Facilitating Nuclear Disarmament:

Verified Declarations of Fissile Material Stocks and Production

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AECL, Chalk River, December 15, 2009

Revision 5


Global Fissile Materi
Report 2008
Scope and Verification of a Fissile M
Third annual report of the International Pane
IPFM
INTERNATIONAL PANEL
ON FISSILE MATERIALS
Global Fissile Material
Report 2009
A Path to Nuclear Disarmament
Fourth annual report of the International Panel on Fissile Materials

Background

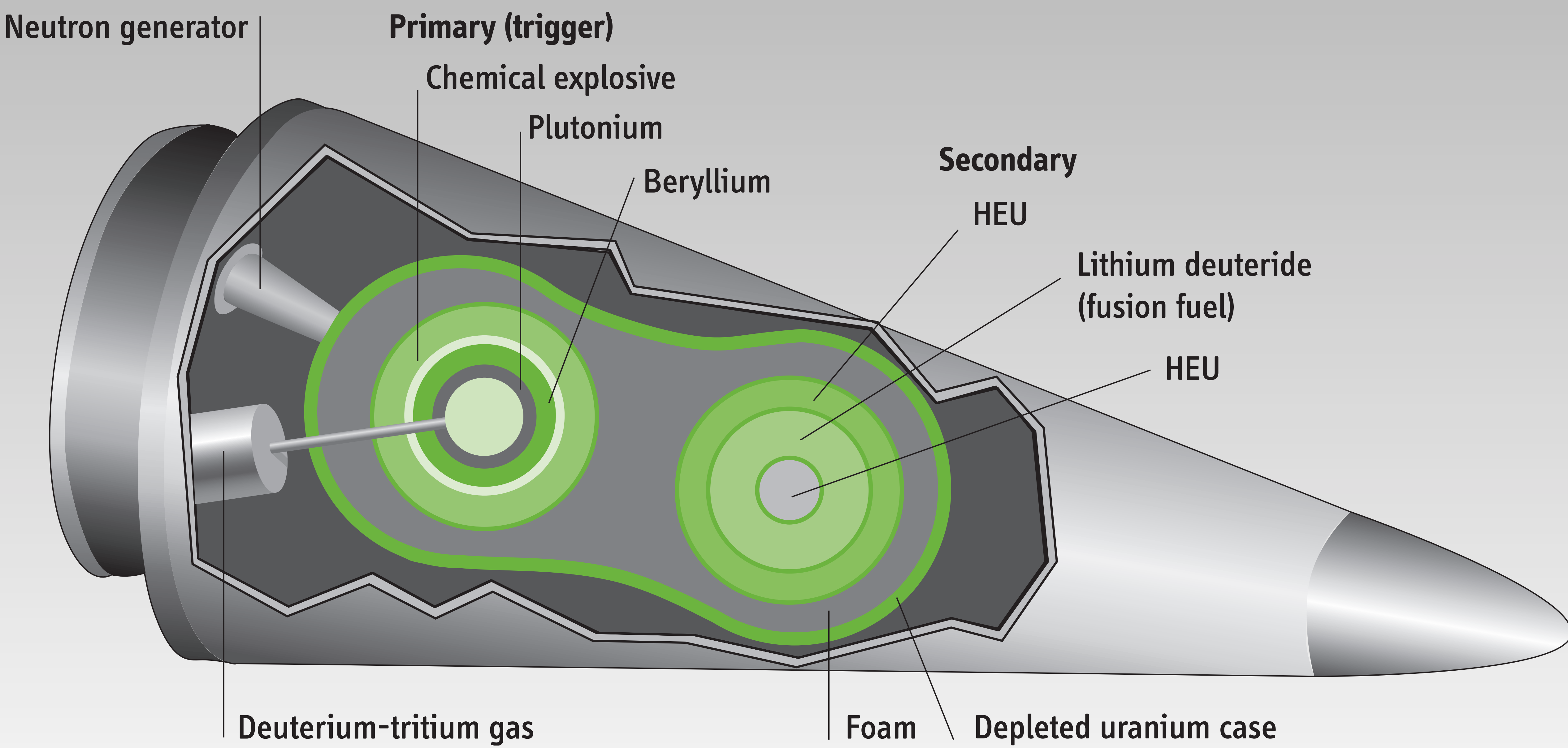
Nuclear Weapon and Fissile Material Stocks, 2009

Nuclear Arsenals, 2009

(GFMR 2009, based on estimates by NRDC/FAS)

Country	Nuclear Warheads
United States	about 10,000 *(of which 4200 are awaiting dismantlement)*
Russia	about 10,000 *(with a large fraction awaiting dismantlement)*
France	fewer than 300
United Kingdom	185
China	about 240
Israel	100-200
Pakistan	70-90
India	60-70
North Korea	fewer than 5

Modern Thermonuclear Warhead

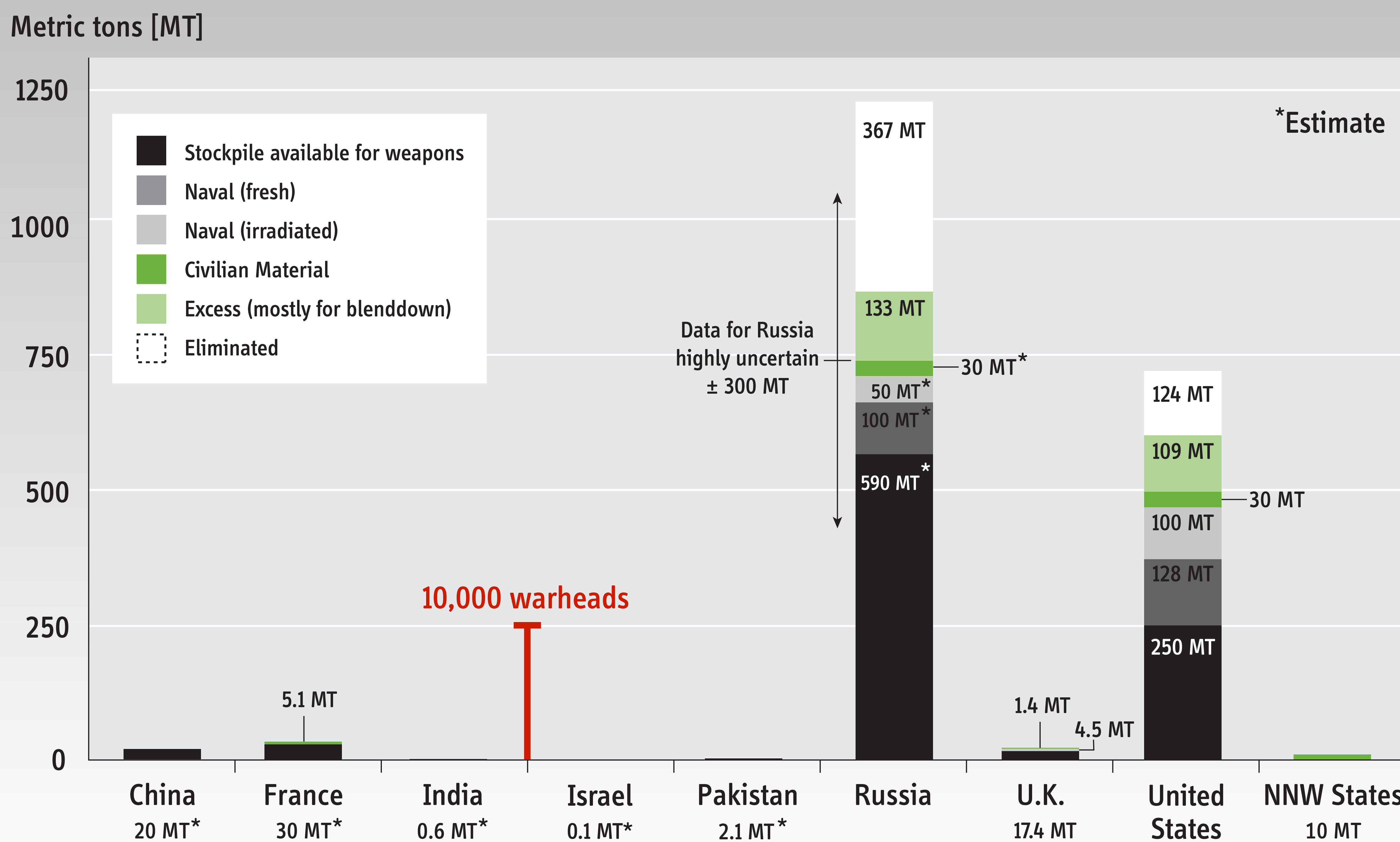


A modern thermonuclear warhead may contain *both* plutonium and highly enriched uranium

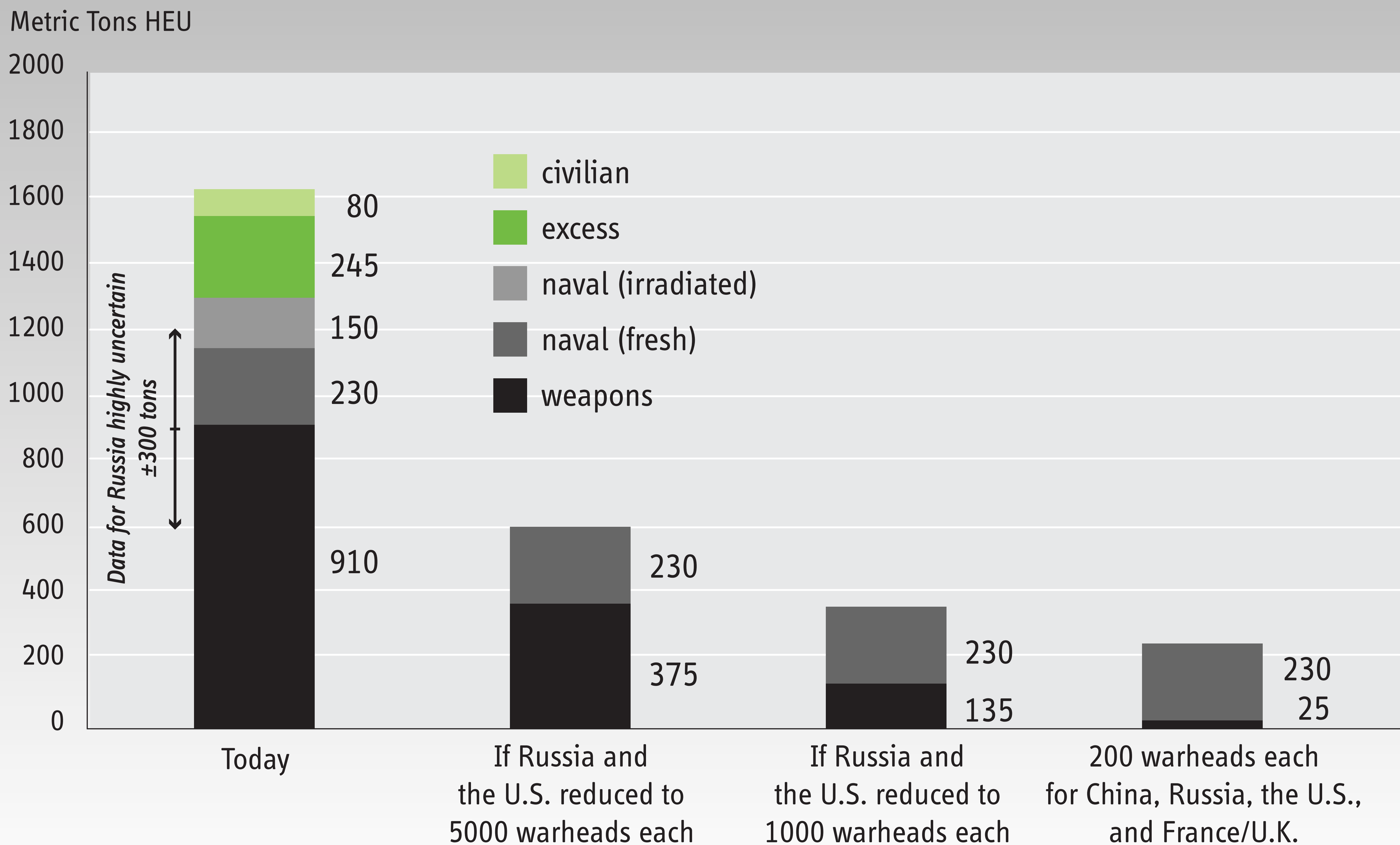
(Average estimated values are 4 kg and 25 kg of plutonium and HEU, respectively)

