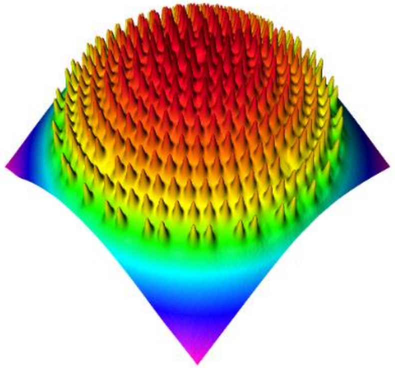
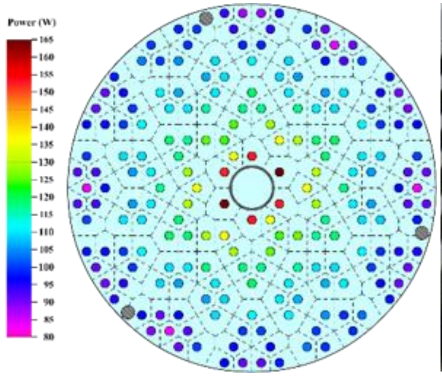
Argonne NATIONAL LABORATORY

Trends and Progress in Research and Test Reactor Design and Deployment





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Outline

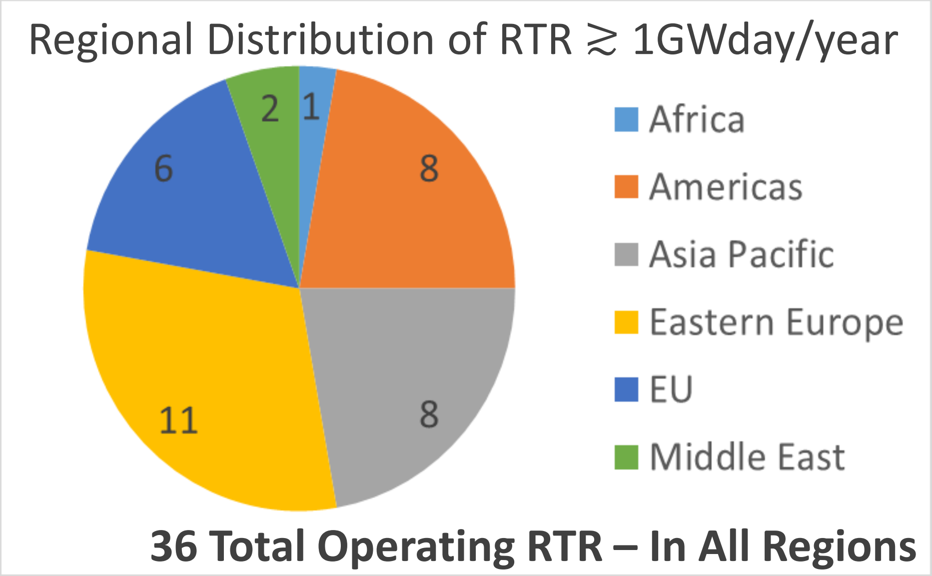
- Research and Test Reactors: U.S. and Worldwide
- Research Reactor Status/Performance
- RTR & HALEU Deployment

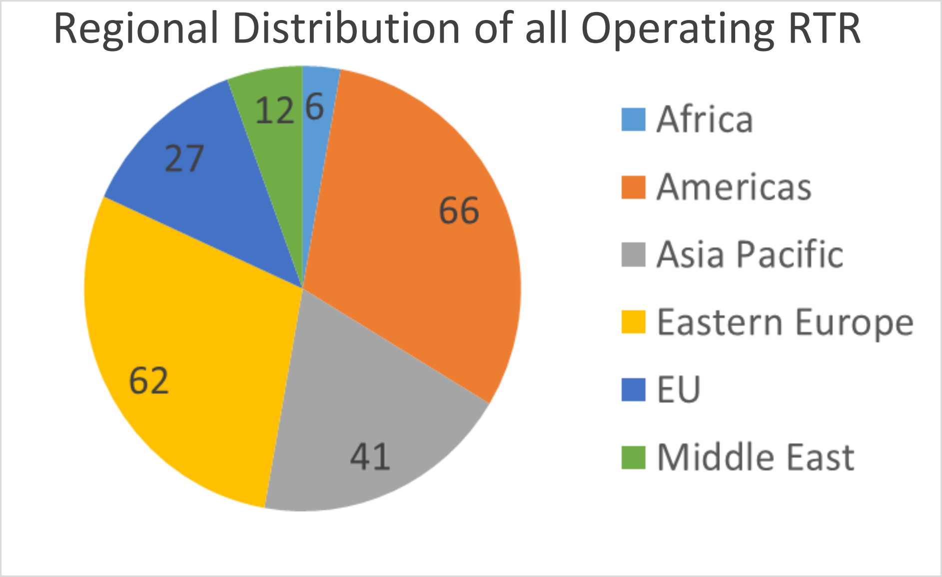
Research and Test Reactors: U.S. and Worldwide

