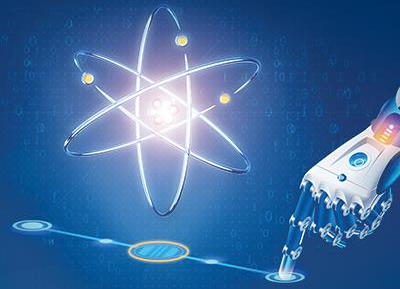
SCIENTIFIC FORUM
NUCLEAR ENERGY FOR CLIMATE



Thorium: Fuel Cycle, Potential Advantages, Challenges, and Prospective Reactors

Nuri Trianti

Research Organization for Nuclear Energy
National Research and Innovation Agency, Republic of Indonesia

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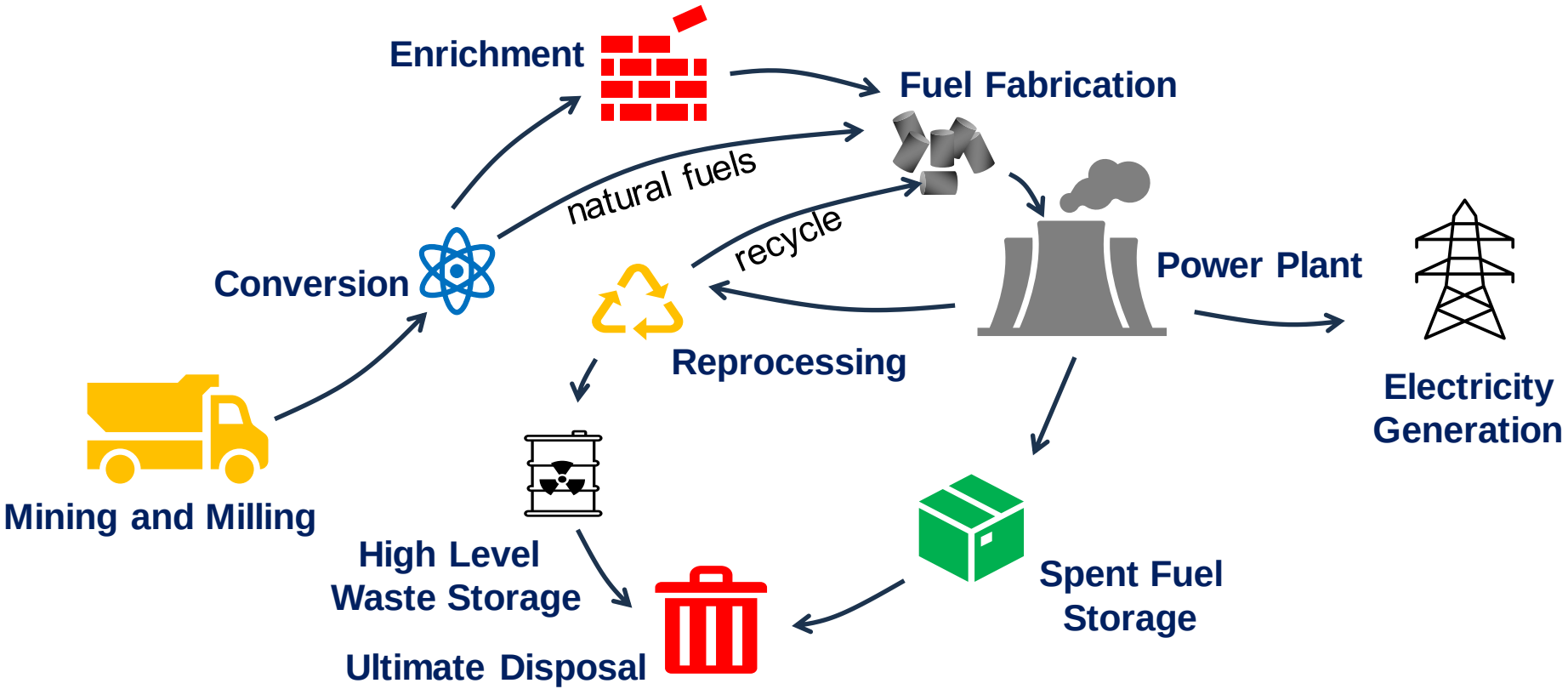
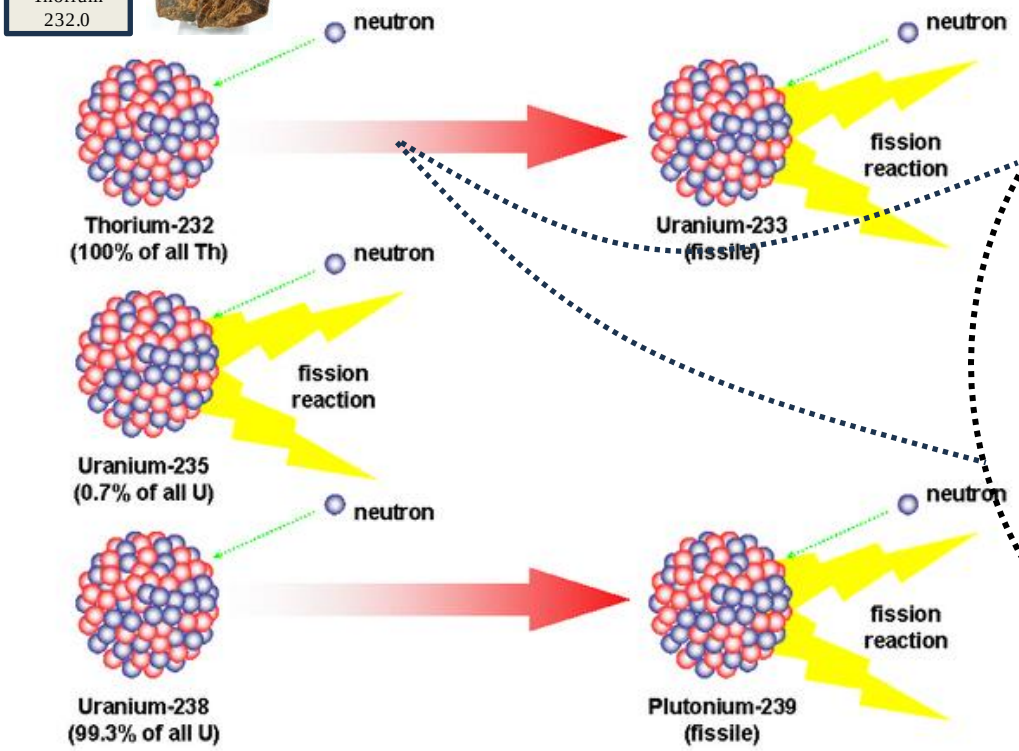
2023