HEU Stockpiles, 2009

Global stockpile is about 1600 tons, over 99% is in weapon states

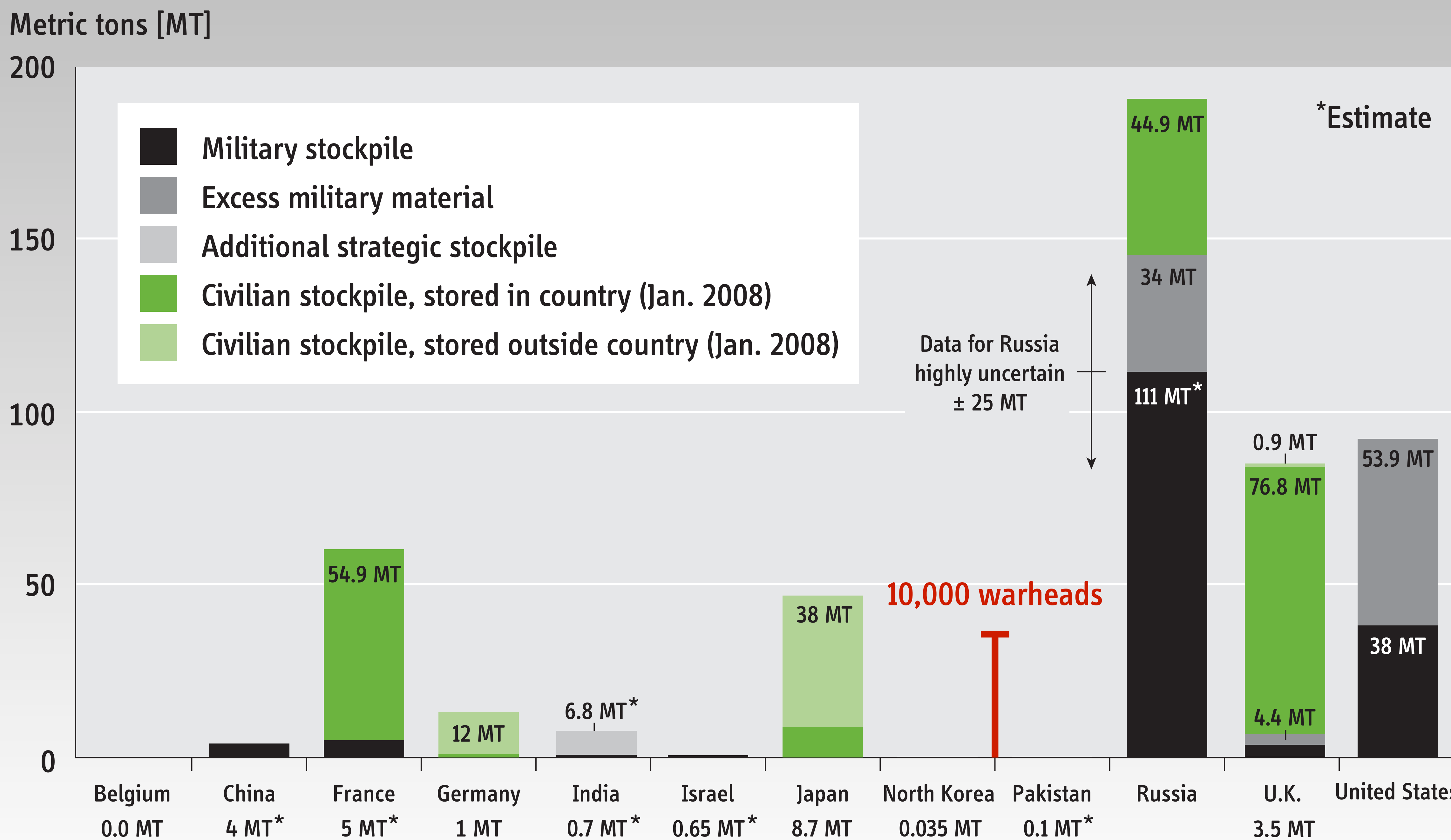


The Naval HEU Problem in a Disarming World

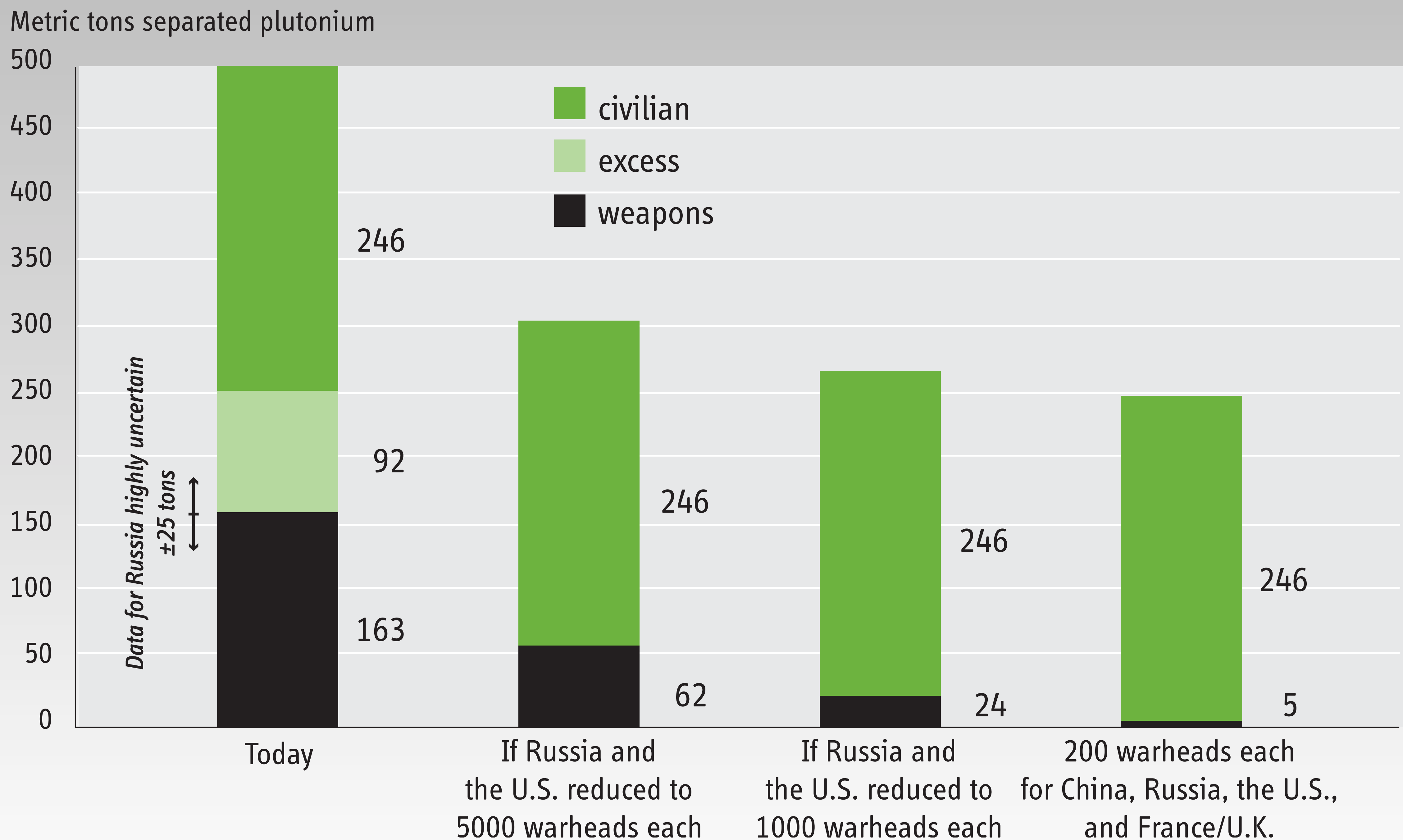


Stockpiles of Separated Plutonium, 2009

Global stockpile is 500 tons, half is civilian and this stock is growing



The Problem of Civilian Separated Plutonium in a Disarming World



Verified Declarations of Fissile Material Stock and Production

Why Declarations Matter

"The U.K. believes that transparency about fissile material acquisition for defence purposes will be necessary if nuclear disarmament is to be achieved; since achieving that goal will depend on building confidence that any figures declared for defence stockpiles of fissile material are consistent with past acquisition and use. This report is a contribution to building such confidence."

Historical Accounting for U.K. Defence Highly Enriched Uranium,
U.K. Ministry of Defence, March 2006, www.ipfmlibrary.org/mod06.pdf

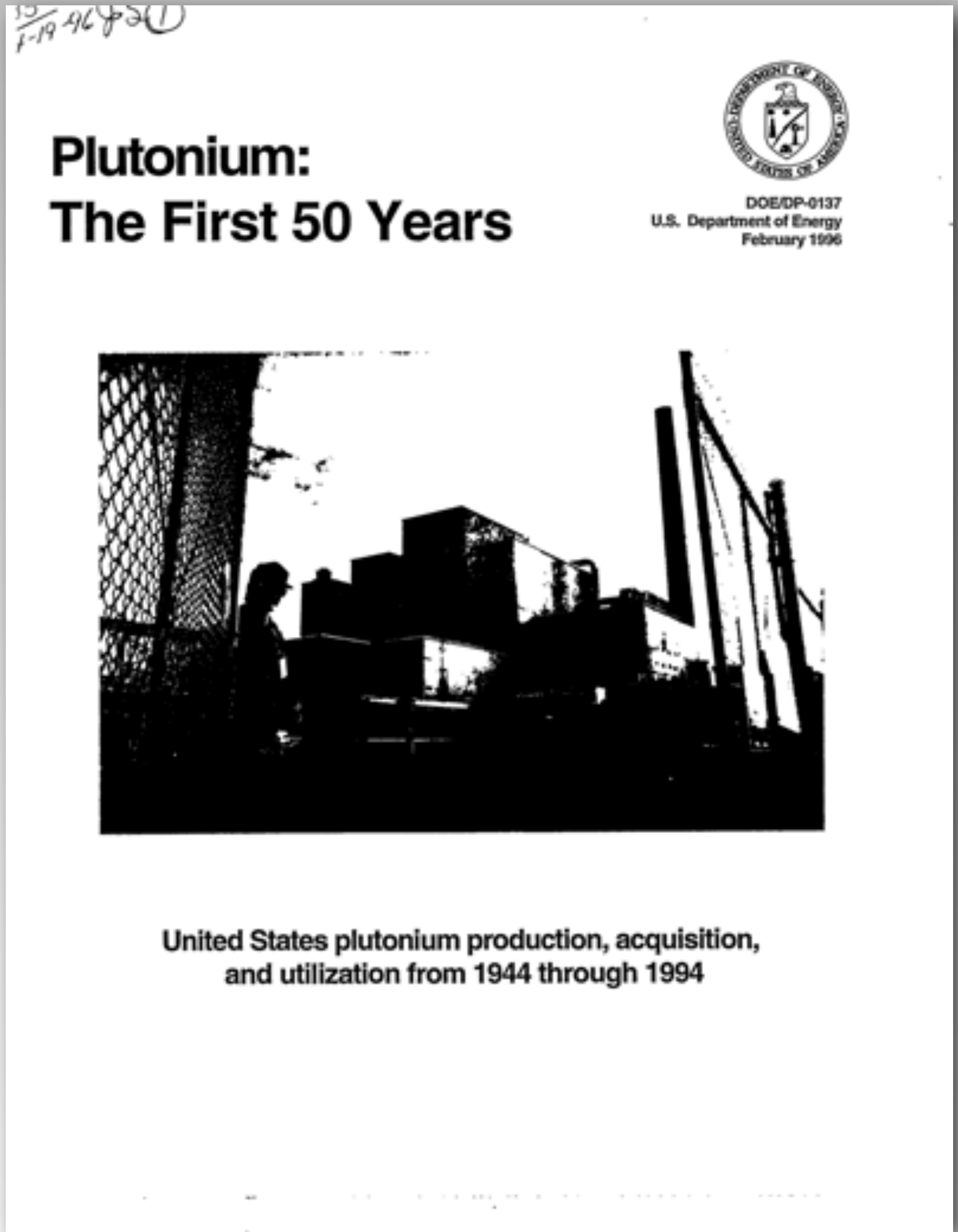
Content of Declarations and Sequencing of Information Release

