Core Performances and Safety Implications of TRU Burning Medium to Large Fast Reactor Core Concepts

The 10th IEMPT
Mito, Japan
6-10 October 2008

Hoon Song, Sang-Ji Kim, Jinwook Jang, Yeong-Il Kim

KAERI
Korea Atomic Energy Research Institute

Outline

KAERI
Korea Atomic Energy Research Institute

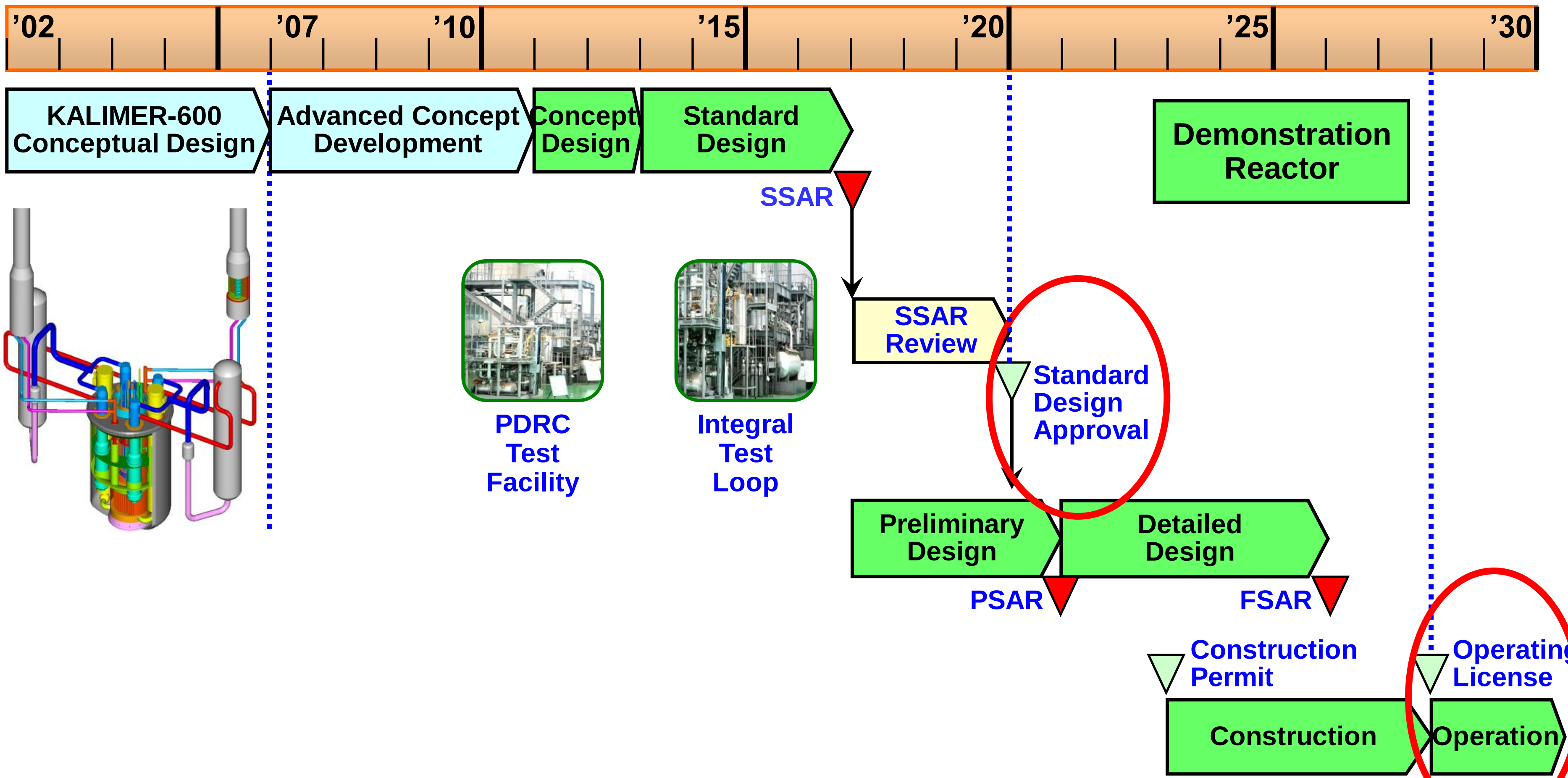
Status of Spent Fuel Storage in Korea

- On-site SF storage limit will be reached from 2016
- Decision making process for interim SF storage