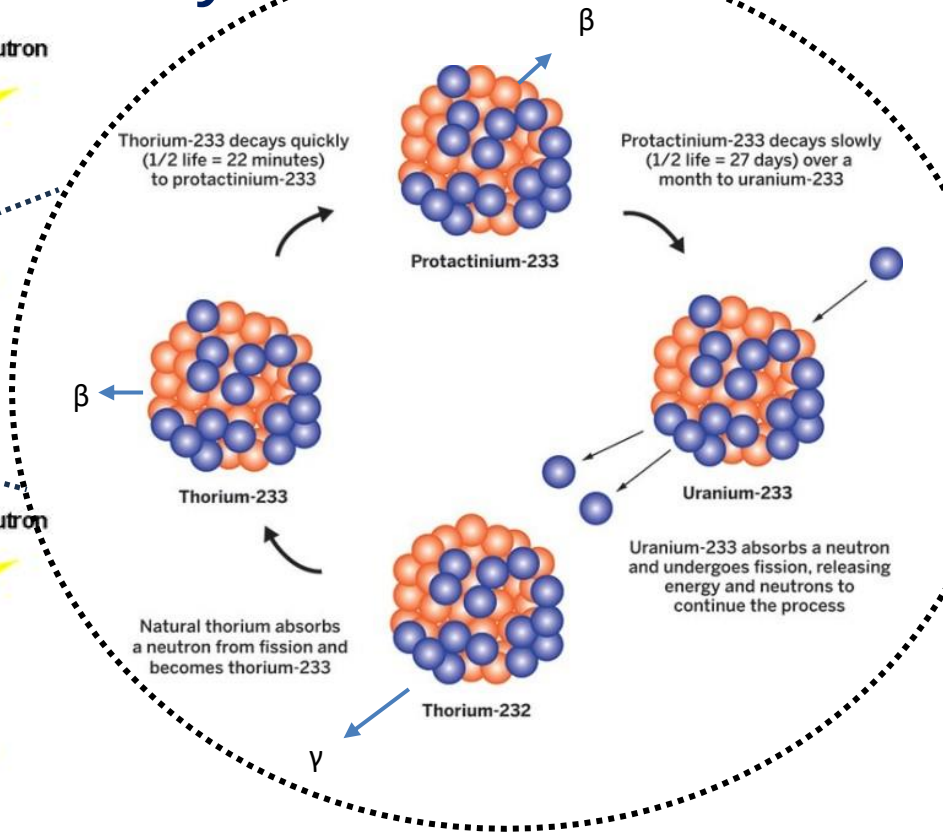
Nuclear Fuel Cycle in General



Thorium Fuel Cycle

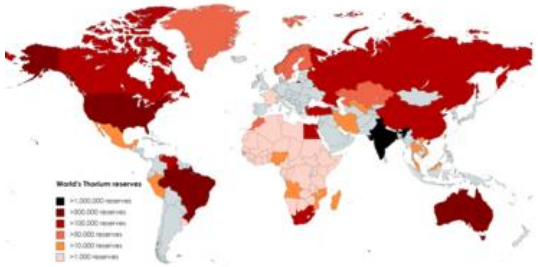
90
Th
Thorium
232.0





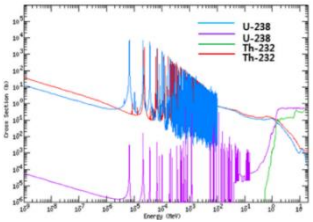
Chemical & Engineering News **2015**, *93*(27). *Nuclear Engineering and Technology* **2019**, *51*, 631-640

Potential Advantages of Thorium



3X more abundant than Uranium

U.S. Geological Survey

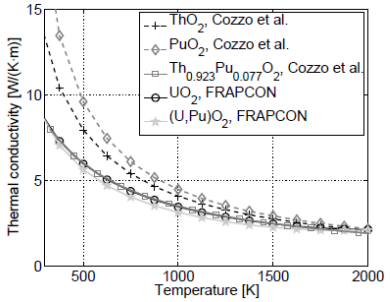


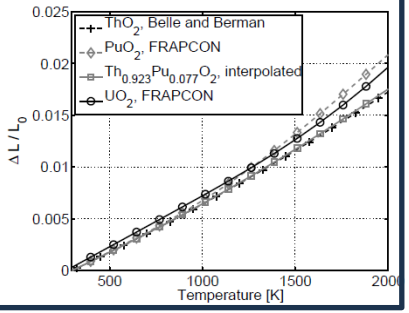
3X higher capture cross-section for thermal neutrons than ^{238}U

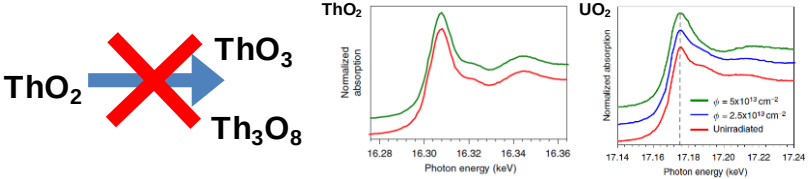
Annals of Nuclear Energy **2015**, *85*, 58-67

Favorable thermophysical properties

Annals of Nuclear Energy 75 (2015) 79–86







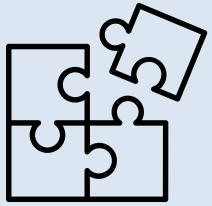
Nature Communications **2014**, *6:6133*

Good chemical and radiation stability

More proliferation-resistance

Progress in Nuclear Energy **2016**, *93*, 306e317; *Nuclear Engineering and Design* **2014**, *271*, 106–113; *Thorium fuel cycle — Potential benefits and challenges*, IAEA-TECDOC-1450 (2005)