	Level of Detail	Example
Initial Declarations *(unverified)*	Aggregate	Total inventory
	By Type	Historical production data for different materials (and selected characteristics)
	By Site / Facility	Same by site/facility
Detailed Declarations *(verified)*	By Item	Location, mass, composition of each item or container

Content of Initial Declarations

1. Material available for weapons
   (in warheads, warhead components and working stocks)
2. Material that has been declared excess for weapons purposes
3. Highly enriched uranium for naval and other military-reactor use
4. Civilian material

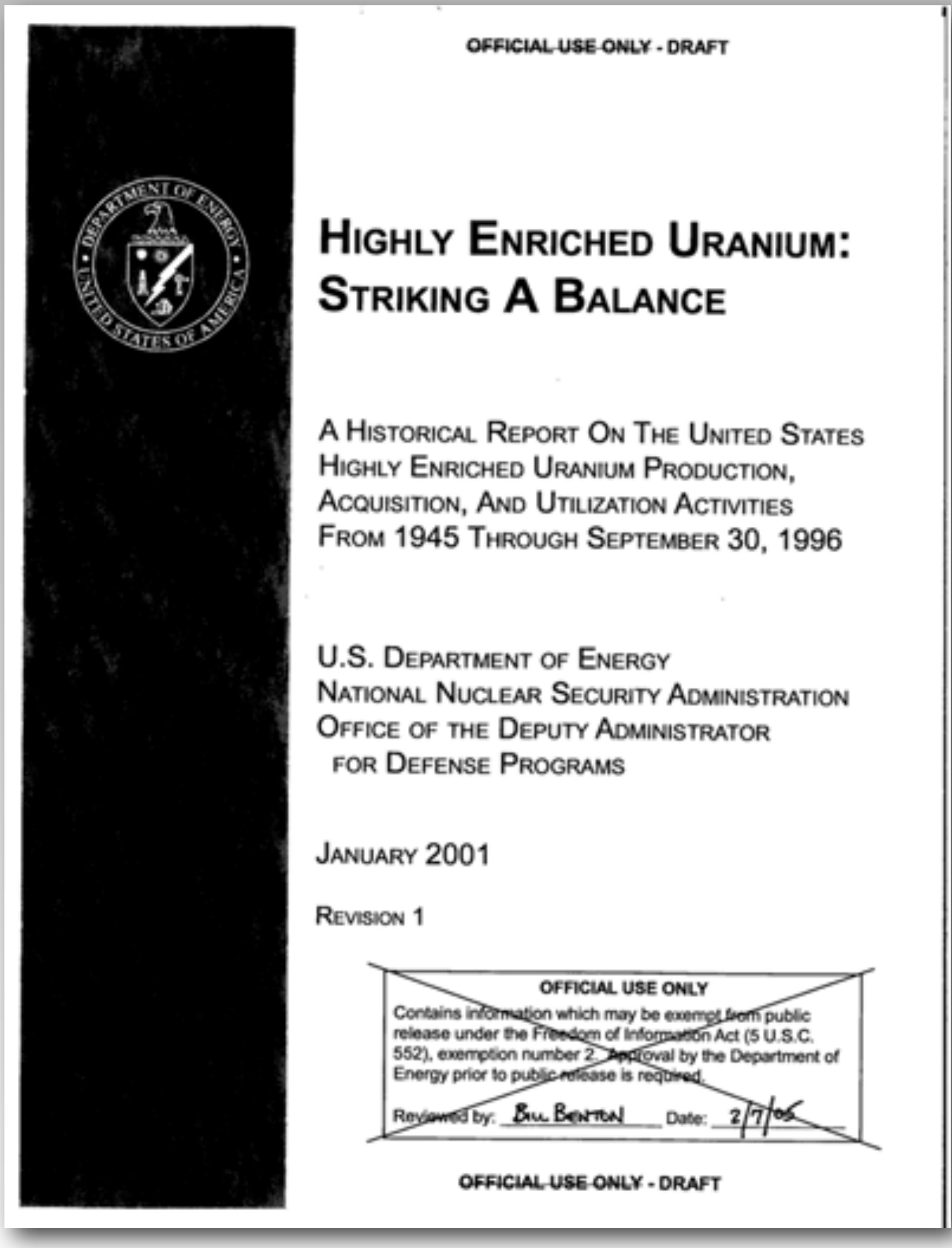
The 1996 and 2001 U.S. Declarations



Plutonium:
The First 50 Years

DOE/DP-0137
U.S. Department of Energy
February 1996

United States plutonium production, acquisition, and utilization from 1944 through 1994



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HIGHLY ENRICHED URANIUM: STRIKING A BALANCE

A HISTORICAL REPORT ON THE UNITED STATES HIGHLY ENRICHED URANIUM PRODUCTION, ACQUISITION, AND UTILIZATION ACTIVITIES FROM 1945 THROUGH SEPTEMBER 30, 1996

U.S. DEPARTMENT OF ENERGY
NATIONAL NUCLEAR SECURITY ADMINISTRATION
OFFICE OF THE DEPUTY ADMINISTRATOR FOR DEFENSE PROGRAMS

JANUARY 2001

REVISION 1

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~~Reviewed by: Bill Benton Date: 2/7/05~~

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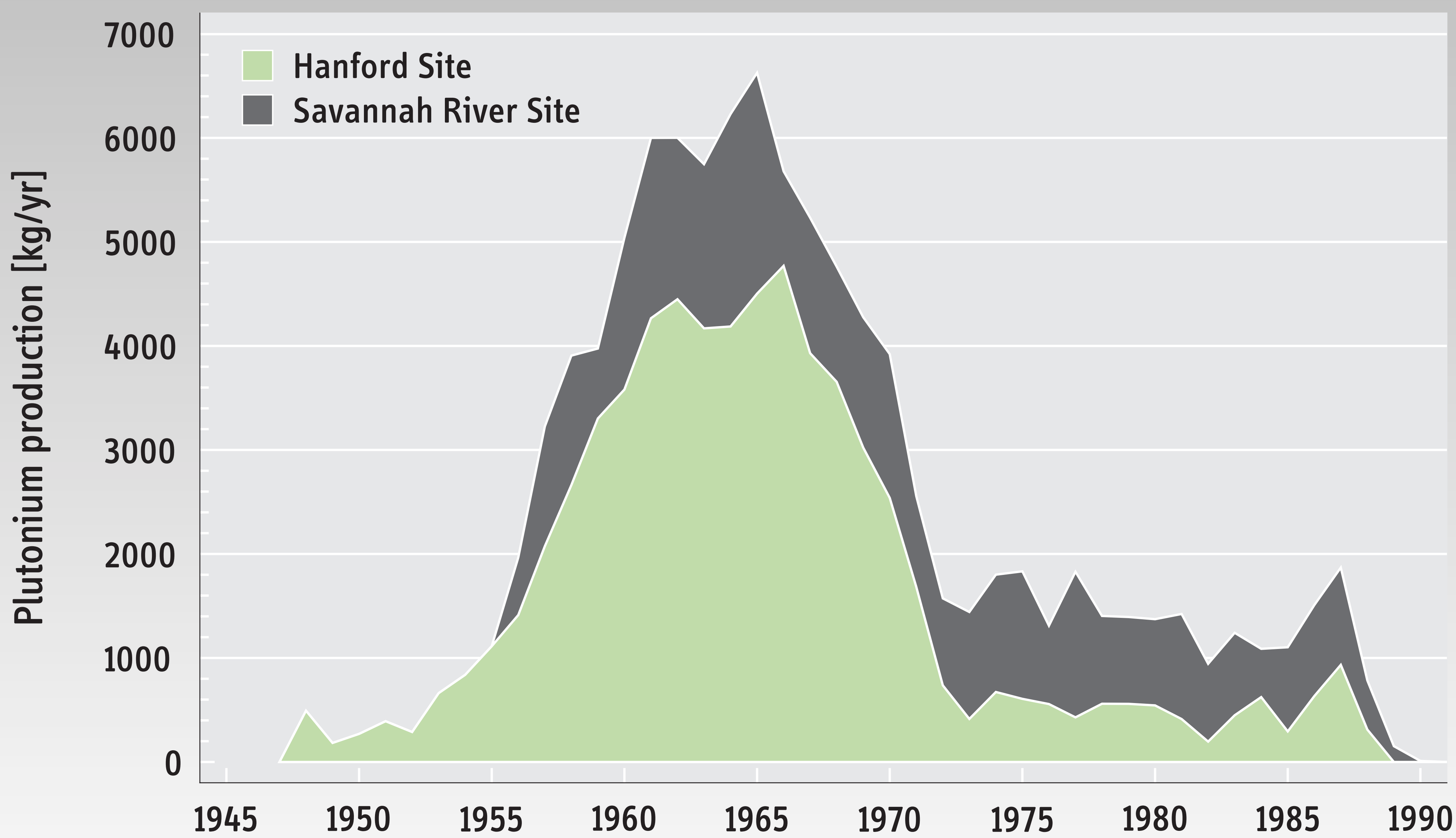
Example from the U.S. Declarations