NPP Sites	As of December 2007			Expansion Plan	
	Cumulative Amount (MTU)	Storage Capacity (MTU)	Year of Saturation	Storage Capacity (MTU)	Year of Saturation
Kori	1,623	2,253	2016	2,253	2016
Yonggwang	1,491	2,686	2016	3,528	2021
Ulchin	1,214	1,642	2008	2,326	2018
Wolsong	5,092	5,980	2009	9,155	2017
Total	9,420	12,561		17,262	

Draft Action Plan for SFR Development

- Prepared by MEST in December 2007
- Finalization process is on-going



KAERI Korea Atomic Energy Research Institute

Objectives

- Investigate TRU burning capability from Medium to Large Fast Reactor Cores
  - 600, 1200 & 1800 MWe
  - Core performances
  - Reactivity coefficients

- Identify the most limiting factor in scaling up core concepts
  - Provide guidance to future R&D directions for economic burning of TRU
  - Achieve maximum benefit in the view point of size of economy

Design Constraints and Targets

	TRU Burner
Design Constraints	-TRU enrichment ≤ 30 wt% -Peak fast neutron fluence < 5.0×10^{23} n/cm^2 -Maximum linear heat generation < 350 W/cm -Maximum cladding inner wall temperature < 650 °C
Design Target	- Maximum pressure drop < 0.15 MPa - TRU conversion ratio ~ 0.6 - Sodium void worth < 7.5 $