Distribution of HPRR Worldwide

- Research and Test Reactors (RTR) – **214 total operating worldwide**

- High Performance Research Reactors (HPRR) are distributed throughout the world



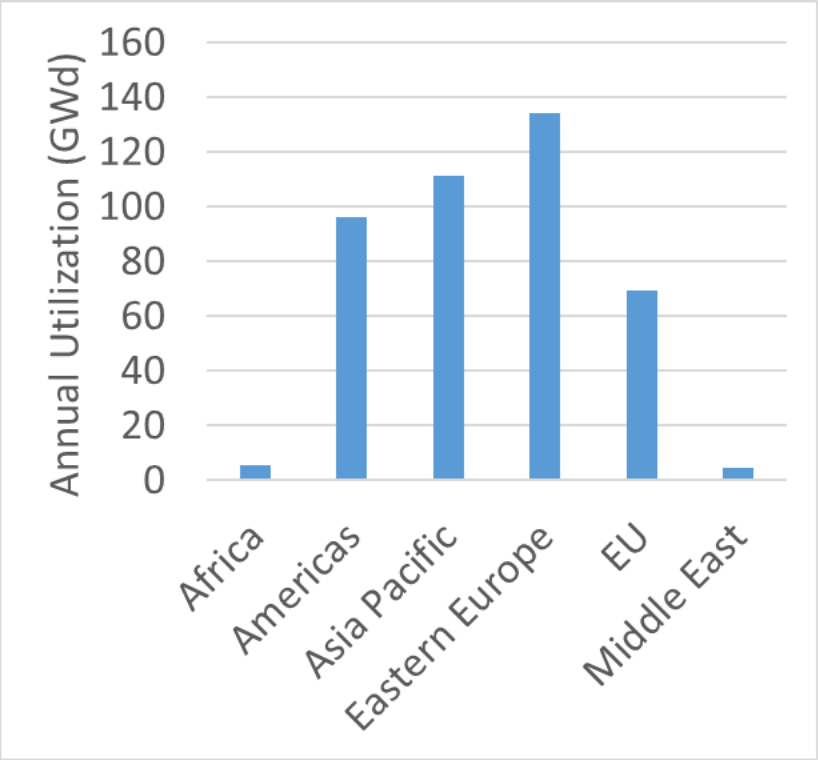


Data on slides from IAEA RRDB reported utilization; includes facilities/critical assemblies listed with power > 0; excludes subcritical facilities & permanent shutdowns