Challenges of Thorium-based Fuel



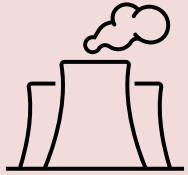
Lack of Infrastructure

Limited Operational Experience

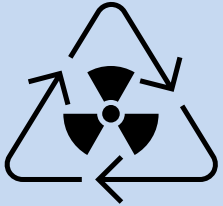
Low-demand of Thorium mineral source, yet

Relatively expensive extraction cost

Economic Viability



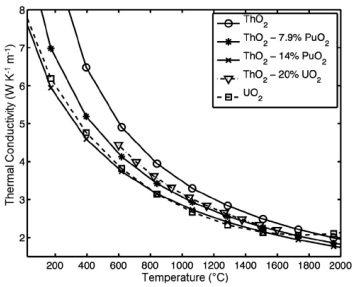
Reactor Design Complexity

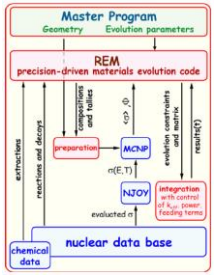


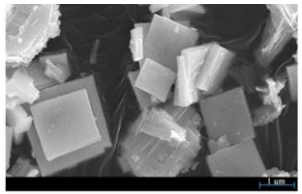
Waste Management

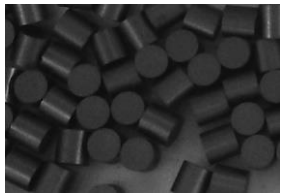
Nuclear Engineering and Design **2014**, *271*, 106–113; *The Thorium Fuel Cycle*, UK National Nuclear Laboratory (2010), *Thoriumfuel cycle — Potential benefits and challenges*, IAEA-TECDOC-1450 (2005)

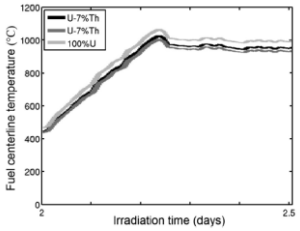
Strategies to Introduce Th-based Nuclear Fuel

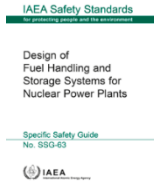












- Characterizations of basic physico-chemical data at laboratory scale
- Qualification of reactor-physics and safety codes
- Testing and qualification of fuel fabrication technology
- Execution of irradiation experiments and integral testing
- Post-irradiation analyses aimed at fuel rod/assembly characterization
- Re-evaluation of safety documents of reactors and fuel cycle facilities

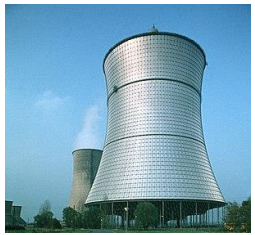
Progress in Nuclear Energy **2021,** *136,* 103728; *Introduction of Thorium in the Nuclear Fuel Cycle*, NEA no. 7224, © OECD 2015; *Progress in Nuclear Energy* **2014,** *72*, 5e10; *Annals of Nuclear Energy* **2014,** *64,* 421–429