KAERI Korea Atomic Energy Research Institute

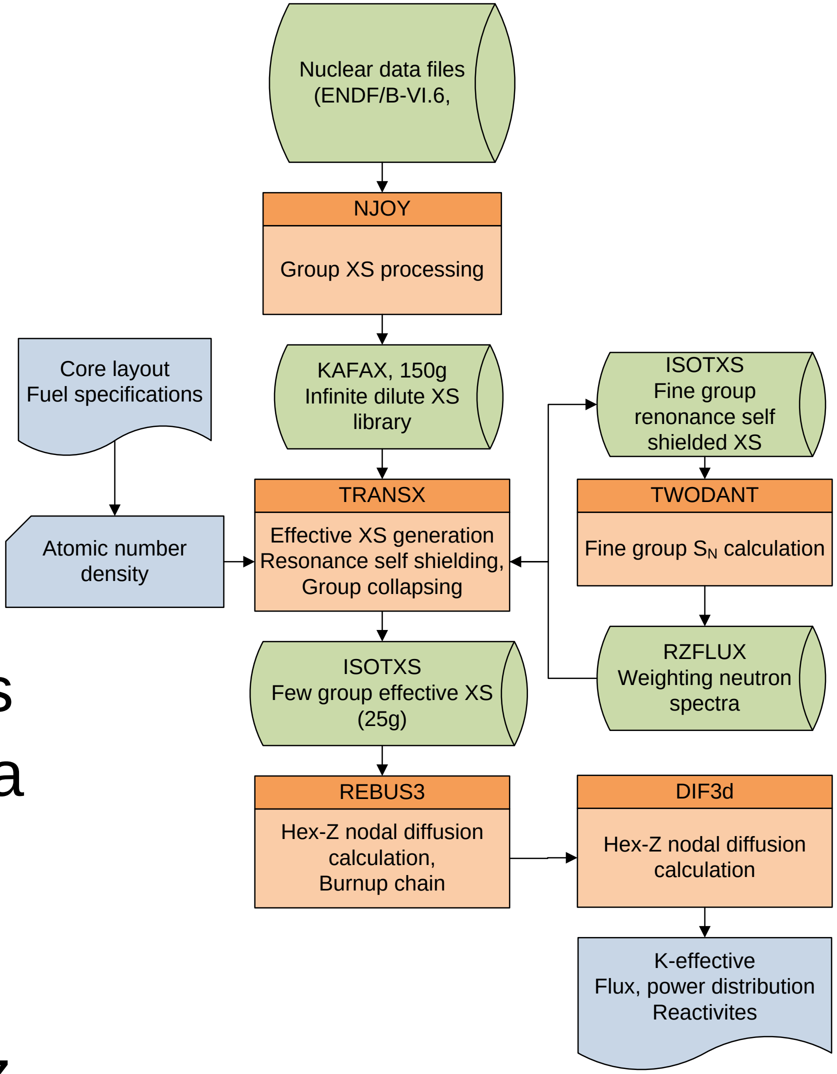
Design Approaches

- Single enrichment
  - Changing cladding thicknesses for power flattening
  - To reach TRU enrichment close to the target 30 wt%
  - Enhance TRU burning than enrichment split approach

- For a consistent comparison with three power levels
  - Region-wise cladding thicknesses are the same
  - Make similar linear power ~ 180 W/cm
  - Adjust active core height to reduce sodium void worth
  - Adjust pitch to diameter ratio to reduce max. pressure drop

Calculation Methods (I)

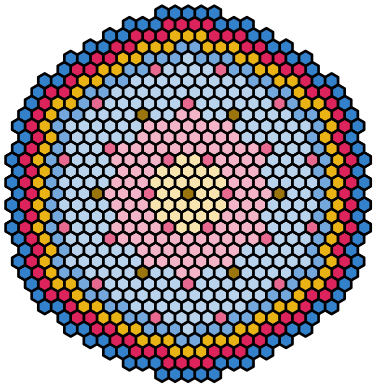
- Master library processing (KAFAX/E66)
  - NJOY
  - ENDF/B-VI.6
- Effective XS generation
  - TRANSX
  - Bondarenko f-factor method
  - Collapse to broad 25 groups
  - Region-wise neutron spectra by TWODANT, R-Z
- Burnup calculation
  - REBUS3 : 25 groups, Hex-Z

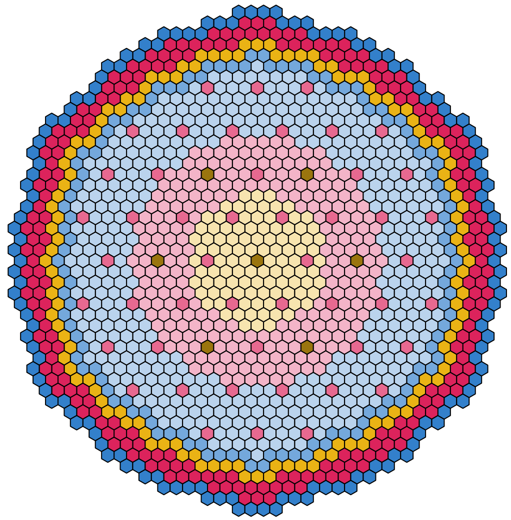


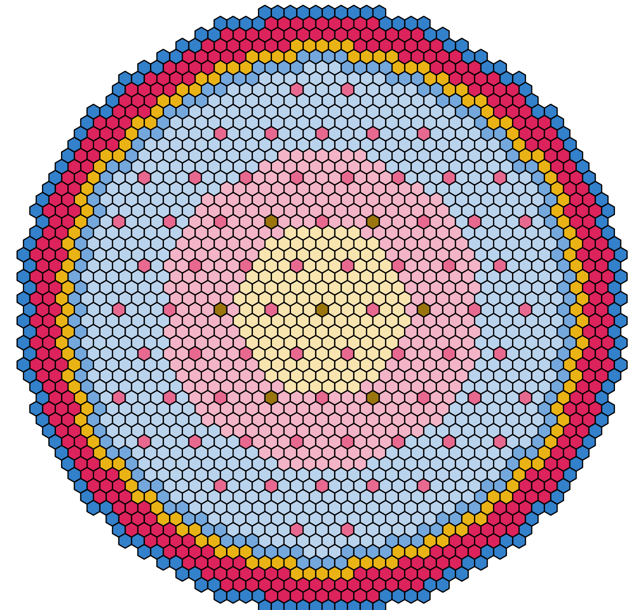
Calculation Methods (II)