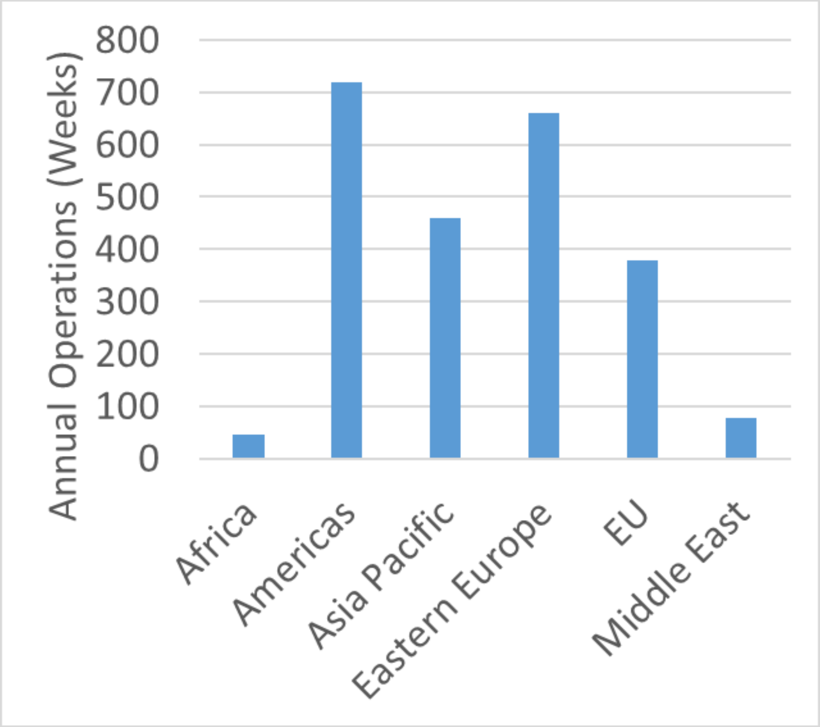
Utilization of all RTR Worldwide

- Together, many regions contribute to the substantial level of RTR operations

Regional Distribution of Utilization

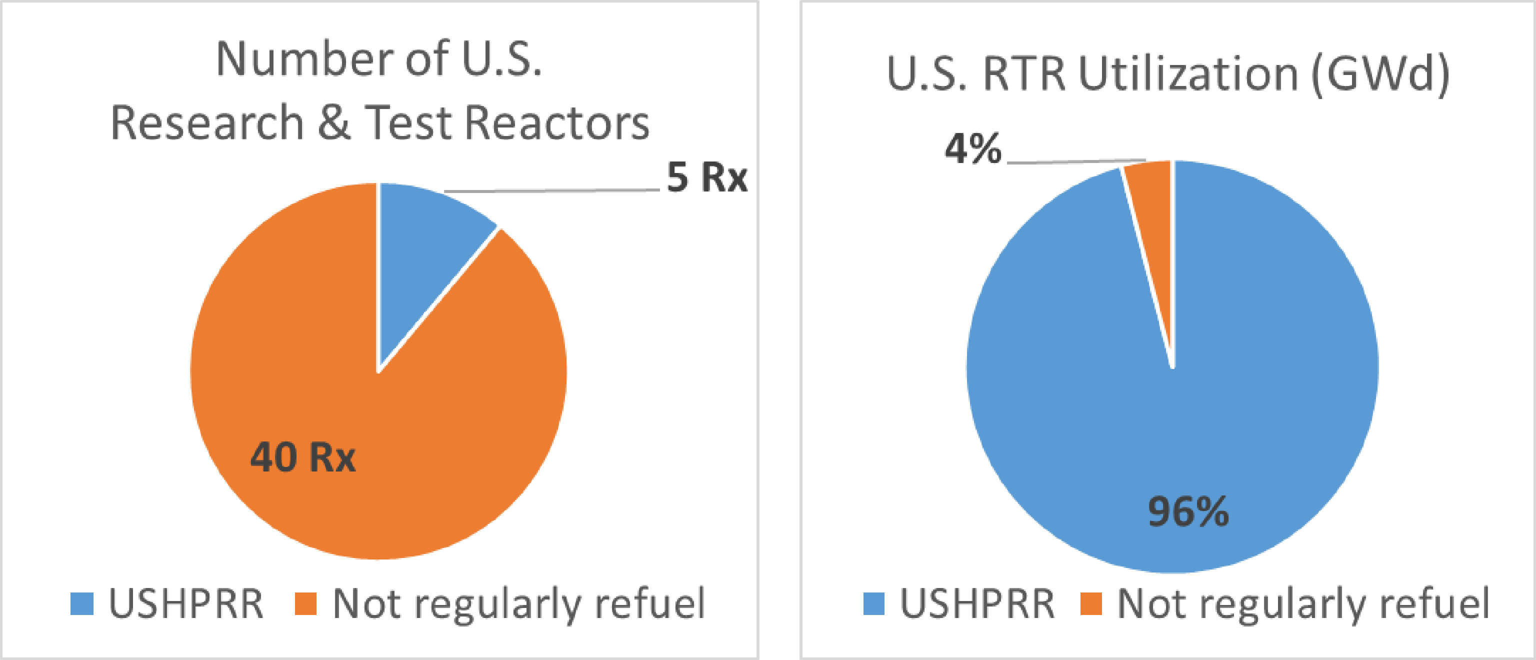


Regional Distribution of Cumulative Annual Operating Time by Region



Distribution and Utilization of U.S. RTR & HPRR

- Broad group of U.S. reactors contribute to the diverse missions that RTR fulfill



  – High-performance reactors make major contribution to overall U.S. RTR level of utilization