Brief History of Thorium Utilization in Reactors

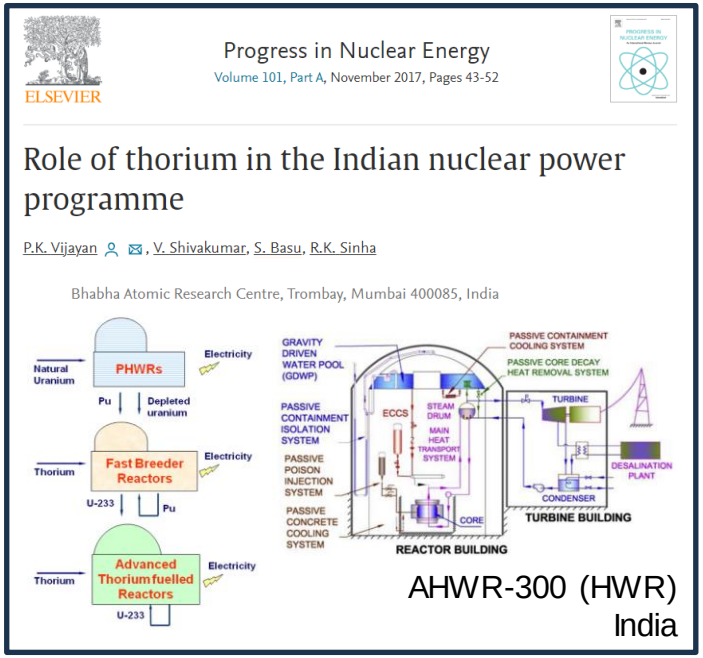
Shippingport (LBWR)
USA

Fort St Vrain (HTGR)
USA

AVR (HTGR)
Germany



THTR-300 (HTGR)
Germany



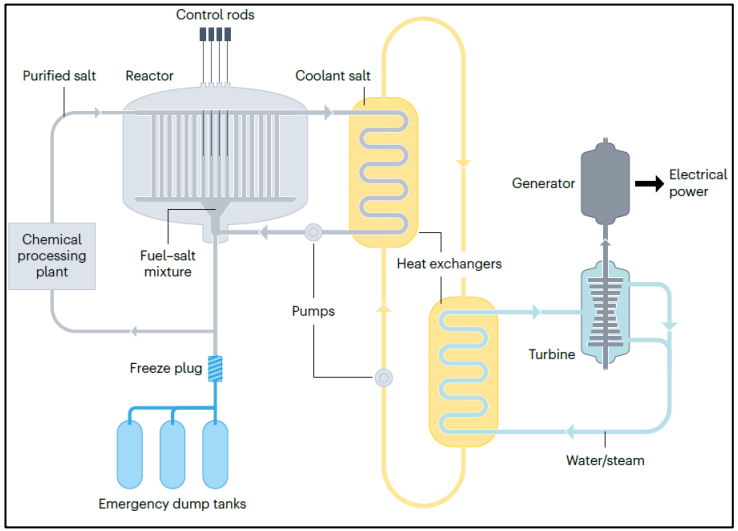
AHWR-300 (HWR)
India

1960 1970 1980 1990 2000 2010 2020

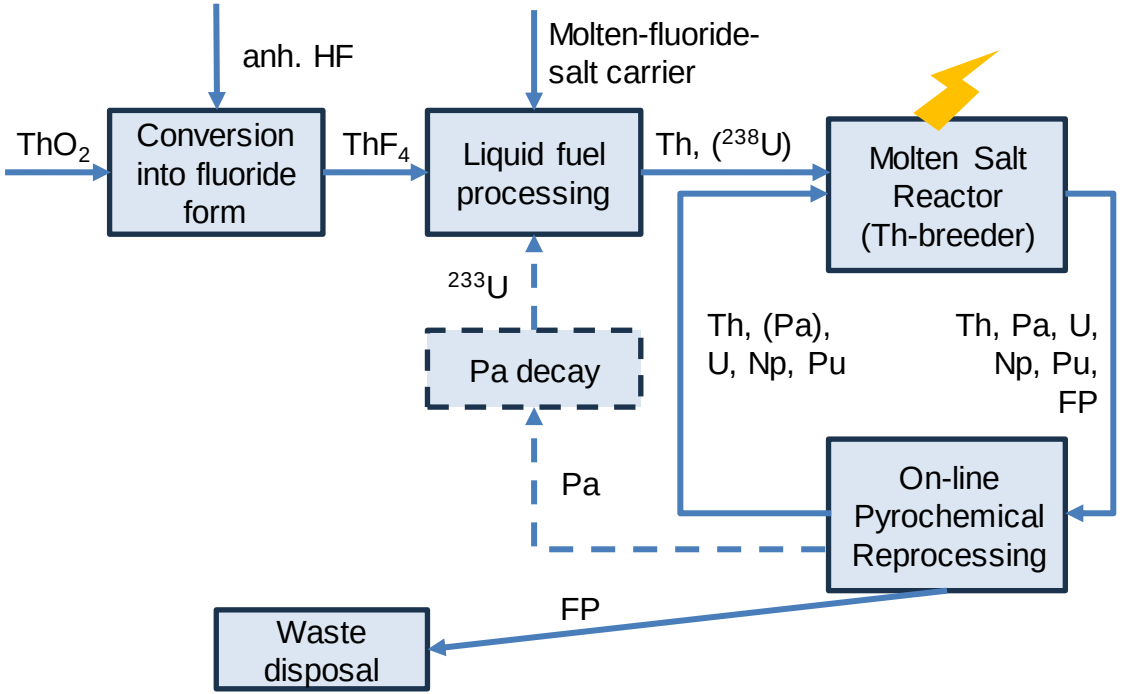
Near Term and Promising Long-Term Options for the Deployment of Thorium Based Nuclear Energy, IAEA-TECDOC-2009 (2022); ; *Role of Thorium to Supplement Fuel Cycles of Future Nuclear Energy Systems*, IAEA Nuclear Energy Series (2012)