- Core physics parameter calculation
  - Neutron flux calculation
    - DIF3D: hex-z model, coarse-mesh nodal diffusion approximation
  - Reactivity parameter calculation
    - PERT-K : First order perturbation theory
    - BETA-K : Beta-effective

Layout of the Designed TRU Burners







CORE1	30	336
CORE2	102	
CORE3	204	
Primary CR	24	31
Secondary CR	7	
Reflector	78	
B_4C Shield	84	
IVS	90	
Radial Shield	96	

600MWe

CORE1	102	786
CORE2	246	
CORE3	438	
Primary CR	48	55
Secondary CR	7	
Reflector	114	
B_4C Shield	120	
IVS	216	
Radial Shield	138	

1,200MWe

CORE1	156	1230
CORE2	378	
CORE3	696	
Primary CR	66	73
Secondary CR	7	
Reflector	138	
B_4C Shield	144	
IVS	330	
Radial Shield	162	

1,800MWe

Design Parameters

- Active core heights are reduced as power level increases to reduce the sodium void worth
- Core shapes tend to be pancake as power level increases

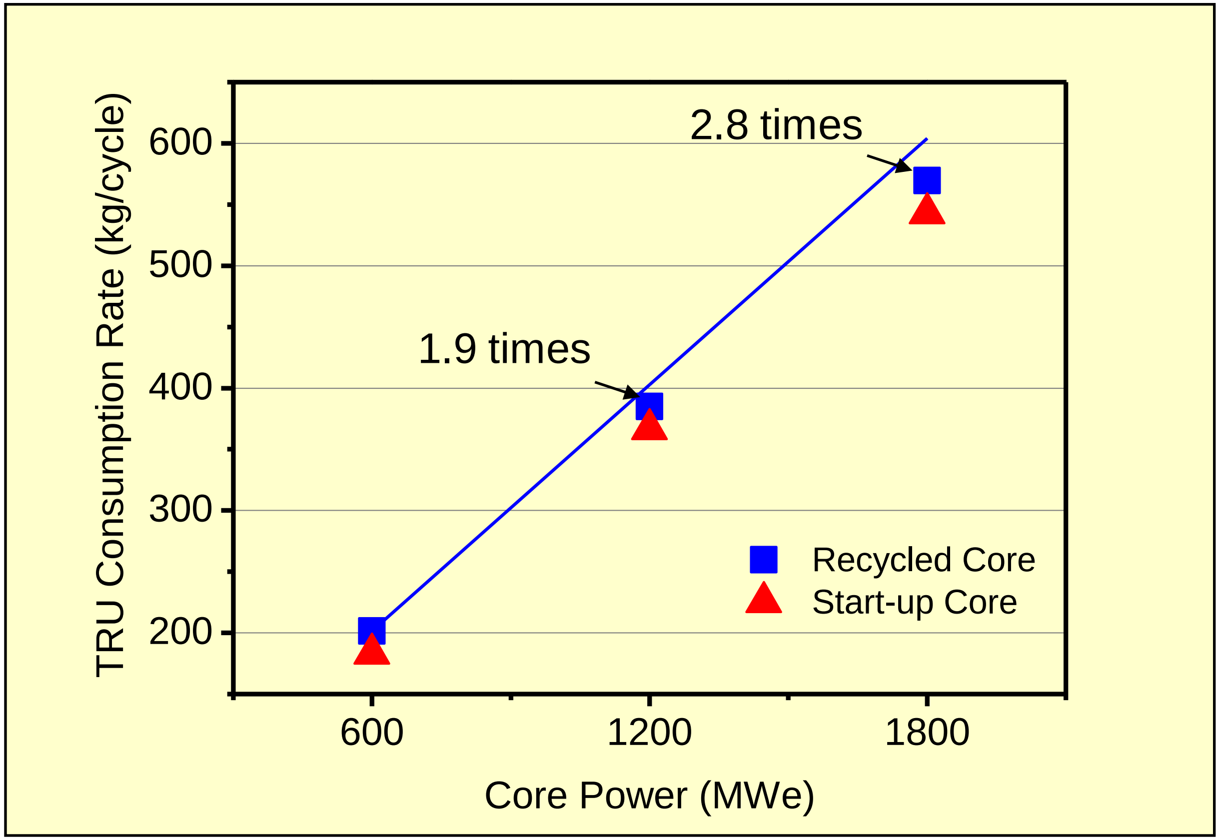
	600MWe	1,200MWe	1,800MWe
Coolant Inlet/Outlet Temperature (℃)	390/545		
Number of Fuel Assemblies	336	786	1230
Assembly Pitch (cm)	16.1	15.9	15.9
Fuel Outer Diameter (mm)	7.0		
Pin Pitch (mm)	8.89	8.79	8.79
P/D Ratio	1.270	1.256	1.256
Cladding Thickness (mm) Inner/Middle/Outer	1.05/0.91/0.77		
Active Core Height (cm)	85.0	73.5	70.0
Eq. Core Diameter (m)	3.09	4.68	5.86
Eq. Reactor Diameter (m)	4.51	6.31	7.61