Research Reactor Status/Performance

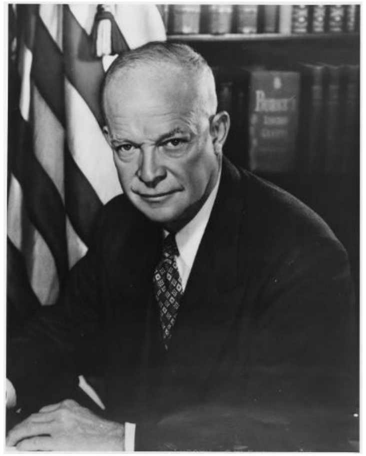
Research & Test Reactors Medical, Scientific & Engineering Missions

- RTR are ideal reactors for training and research
  - Often **multipurpose facilities serving a broad range of users**

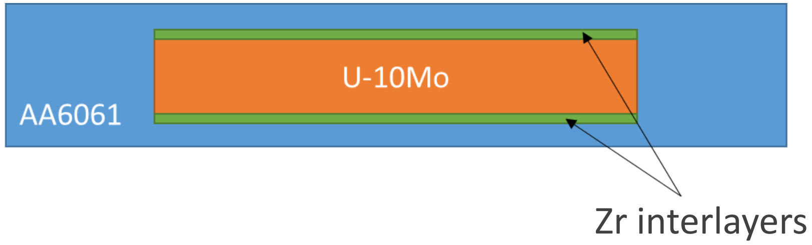
- Some **RTR can specialize in specific missions** in areas of key importance to medicine, science and engineering
  - Innovative nuclear energy research on nuclear materials (new fuels and cladding…)
  - Neutron scattering is specially able to image materials, molecules and biological cells including for the development of pharmaceuticals
  - Crucial source of many radioisotopes used for nuclear medicine and industry
  - These and many other radioisotopes are produced mainly from a small number of high-performance research and test reactors worldwide that provide many life-saving procedures and serve other critical needs for society

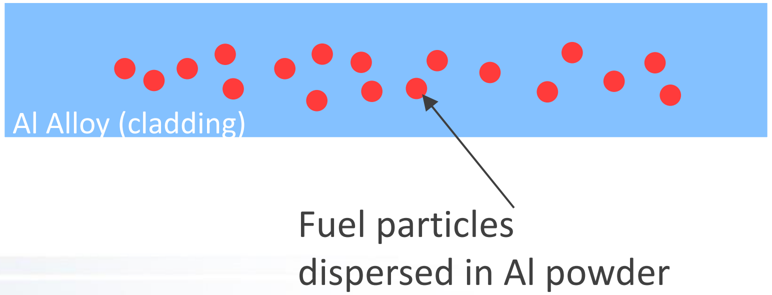
Isotope	Critical Uses
NTD Si P-31	High power electronics (e.g. hybrid-electric vehicles)
Ni-63	Explosives detection
Y-90	Treats liver cancer
Mo-99	> 40 M medical diagnostics/year worldwide
I-131	Treats thyroid cancer
Sm-153	Treats bone cancer pain
Lu-177	Treats stomach & other cancers
W-188	Diagnose and treat cancers
Pu-238	Powers space exploration
Ir-192	Treats prostate & breast cancers, industrial gauges
Bk-249	Heavy isotope discovery
Cf-252	Reactor start-up sources

