IAEA Safeguards Considerations Associated with HALEU

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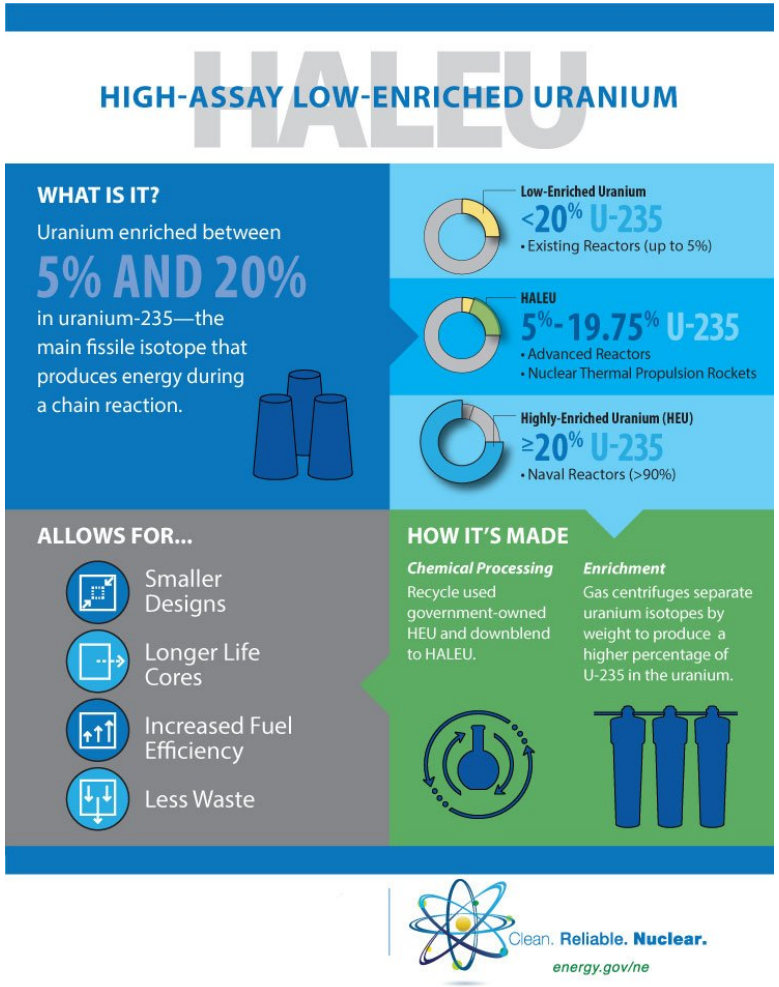
Identifying Relevant Safeguards Factors

- Materials Accountancy Challenges
- Continuity of Knowledge
- Applicability of Current Safeguards Approaches

- Key characteristics
  - Fuel-loading
  - Refueling Schedules
  - Fuel cycle management
  - Fuel form and composition
  - **Enrichment level**
  - Other related characteristics