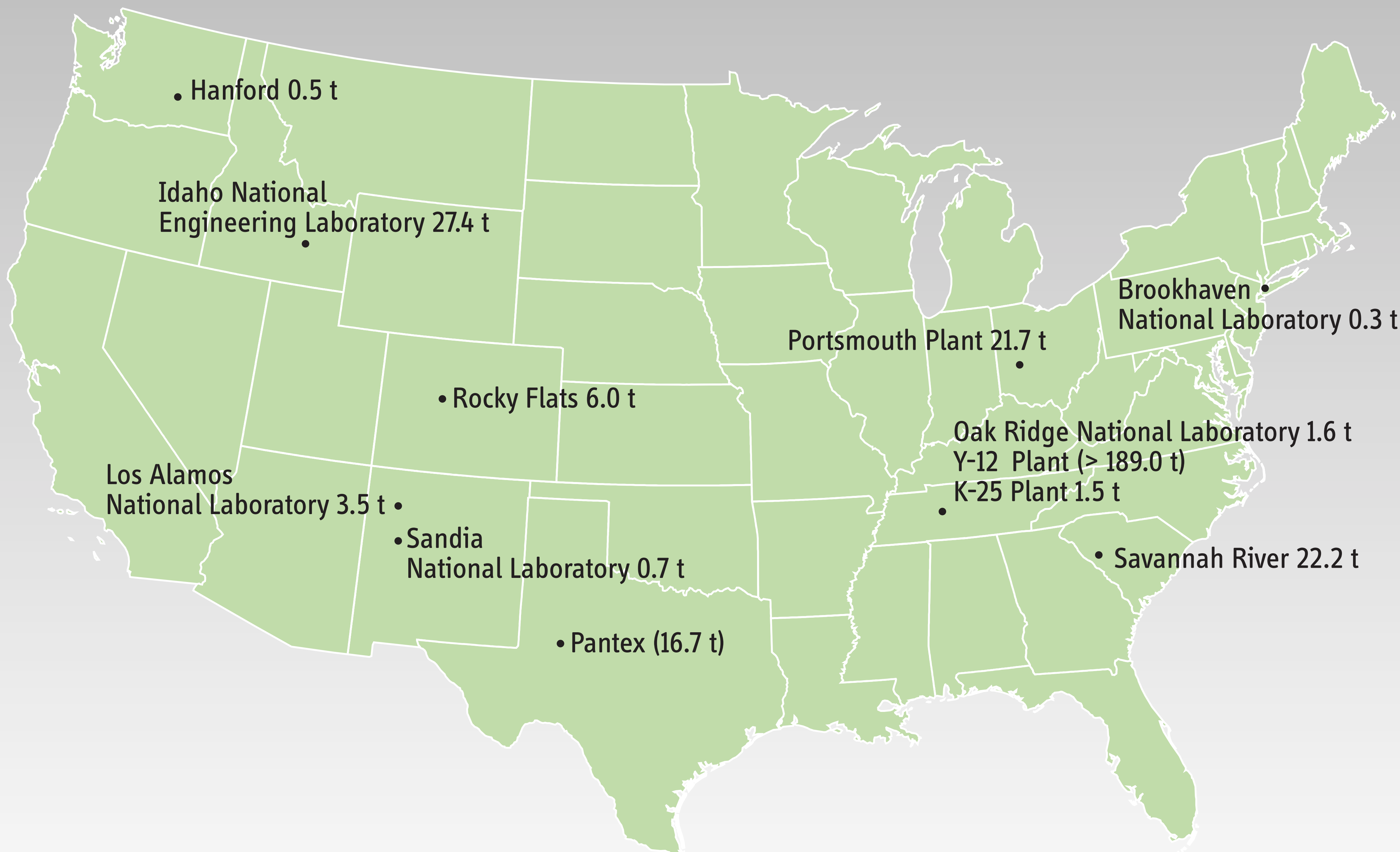
Plutonium Production by Year and Site



Plutonium: The First 50 Years: United States Plutonium Production, Acquisition and Utilization from 1944 Through 1994
U.S. Department of Energy, DOE/DP-0137, 1996, www.ipfmlibrary.org/doe96.pdf

Example from the U.S. Declarations

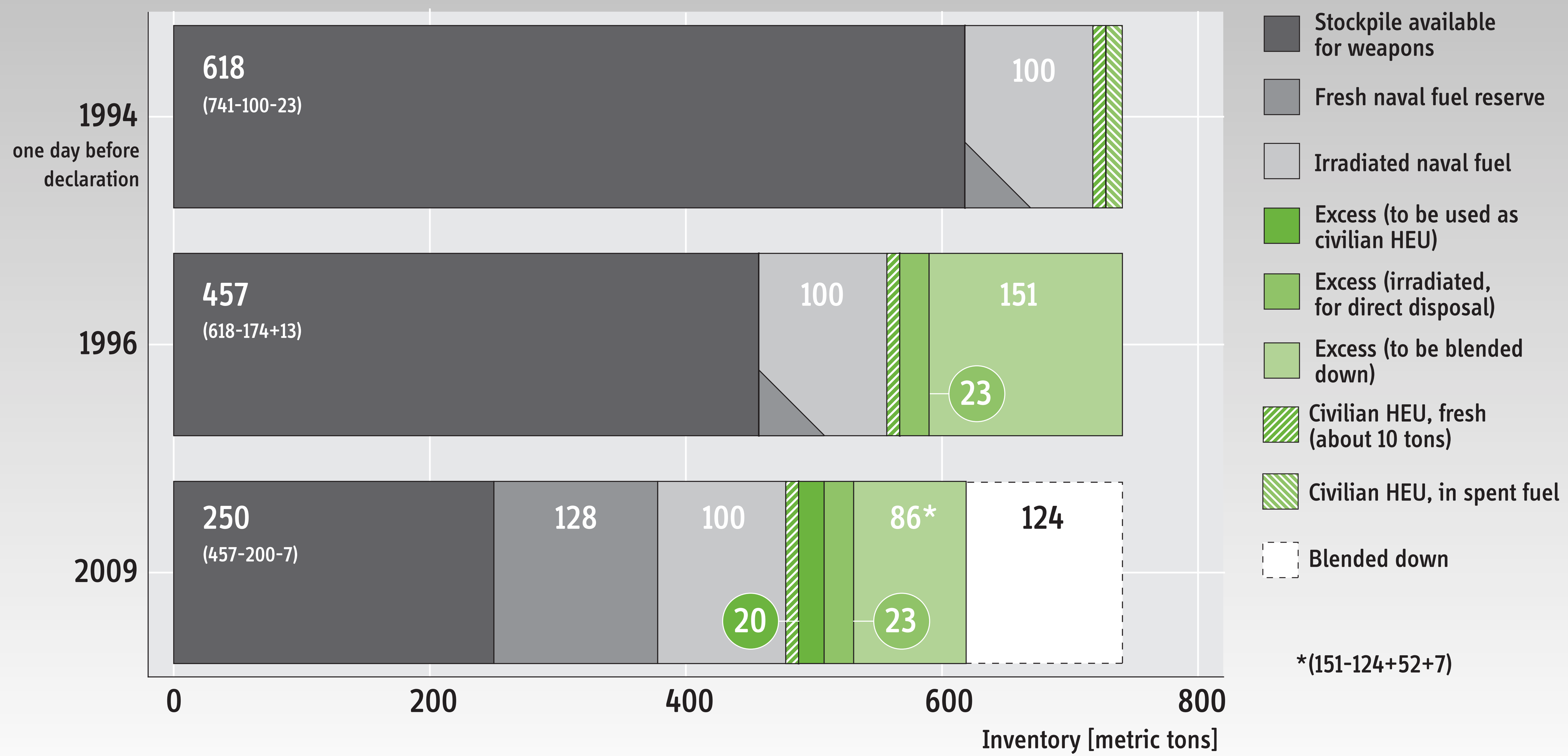
Stockpile of Highly Enriched Uranium by Location (U.S. DOE Sites, 1996)



Highly Enriched Uranium: Striking a Balance. A Historical Report on the United States Highly Enriched Uranium Production, Acquisition, and Utilization Activities from 1945 through September 30, 1996, U.S. Department of Energy, January 2001 (publicly released in 2006), www.ipfmlibrary.org/doe01.pdf