Progress and Efforts for High-Density HALEU Fuels



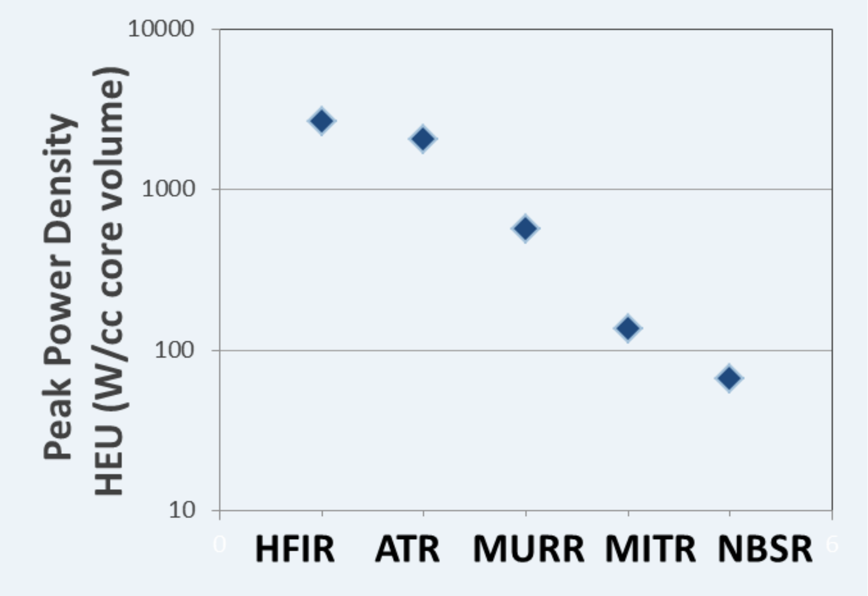
- ‘Atoms for peace’ in 1953 by U.S. President Dwight Eisenhower
  - **Initiated research and test reactor fuel development at 20% enrichment**
- Alvin Weinberg of ORNL at the 1st United Nations Conference on Peaceful Uses of Atomic Energy
  - Geneva ‘swimming pool’ reactor exhibited as the first international MTR-type
  - *“sample UO_2-aluminum 20 per cent enriched fuel elements of the type which will be available …have now been tested… No failures have been encountered to …10 per cent burn-up.”* (1955)
  - **Origen of high-density dispersion fuels:** overcame fabrication challenges to allow LEU export
- Dispersion fuels replaced solid metallic fuel in new high-power MTR-type plate reactors built in the 1960’s onward
  - UO_2-Al, U_3O_8-Al, UAl_x-Al (aluminide)… with densities up to ~ 1 gU-235/cm^3
- High-density HALEU fuel have been developed and deployed since ~1990
  - UZrH 30/20 alloy (TRIGA®), U_3Si–Al (rod), U_3Si_2-Al, U-7Mo dispersion and U-10Mo monolithic
  - **Fuel densities up to 3 gU-235/cm^3**

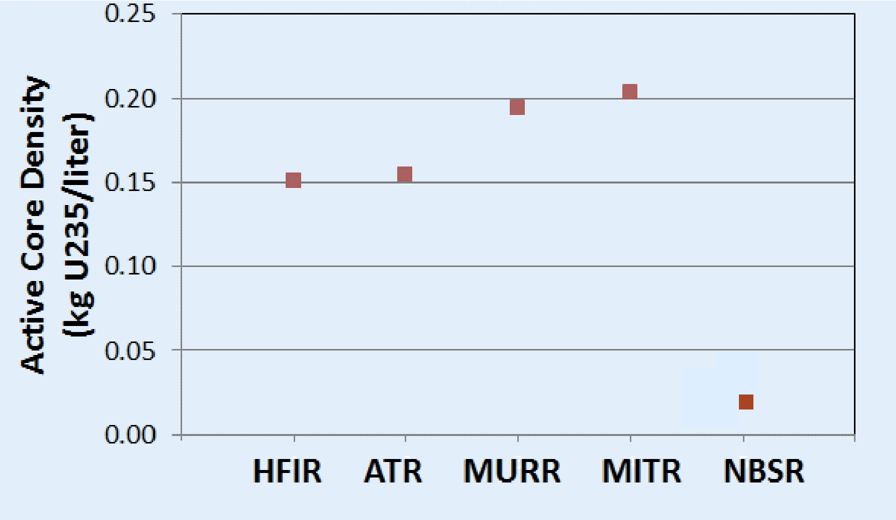




HALEU Designs: Trends and U.S. High Performance Reactor Example

- Use of HALEU facilitated by high density fuels developed, often for LEU conversions
- Engineering approaches to HALEU RTR include managing active core fuel and power densities
  - *Plate/rod design of fuel / cladding*
  - *Pitch*
  - *Symmetry*
- Most fuel element designs **AND** core fuel management require engineering features designed to manage power peaking and advanced modeling (full core 3-D) shuffling