Prospective Reactors Using Thorium-based Fuels

Molten Salt Reactor (MSR)



Scheme of fuel cycle of MSR Th-breeder

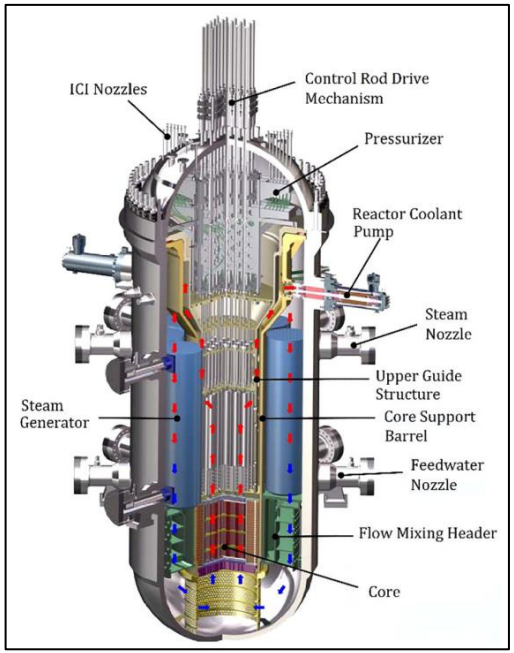


S. Mallapaty, *Nature* **2021,** *597*, 311–312.
US Department of Energy, Nuclear Energy Research Advisory Committee

Jan Uhlíř, 8 - Chemical processing of liquid fuel, Editor(s): Thomas J. Dolan, Molten Salt Reactors and Thorium Energy, Woodhead Publishing, 2017

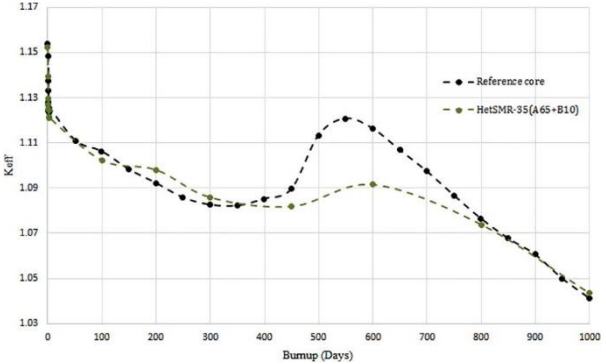
Prospective Reactors Using Thorium-based Fuels

Small Modular Reactor (SMR)

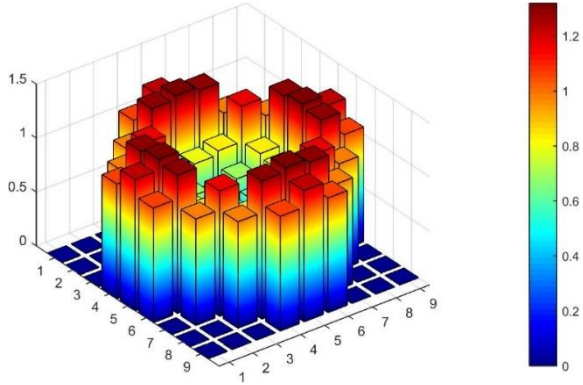


Annals of Nuclear Energy **2018,** *120,* 422–430

Burnup Calculation $(Th/U)O_2$ vs Reference Core



Power Peaking Factor of $(Th/U)O_2$ at the Beginning of Cycle (BOC)



Future Perspectives

- Thorium as a complement to the uranium/plutonium cycle
- Thorium minerals exploration activities need to be increased worldwide
- Develop an industrial-scale reprocessing capability to recover ^{233}U from spent fuel and a fuel fabrication facility
- Increase the initiatives in research and development of thorium-based fuel and reactors
- Clear economic incentives for industries and operators of nuclear power plants using thorium-based fuel

THANK YOU