Project Objectives

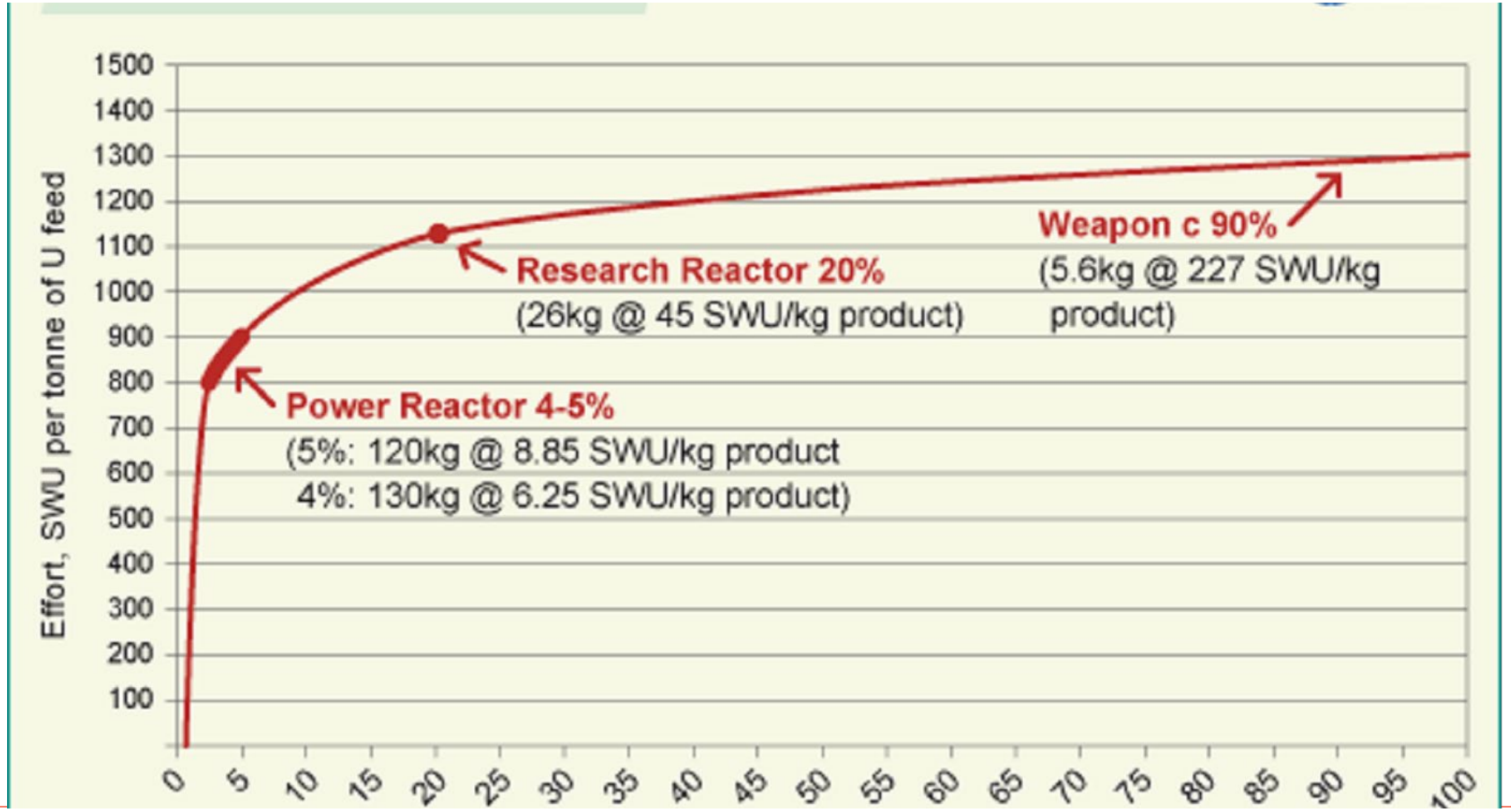
- Examine what implications widespread use of HALEU will have for IAEA safeguards and resources
  - Need to prepare for the future.
  - Identify and analyze areas where safeguards approaches, and level of effort may change.
  - Focus on enrichment-related issues but recognize other a characteristics of new reactors may have significant impact on safeguards. Not always easy to separate.



HALEU IN ADVANCED REACTORS

Vendor	Design Type/Model	Enrichment
Advanced Reactor Concepts	**ARC-100: Pool-type modular sodium-cooled fast-neutron-spectrum reactor**	**10.1-17.2%**
Elysium Industries	Molten Chloride Salt Fast Reactor (MCSFR)	15%
Framatome	Steam Cycle High Temperature Gas-cooled Reactor (SC-HTGR)	14.5-18.5%
General Atomics	Energy Multiplier Module (EM^2): Fast-neutron version of the Gas Turbine Modular Helium Reactor (GT-MHR)	12%
GE Hitachi	Power Reactor Innovative Small Module (PRISM): Pool-type modular sodium-cooled fast reactor	11-17% Pu
Kairos Power	**KP-FHR: Modular fluoride-salt-cooled high-temperature reactor**	**15-19.75%**
Oklo	Aurora: Compact Fast Microreactor cooled by liquid metal	15-19.75%
TerraPower	Traveling Wave Reactor-Prototype (TWR-P): Pool-type sodium-cooled fast reactor	15.75%
TerraPower & GE Hitachi	**Natrium: pool-type sodium fast reactor**	**20%**
ThorCon US	Thorium cycle modular molten salt reactor	19.70%
Ultra Safe Nuclear Corporation	MMR™ (Micro Modular Reactor) Micro-reactor HTGR	19.75%
Westinghouse	Lead Fast Reactor (W-LFR): Pool-type lead-cooled fast reactor	≤19.75%
Westinghouse	**e-Vinci Micro reactor**	**5-19.75%**
X-Energy	**Xe-100: Modular High-Temperature Gas-cooled Reactors (HTGR)**	**15.50%**