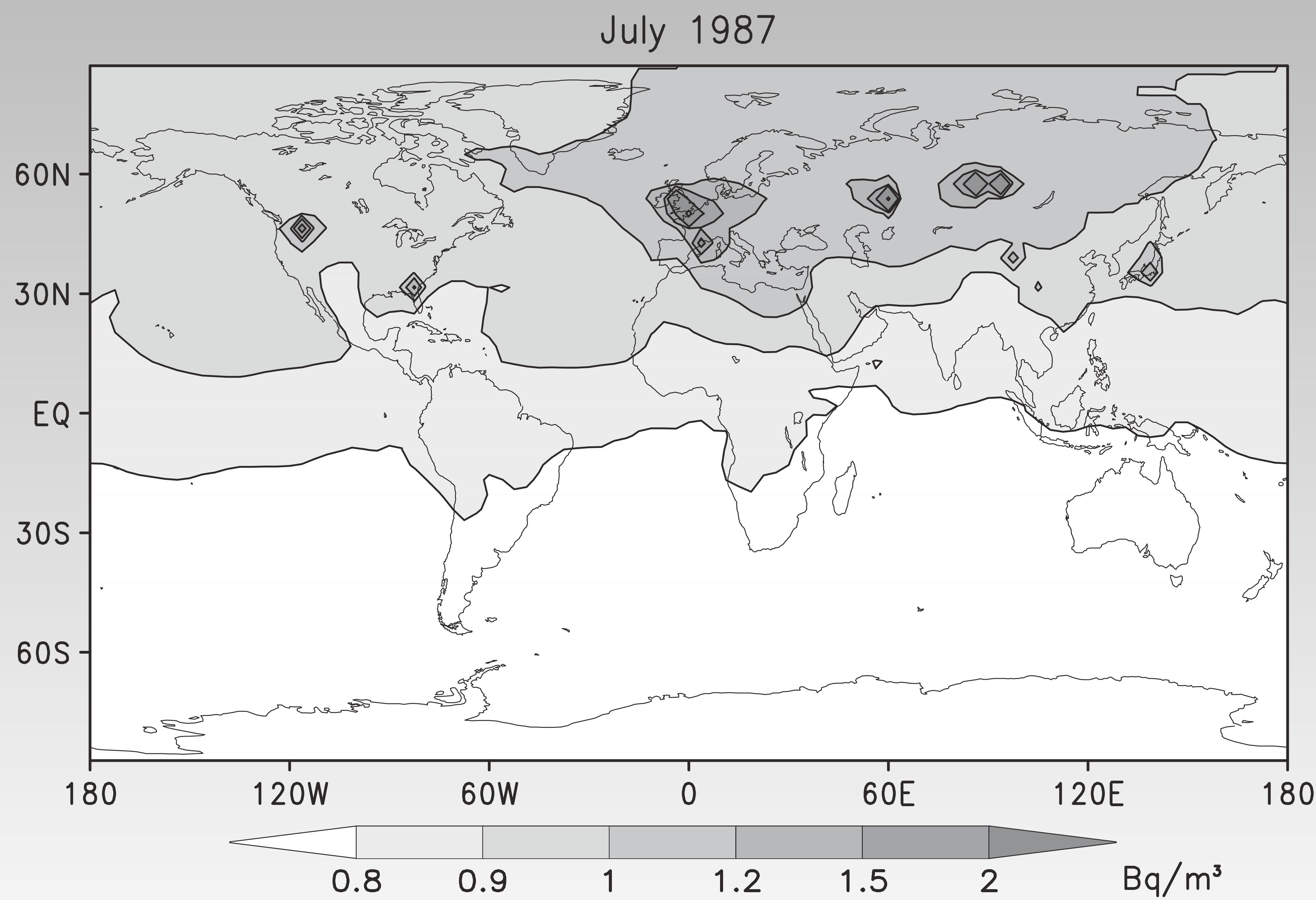
Example from the U.S. Declarations

Stockpile of Highly Enriched Uranium by Category



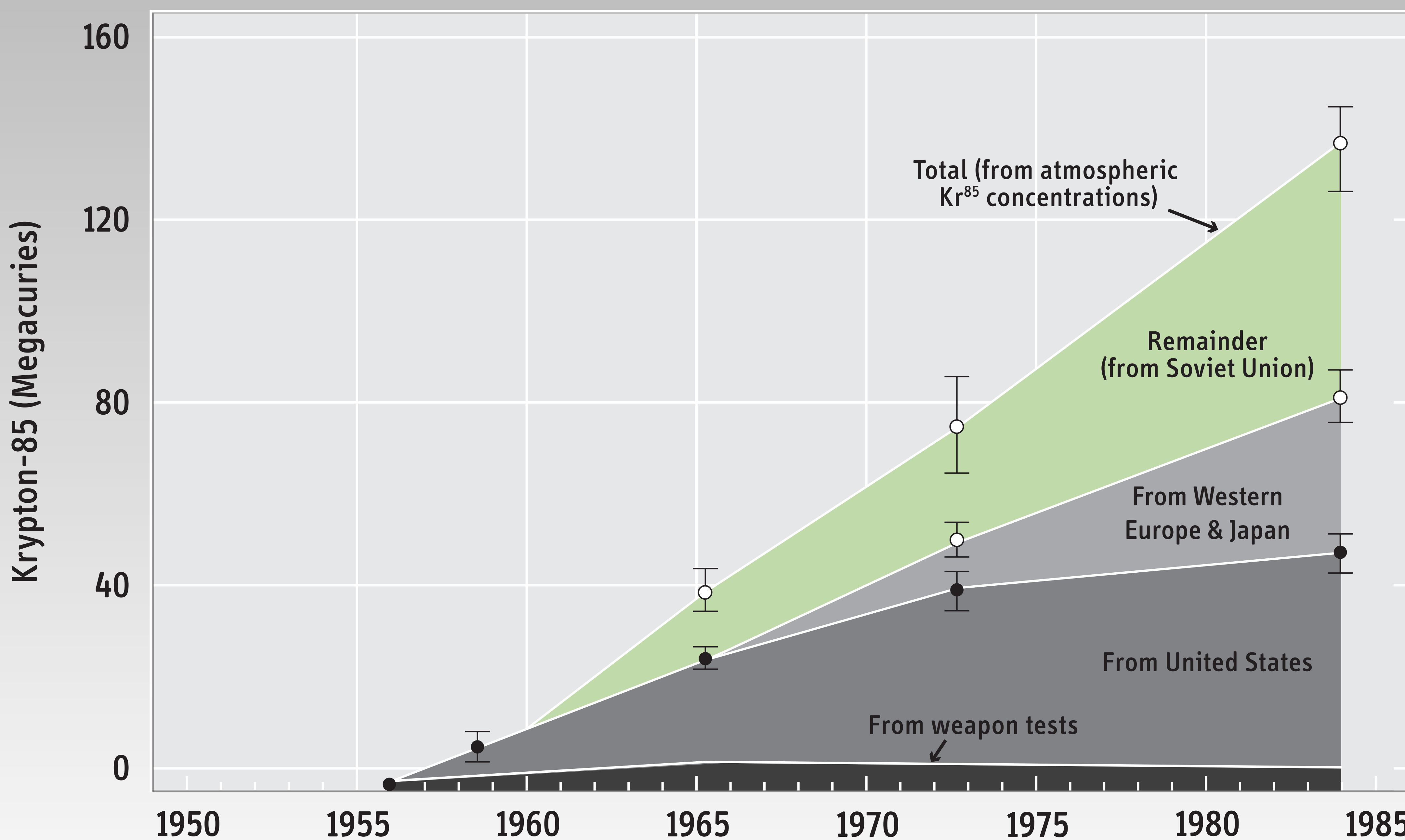
Approaches to Verifying Historic Production of Fissile Materials

Atmospheric Krypton-85 Levels



K. Winger, J. Feichter, M. B. Kalinowski, H. Sartorius and C. Schlosser, "A New Compilation of the Atmospheric Krypton-85 Inventories from 1945 to 2000 and its Evaluation in a Global Transport Model," *Journal of Environmental Radioactivity*, Vol. 80, 2005, pp. 183–215

Atmospheric Krypton-85 Levels



Frank von Hippel, David H. Albright and Barbara G. Levi, "Stopping the Production of Fissile Materials for Weapons," *Scientific American*, September 1985

Nuclear Archaeology

"A set of methods and tools to estimate historic fissile material production through on-site measurements at fissile-material production and storage sites"

Nuclear Archaeology for Plutonium

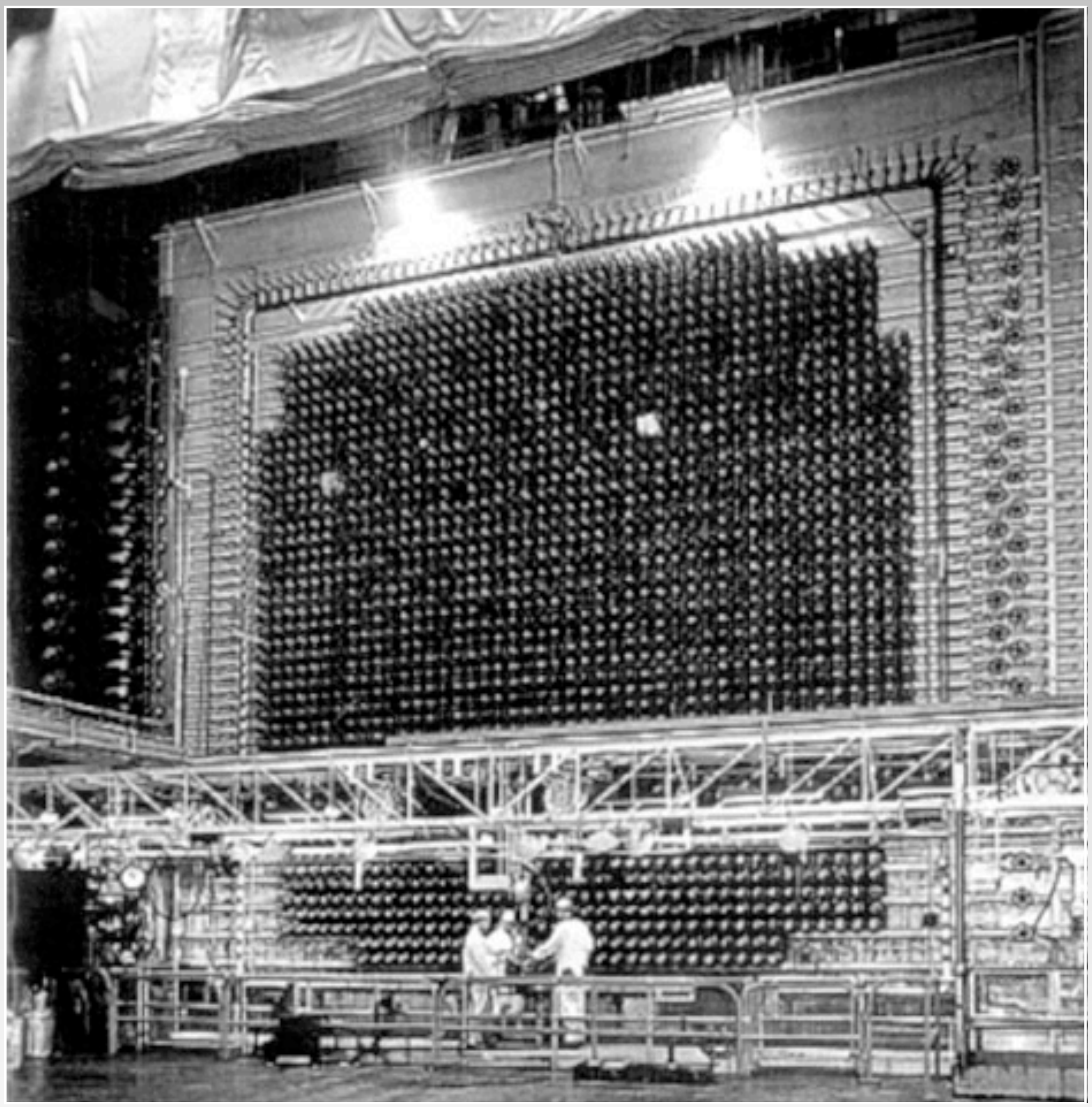
In Graphite-moderated Reactors: Graphite Isotope-Ratio Method (GIRM)

Measurements of the degree of transmutation of trace elements
in the graphite moderator of a production reactor to estimate the cumulative neutron flow
through the graphite and thereby the cumulative plutonium production in this reactor

GIRM has been applied to several case studies of historical plutonium production,
including the U.S. Hanford reactors, the U.K. Calder-Hall-type reactors,
and the French Marcoule G-Series reactors

Nuclear Archaeology for Plutonium

(U.S. Hanford B Reactor, 1944-1968)



Nuclear Archaeology for Plutonium

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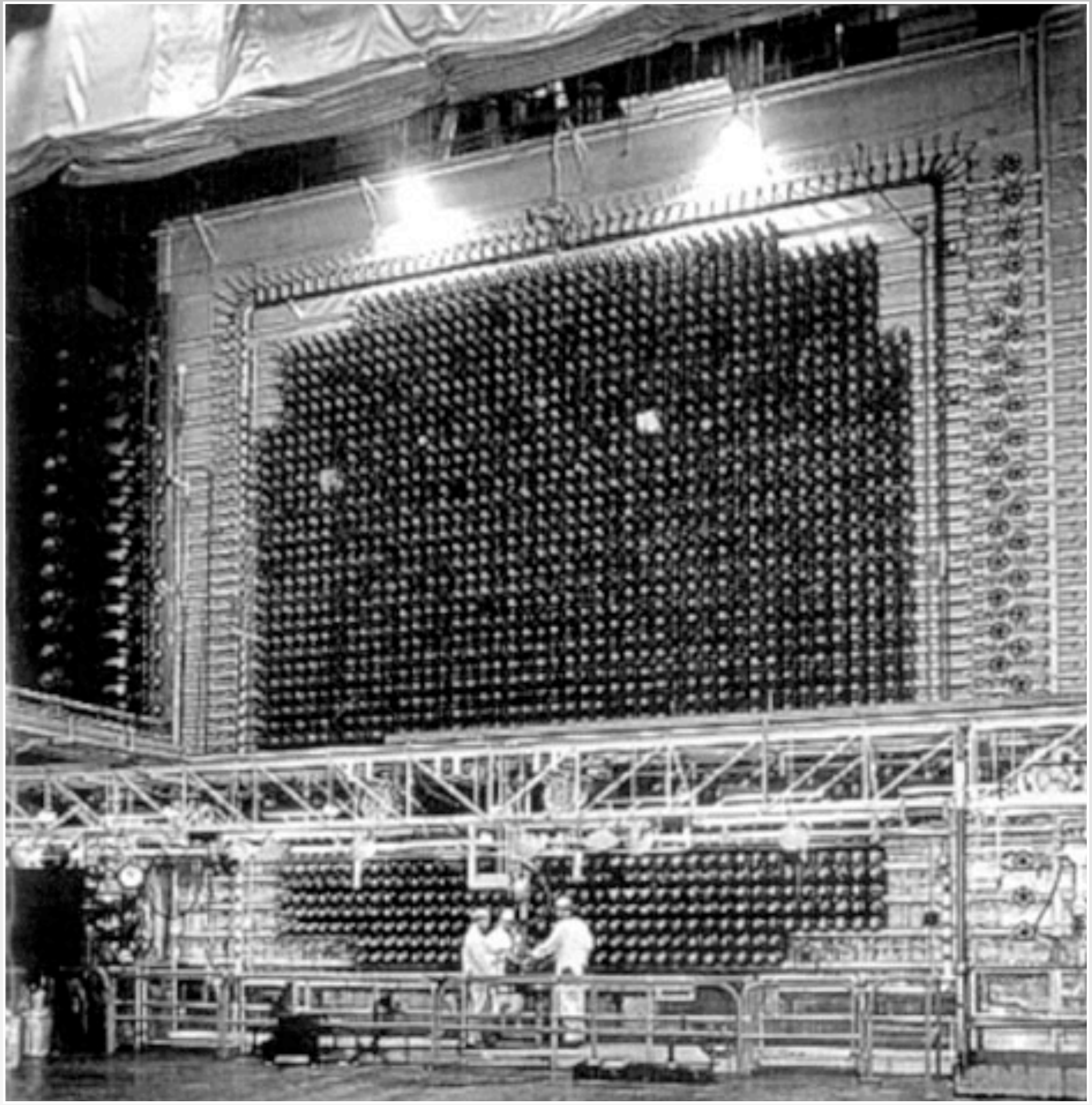

