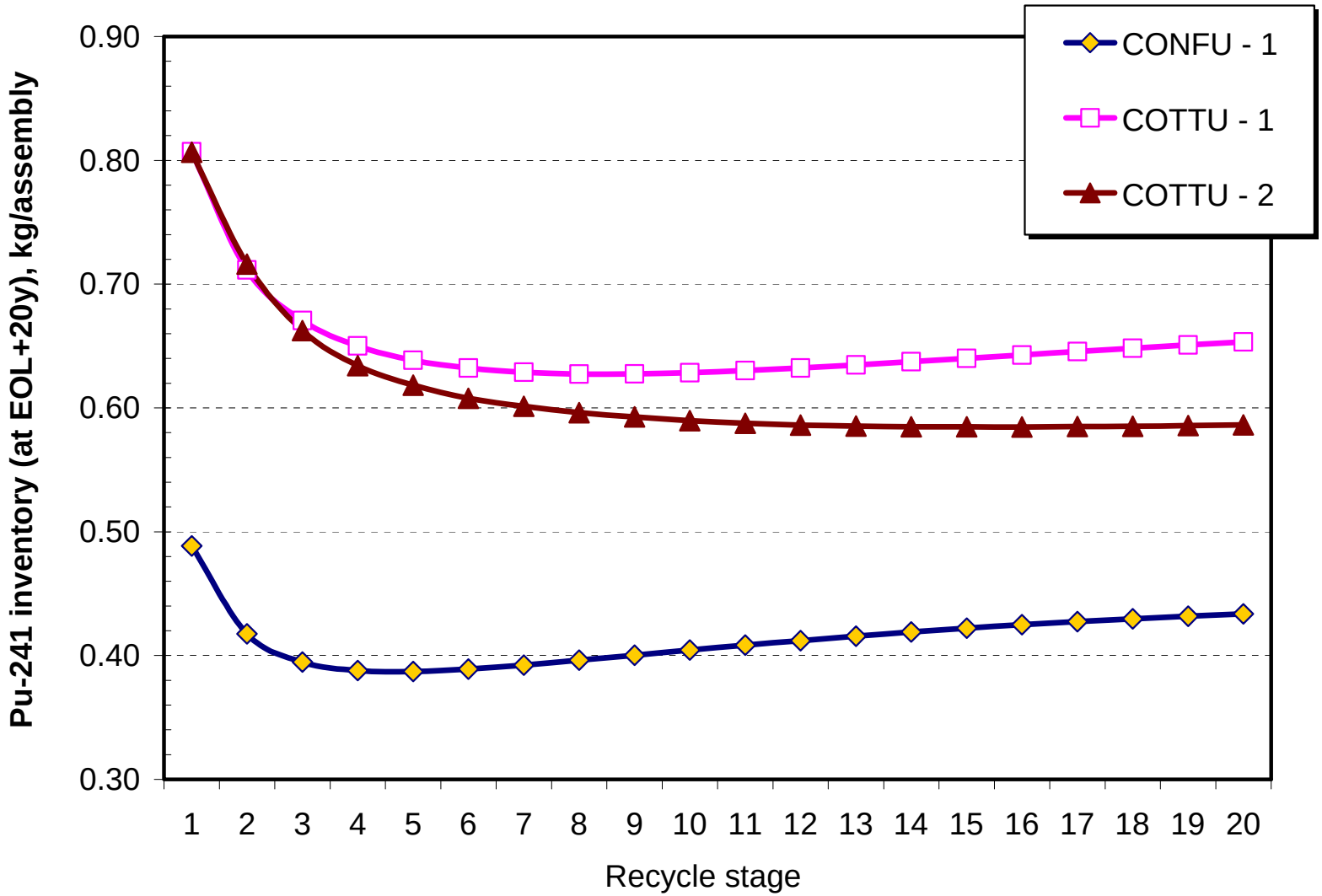
Pu-239 Inventory



Pu-240 Inventory



Pu-241 Inventory



Pu-242 Inventory