Core Performances

	600MWe	1,200MWe	1,800MWe
Charged TRU (wt%)	29.92	29.16	28.92
Conversion Ratio (Fissile/TRU)	0.74/0.57	0.76/0.58	0.76/0.59
Burnup Reactivity Swing (pcm)	3,671	3,512	3,508
Cycle Length (EFPD)	332	332	332
Sodium Void Worth (BOEC/EOEC)	6.68/7.28	6.91/7.52	6.87/7.55
Peak Fast Neutron Fluence (n/cm^2)	4.64	4.31	4.42
Max. Pressure Drop (MPa)	0.156	0.136	0.134
Max. Cladding Inner Wall Temp.(℃)	591	576	572
Average Linear Power (W/cm)	180.4	178.1	179.1
Power Peaking Factor	1.52	1.48	1.55
TRU Consumption Rate (kg/cycle)	201.4	384.9	569.5

TRU Consumption Rate

- ❑TRU consumption rate is increased almost the same rate
- ❑Little preference at any power level with the same TRU enrichment



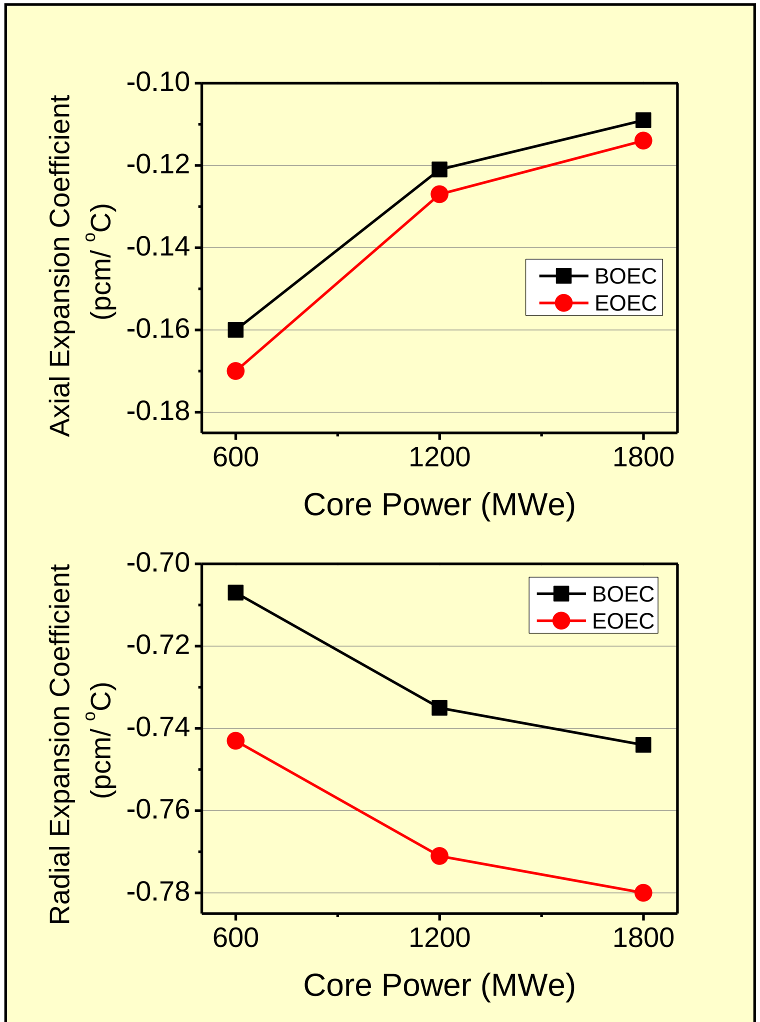
Reactivity Coefficients

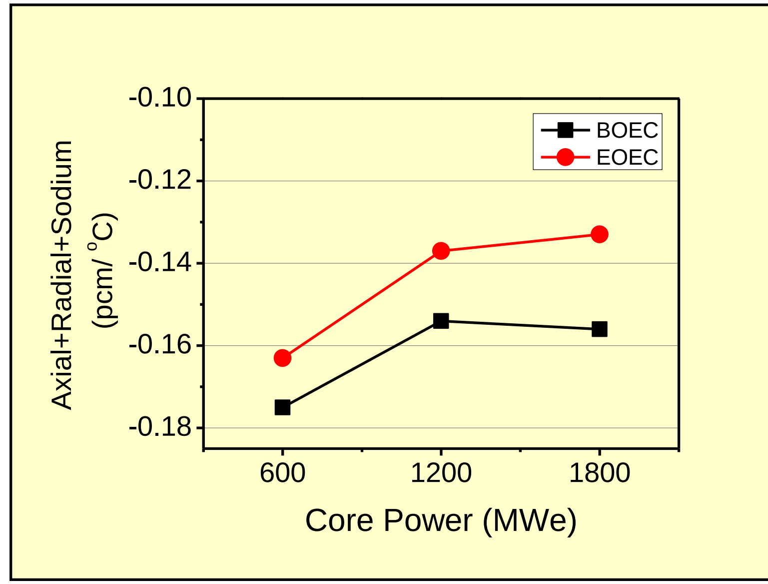
- Core with an increased power rating
  - Less negative axial expansion coefficient
  - More negative radial expansion coefficient
  - Constant sodium density coefficient

	600 MWe		1,200 MWe		1,800 MWe	
	BOEC	EOEC	BOEC	EOEC	BOEC	EOEC