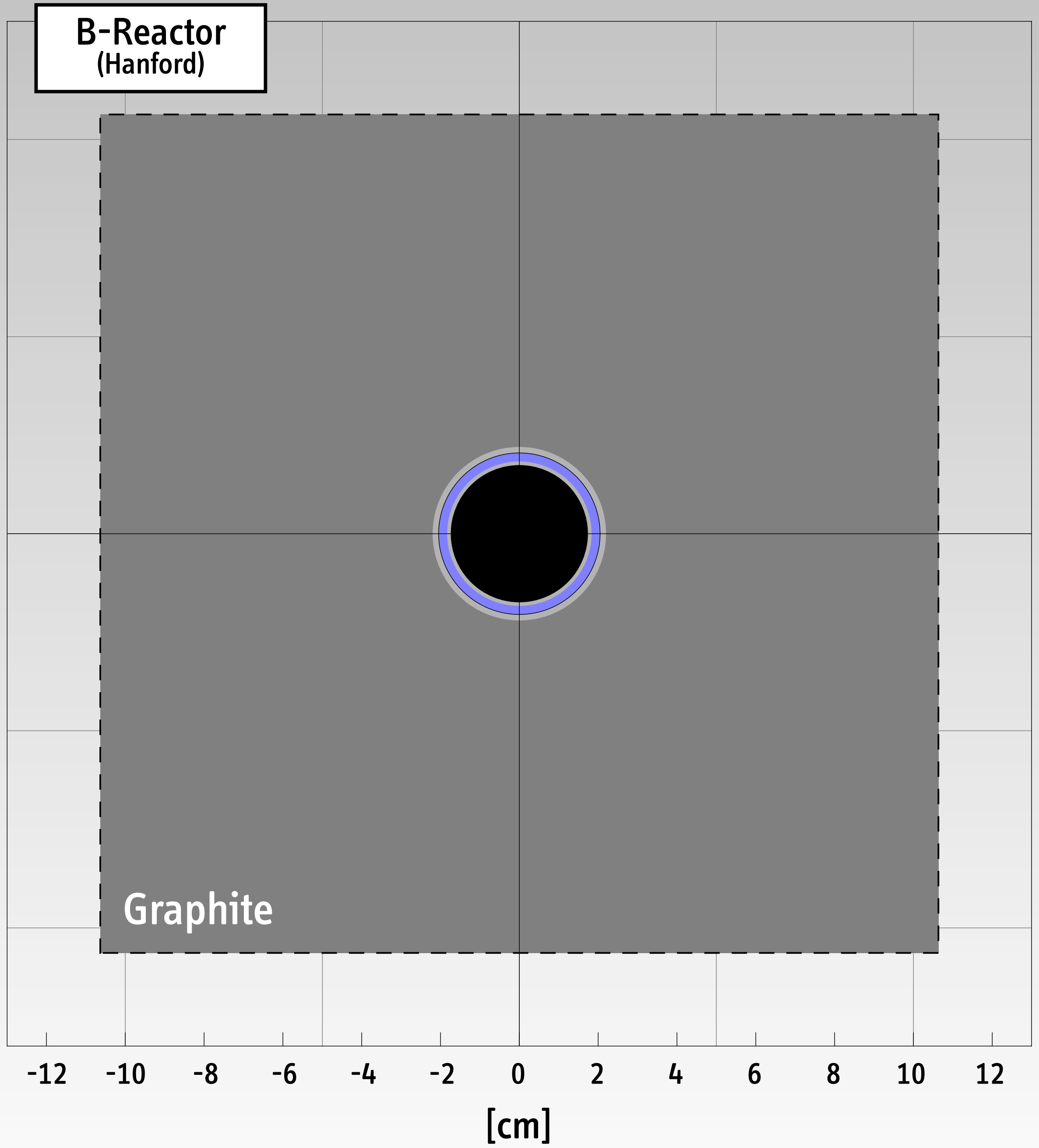

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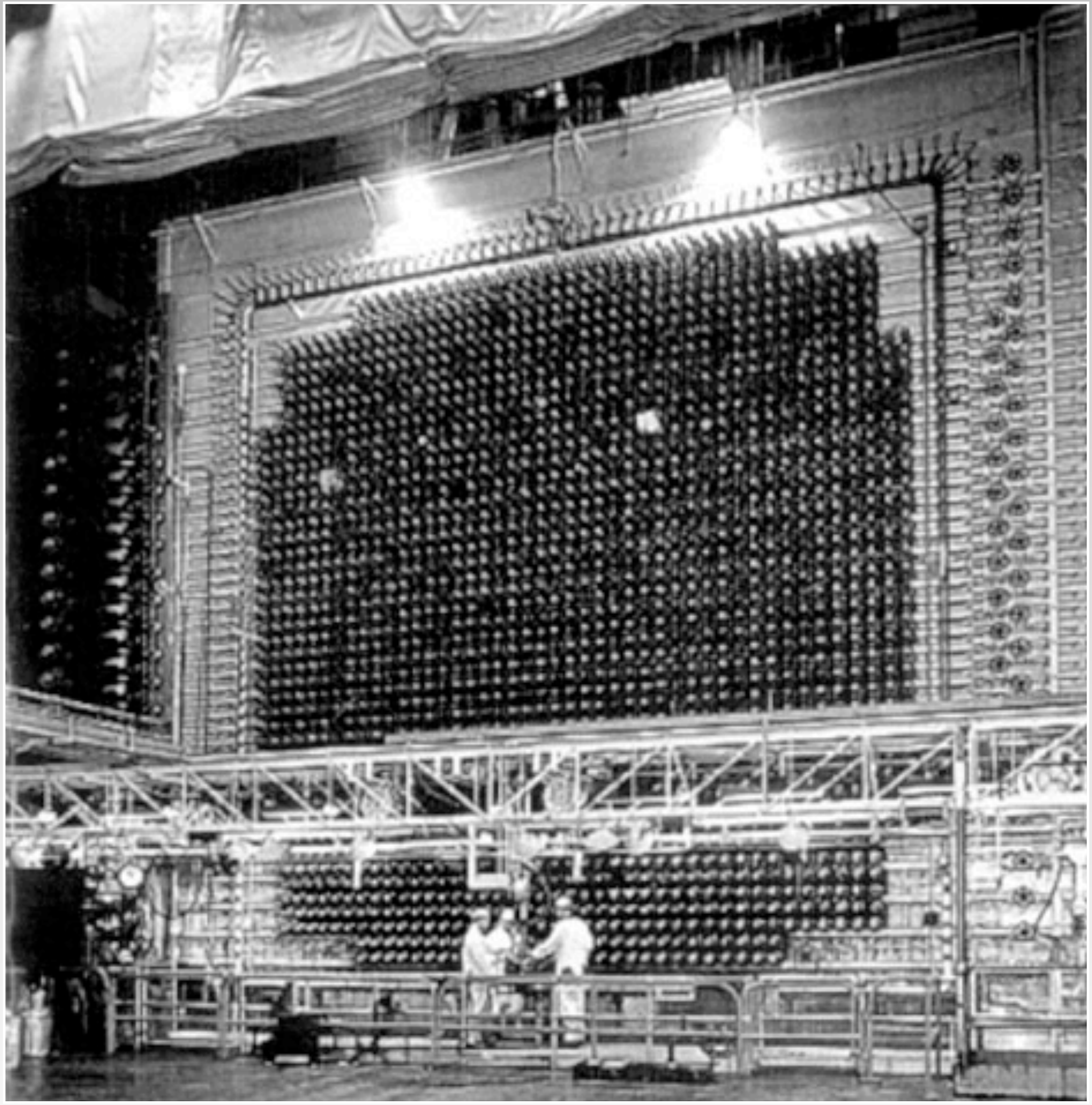
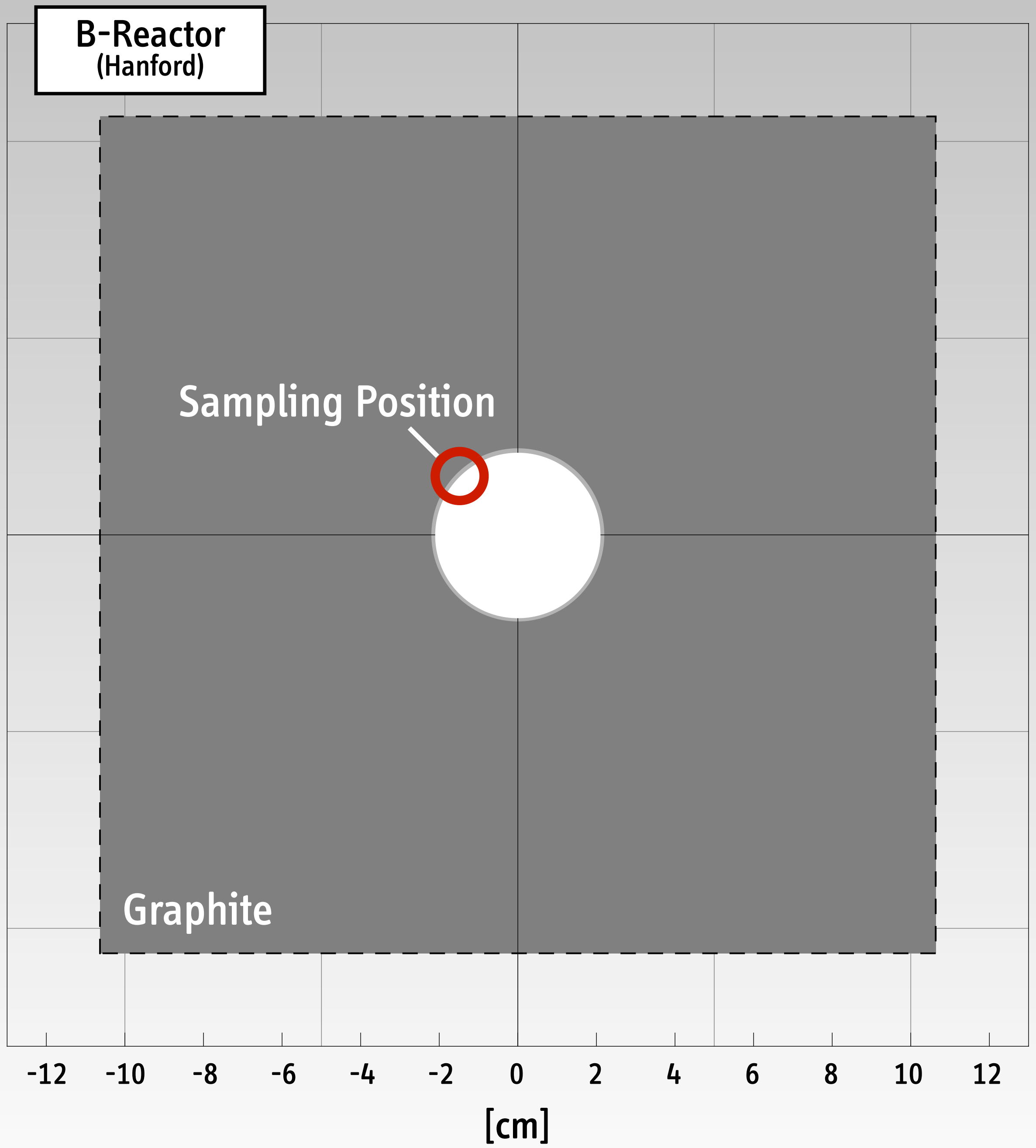
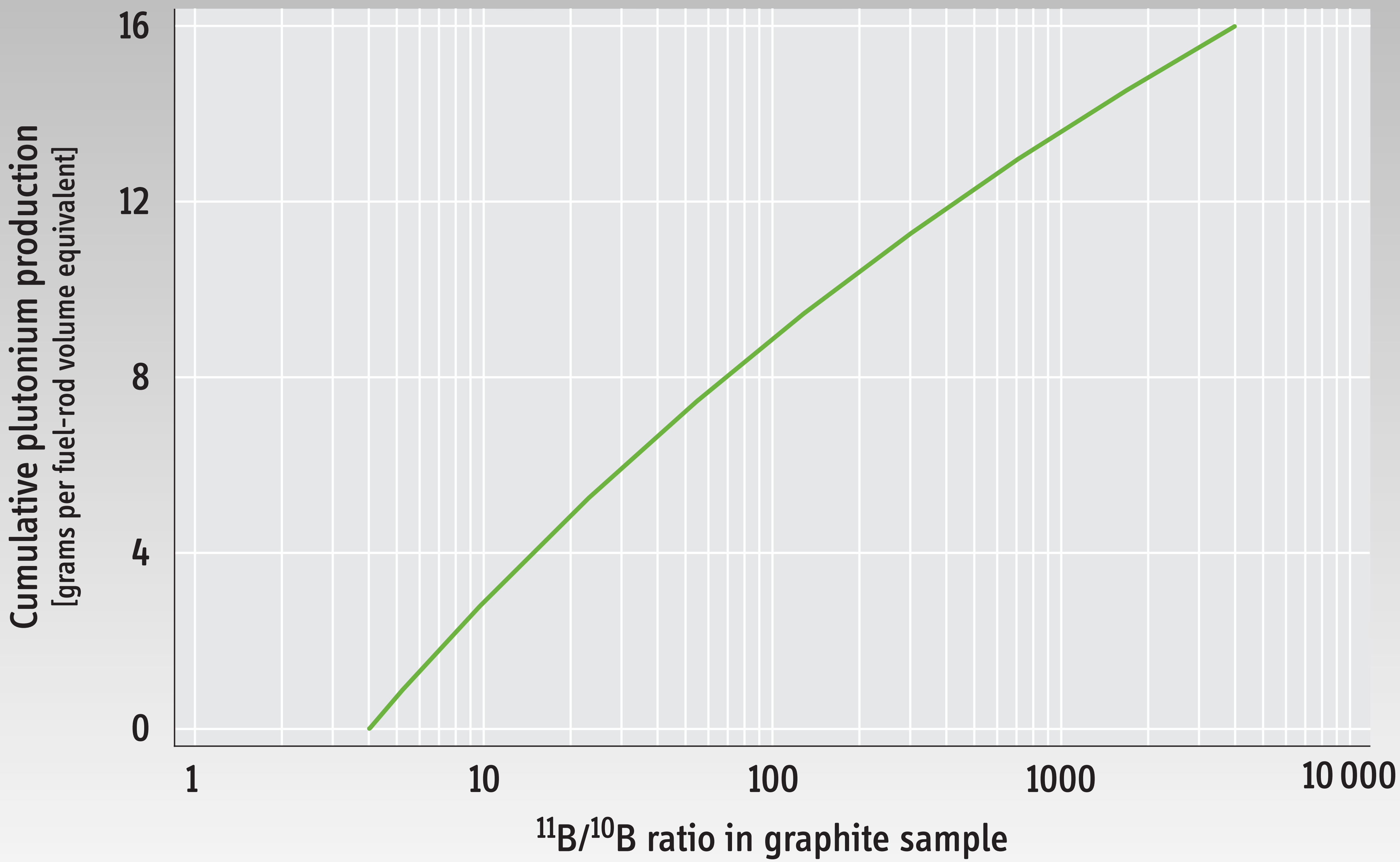