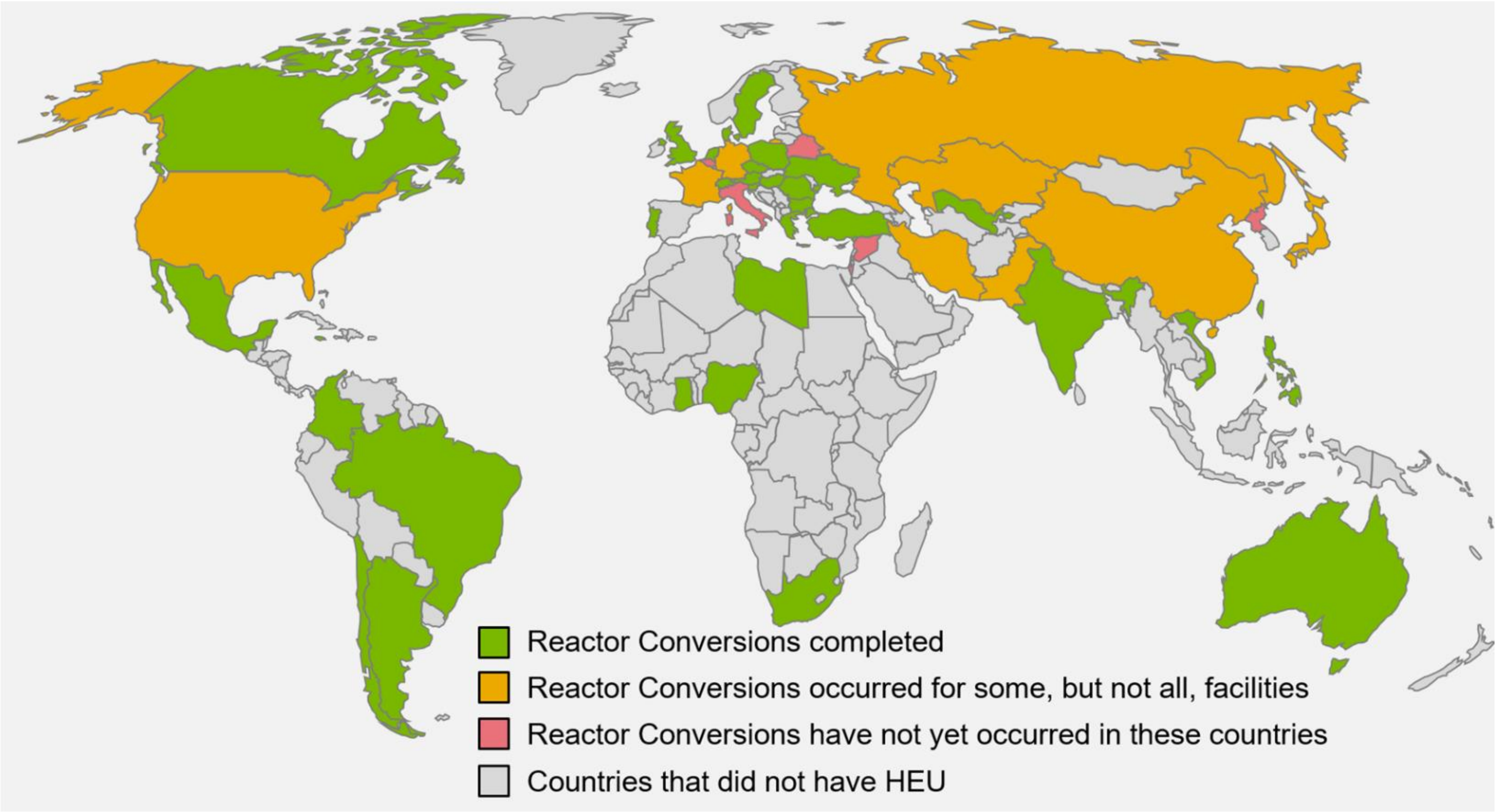




RTR & HALEU Deployment

High-Assay LEU Deployment in RTR through Conversions

- Successes have been enabled by the RTR community's engineering efforts to:
  - develop and LEU qualify fuel
  - design and fabricate fuel elements
  - model fuel cycles and reactor operations/safety
- Collaborative efforts have led to continued work on Reduced Enrichment For Research and Test Reactors **(RERTR)**
- Allows return of HEU to the country of origin as a major accomplishment in non-proliferation
- Worldwide over 70 reactors have converted to LEU fuel



HEU reduced (or eliminated) in over 40 countries and on 6 continents

Includes IVG.1M reactor conversion in Kazakhstan in 2022

High-Assay LEU Deployment in Future RTR

- Additional Infrastructure development needed for advanced reactors will also be useful to supply HALEU to future RTR
  - HALEU enrichment and associated front-end fuel cycle capabilities are needed to meet advanced reactor needs and research reactor/medical isotope production needs
- Design efforts to understand requirements for future, high-performance RTR are complementary to these efforts
- Demand timing, and commercial contracts for supply, will remain to HALEU <20% enriched for both Advanced Reactors **and to allow RTR to continue to perform essential missions for society**
- Front-end HALEU supply and **RTR fuel element fabrication remains important for commercialization** in the U.S. and around the world

Thank you for your attention.

Questions?