Doppler coefficient (pcm/ ^{o}C)	-804.5 $T^{-1.113}$	-801.6 $T^{-1.109}$	-819.3 $T^{-1.109}$	-816.6 $T^{-1.106}$	-835.1 $T^{-1.110}$	-834.3 $T^{-1.107}$
Axial expansion coefficient (pcm/ ^{o}C)	-0.160	-0.170	-0.121	-0.127	-0.109	-0.114
Radial expansion coefficient (pcm/ ^{o}C)	-0.707	-0.743	-0.735	-0.771	-0.744	-0.780
Sodium density coefficient (pcm/ ^{o}C)	0.692	0.750	0.702	0.761	0.697	0.761
Sodium void worth ($)	6.68	7.28	6.91	7.52	6.87	7.55

Reactivity effects

- Minor effects on the reactivity with a higher power





KAERI
Korea Atomic Energy Research Institute

Summary & Future Works

- Investigate the performances and reactivity coefficients from medium to large TRU burners
  - Almost the same TRU burning rate per power
  - Little preference at any power level with the same TRU enrichment
  - Minor effects on the reactivity with a higher power

- Future works
  - Conversion ratio changes of these designed cores
  - Safety evaluation of the designed cores
  - Overall evaluation of core designs to determine an optimum power level and optimum conversion ratio

Thank you for your attention