Graphite Isotope-Ratio Method (GIRM)



Jungmin Kang, "Using Graphite Isotope Ratio Method to Verify DPRK's Declaration of Plutonium Production," *under review*

North Korea’s Yongbyon Reactor

(Design based on the U.K. Calder Hall Reactor)

Photo: Keith Luse

Demolition of cooling tower, June 26, 2008

North Korea’s Yongbyon Reactor

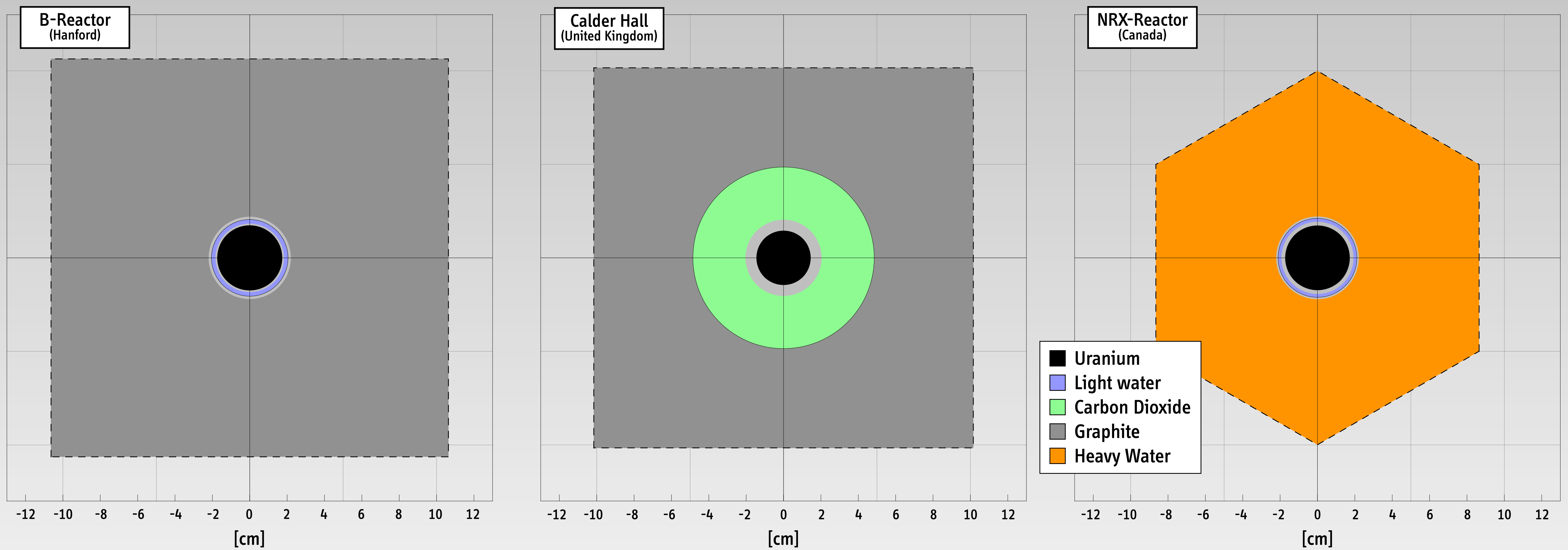
Credit: CNN/Brian Rokus

Plutonium Production Reactor Types

	Graphite moderated		Heavy-water moderated		Driver fuel with external DU targets
	H_2O cooled	CO_2 cooled	H_2O cooled	D_2O cooled	
United States	Hanford				Savannah River
Russia	“Tomsk-7”				
U.K.		Calder Hall			
France		G-Series			Célestin
China	“Jiuquan”				
Israel				Dimona	
India			Cirus/NRX	Dhruva	
Pakistan			Khushab		
DPRK		Yongbyon			

A. Glaser, Isotopic Signatures of Weapon-grade Plutonium from Dedicated Natural-uranium-fueled Production Reactors and Their Relevance for Nuclear Forensic Analysis, *Nuclear Science & Engineering*, September 2009

Unit Cells of Early Natural-Uranium-Fueled Reactors



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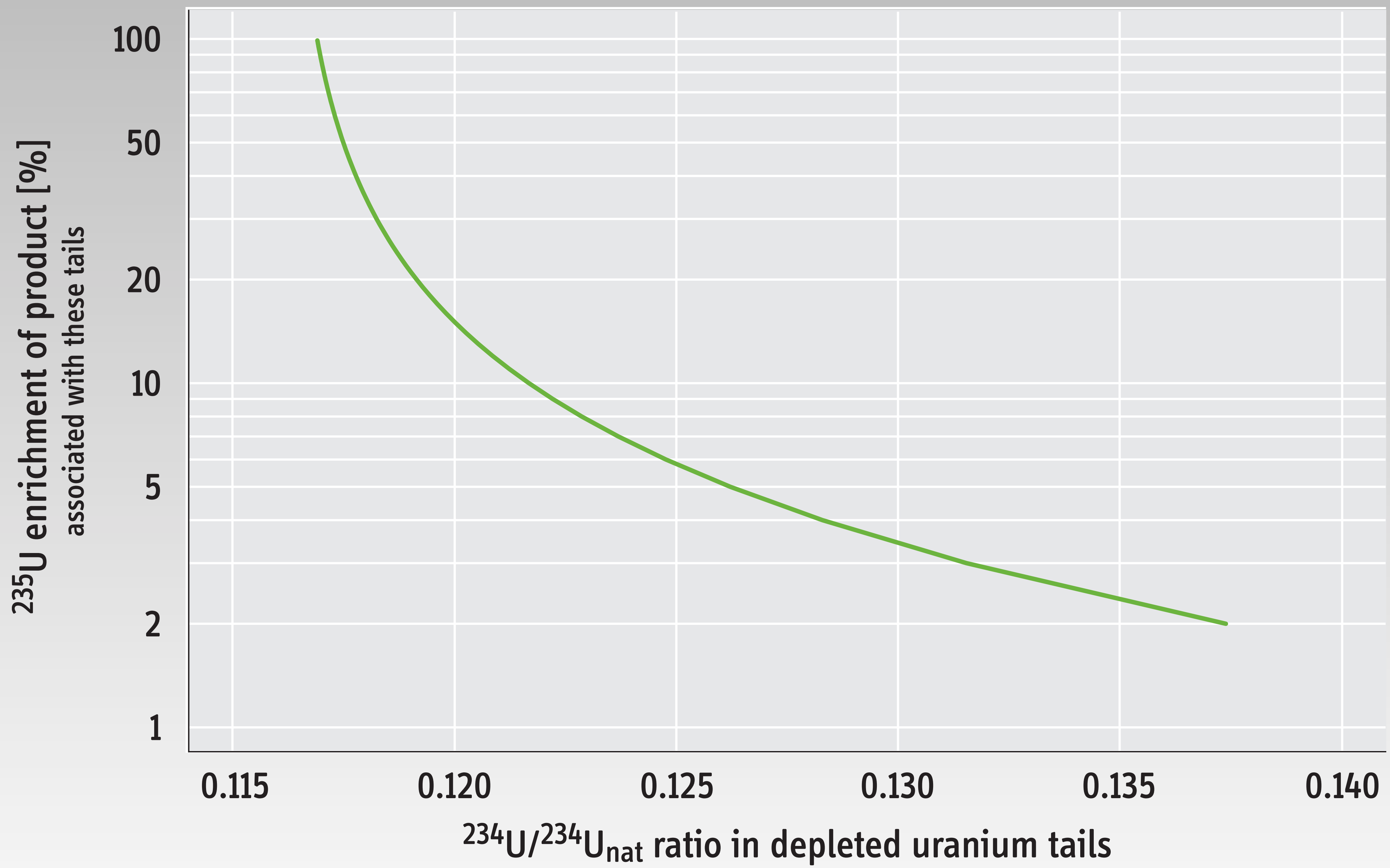
Nuclear Archaeology for Uranium Enrichment