SWU for Different Enrichment Changes



Goals, Quantity and Timeliness

- Inspection approaches are designed to meet IAEA inspection goals.
- The inspection goal for a facility consists of a quantity component and a timeliness component (i.e., detect diversion of one SQ within a specified time)

Safeguards grouping/categories

- The IAEA's safeguards system seeks to detect diversion of "Quantities of Significance" for the manufacture of one nuclear explosive.
- For Low-Enriched U (Less than 20%), the IAEA uses 75 kg of contained U-235 as the Significant Quantity (SQ).
- For HEU (above 20%), the IAEA uses 25 kg of contained U-235
- HALEU is treated as LEU.
- As safeguards are implemented today, the enrichment level of HALEU (i.e., 5% vs. 19%) has a limited impact because there is so little of it in use, only in research reactors and then only a few kg per research reactor.

IAEA timeliness detection goal

- The target detection times are linked to the type of nuclear material (U OR Pu); whether it is HEU or LEU; and whether the nuclear material is irradiated or not.
- The inspection goals are used to establish the frequency of inspections and safeguards activities (for example sampling plans) at a facility during a calendar year,
- Where there is no additional protocol in force or where the IAEA has not drawn and maintained a conclusion of the absence of undeclared nuclear material and activities in a State, the detection goals are:
    - —One month for unirradiated direct use material (Pu OR HEU),
    - —Three months for irradiated direct use material,
    - —**One year for indirect use material** (LEU OR Th).

NRC Categories (And CPPNM)

Category I - Strategic SNM (SSNM)

5 kgs or more of U-235 (contained in uranium enriched to 20 percent or more in the U-235 isotope)

Category II - SNM of moderate strategic significance

Less than 5kgs but greater than or equal to 1kg of uranium-235 (contained in uranium enriched to 20 percent or more in the U-235 isotope); or

10kg or more of uranium-235 (contained in uranium enriched to 10 percent or more but less than 20 percent in the U-235 isotope)

Category III - SNM of low strategic significance

Less than 1kg but more than 15 grams of uranium-235 (contained in uranium enriched to 20 percent or more in the U-235 isotope)

Less than 10kgs but more than 1kg of uranium-235 (contained in uranium enriched to 10 percent or more but less than 20 percent in the U-235 isotope); or

10 kgs or more of uranium-235 (contained in uranium enriched above natural but less than 10 percent in the U-235 isotope)

State-level Safeguards Approach

- The IAEA has developed a State-level safeguards approach (SLA) for each State on the basis of a structured, technical method used to analyze the plausible paths by which nuclear material suitable for use in a nuclear weapon or other nuclear explosive device could be acquired.
- The SLA establishes technical objectives associated with the steps along such a path To guide the planning, conduct and evaluation of safeguards activities for that State.
- As of 30 June 2020, State-level safeguards approaches had been developed for 131 States with a comprehensive safeguards agreement in force.

General Observations

- Widespread use of HALEU could have significant impact on safeguards at reactors and other facilities.
- Impact will depend on the specific design of the reactor, for example fuel type, storage plans, and refueling schedules.
- New approaches to detect undeclared HEU production by IAEA may be needed.
- Greater focus on detecting undeclared enrichment at uranium enrichment plants producing HALEU.
- A fundamental issue is whether there should be a HALEU safeguards category and how that will affect safeguards.
- Establishing a new category for HALEU would require creating a corresponding Significant Quantity (SQ), as well as new Timeliness goals and detection probabilities.
- This would significantly impact safeguards at facilities including reactors.

Next Steps

- Identify specific impact of wide-spread use of HALEU on safeguards implementation
- Assess personnel/cost impacts of different scenarios (including new category)—difficult to separate from other reactor characteristics
- Assess political and other considerations associated with new category (Board approval? Affect on other parts of NP regime?)
- Need to analyze more thoroughly the interface between security and safeguards in categorization and in flexibility in categorization.