Nuclear Archaeology
for Uranium Enrichment

Novouralsk Tails Storage Area

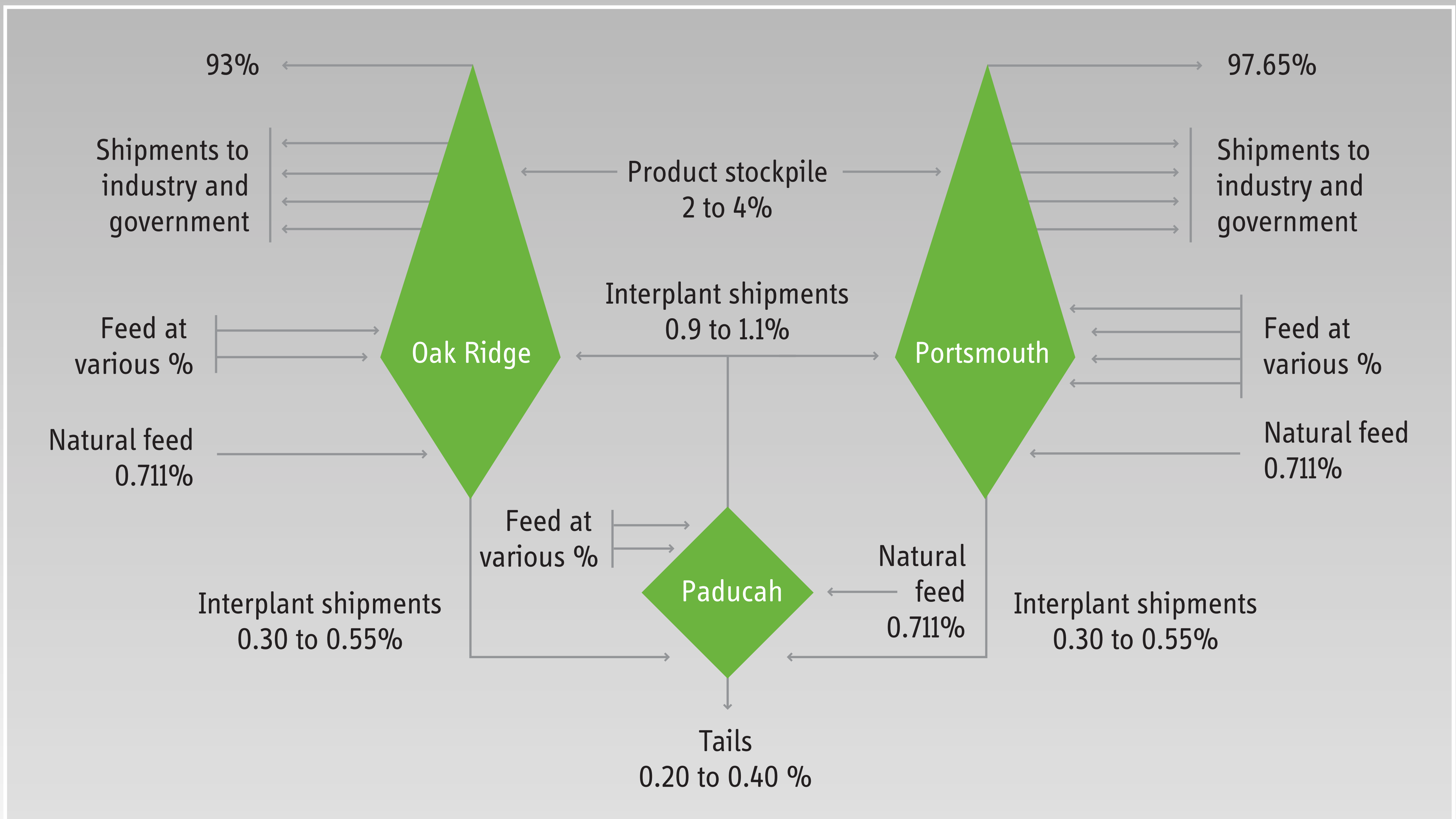
Measurements on Uranium Tails



M. Sharp, "Applications and Limitations of Nuclear Archaeology," *in preparation*

Integrated Assessment of Fissile Material Production

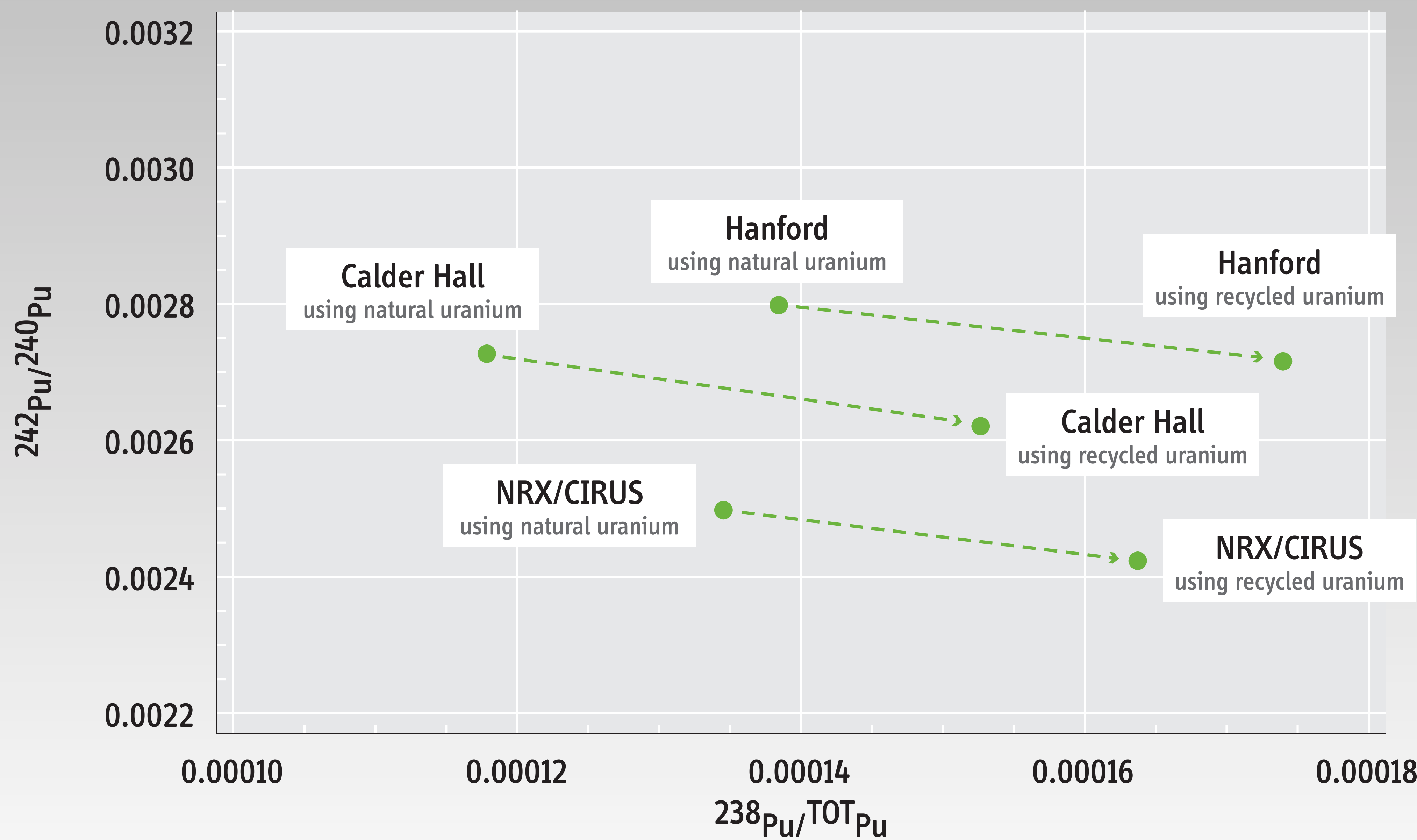
Integrated Operation of the U.S. Gaseous Diffusion Plants



Highly Enriched Uranium: Striking a Balance. A Historical Report on the United States Highly Enriched Uranium Production, Acquisition, and Utilization Activities from 1945 through September 30, 1996, U.S. Department of Energy, January 2001 (publicly released in 2006), www.ipfmlibrary.org/doe01.pdf

Isotopics of Weapon-Grade Plutonium

93.8% Pu-239, produced from natural and pre-irradiated uranium



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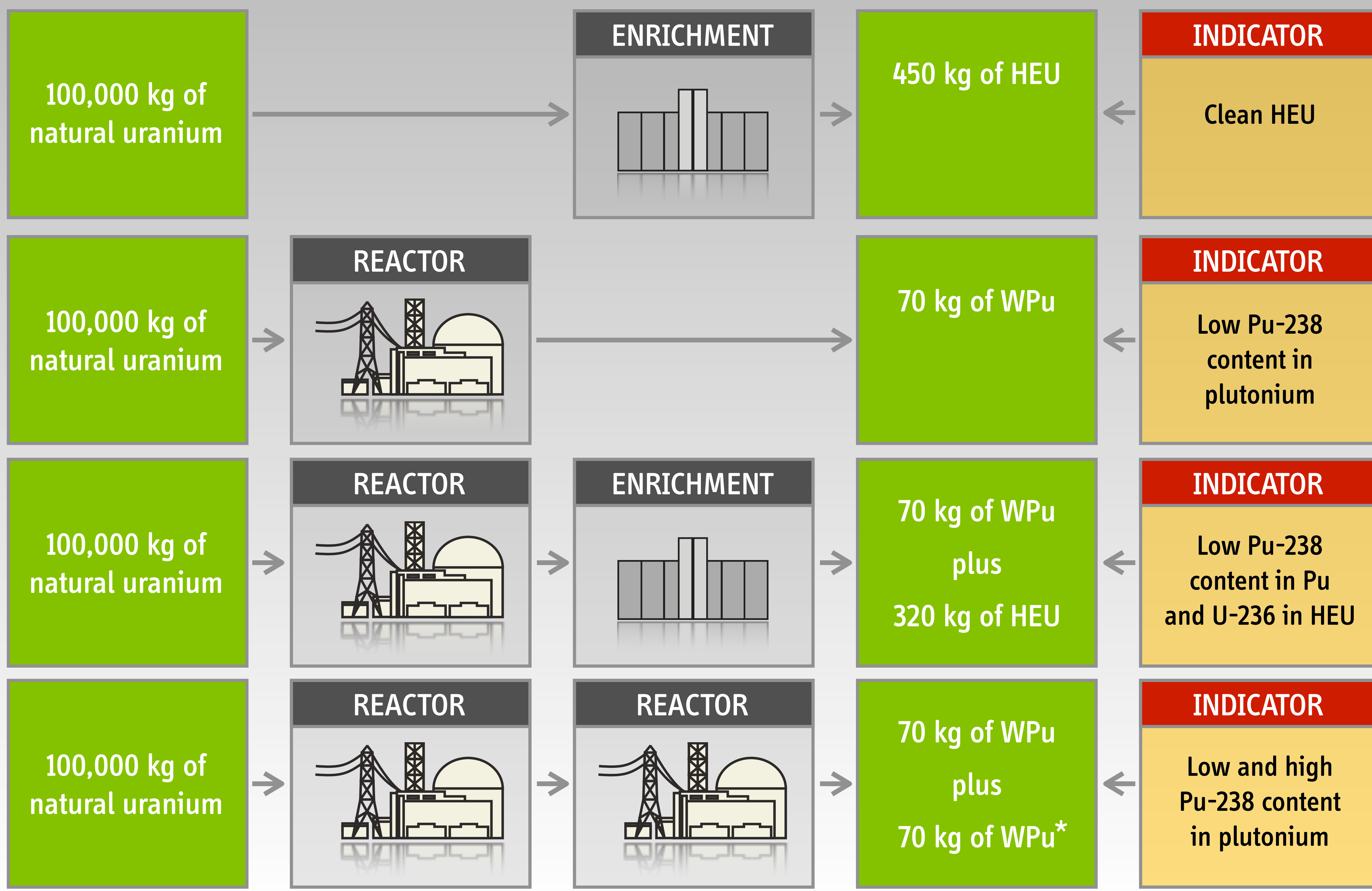
Production Modes Leave Characteristic Signatures in the Fissile Materials



The Way Forward

Verified Declarations of Fissile-Material Stocks and Production

Most former production facilities are already shut-down or in various stages of decommissioning

To retain the option of verifying declarations:
Need to preserve production reactors (and depleted uranium tails) in a condition that will permit nuclear archaeology

Some precedents and many opportunities for cooperative initiatives

Start with joint demonstration exercises
to establish the methods and tools for all types of relevant plants