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Atoms for Peace and Development

Molybdenum 99 Production Overview

WOSMIP 2022

June 9, 2022

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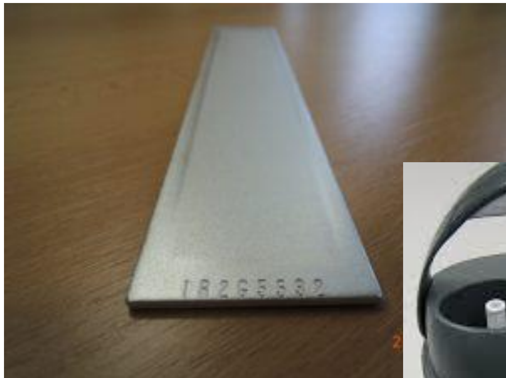
International Atomic Energy Agency

A Brief History of Mo-99/Tc-99m



- First practical medical use in the 1960s
- Early on neutron capture (Mo-98(n,γ)Mo-99) dominated
- Cintichem process from 1968 on and the rise of fission production
- Tc-99m used in ~80% of all nuc. med. procedures worldwide

IAEA Support for Mo-99/Tc-99m Technology

Department of Nuclear Sciences and Applications

- Radioisotope Products and Radiation Technology Section
- Focuses on Technology Development, Application

Department of Nuclear Energy

- Research Reactor Section
- Focuses on HEU Minimization

Radioisotope Products and Radiation Technology Section Activities Relevant to Mo-99

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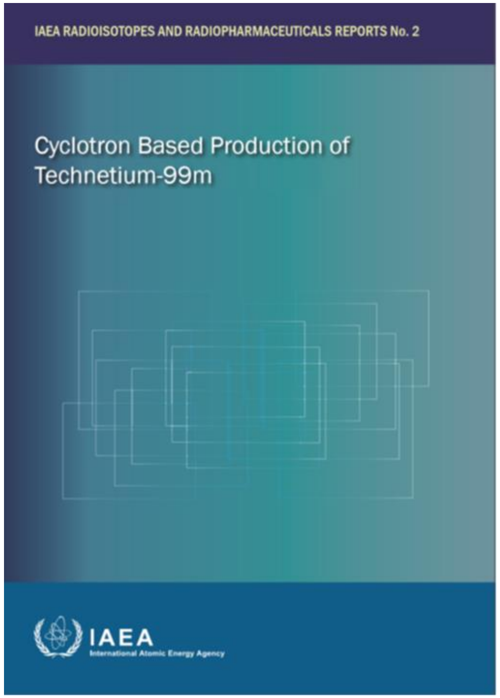
- Research and Development
- Implementation of Technologies
- Education / Training / Qualification

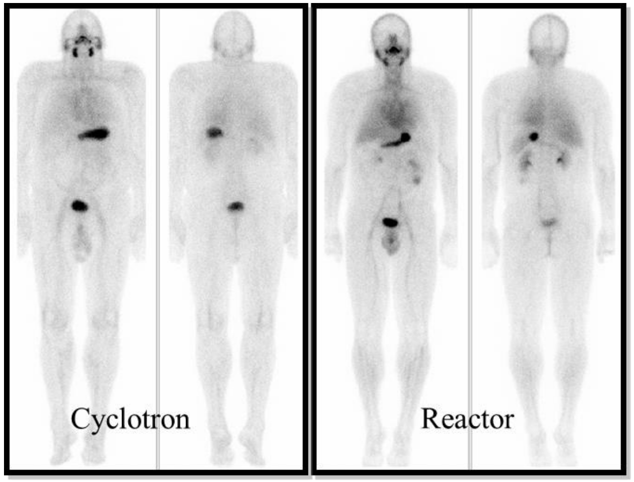
Areas:

- Production of radioisotopes and radiopharmaceuticals
- Accelerator-based radiation technologies for industry, environment, and cultural heritage
- Sealed radiation sources for NDT and other applications

Accelerator-based Alternatives to Non-HEU production of Mo-99/Tc-99m

- 2011-2015
- 18 participants from 16 Member States
- Production of Tc-99m in cyclotron - very successful
- Technology to produce several (>30) Ci Tc-99m per run in medical cyclotrons of energies below 24 MeV proven; clinical trials under way; regulatory approvals sought
- Monograph approved in Europe
- Self-sufficiency in hospitals/towns/country
- Good option for hospital or radiopharmacy; local productions
- Target specifications; reuse of targets etc. need consideration





Comparison of cyclotron- and reactor-based Tc-99m pertechnetate for the Univ. of Alberta Clinical Trial (cancer thyroid patients imaged post-thyroidectomy)

CRP: Photonuclear Route for Producing Tc-99m and Tc-99m Generators

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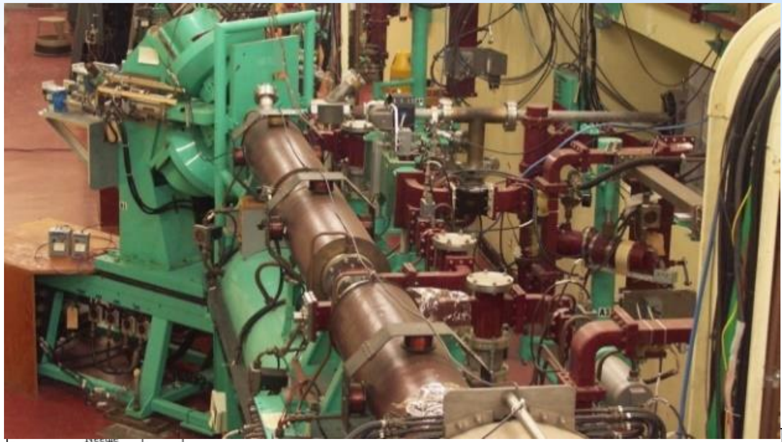
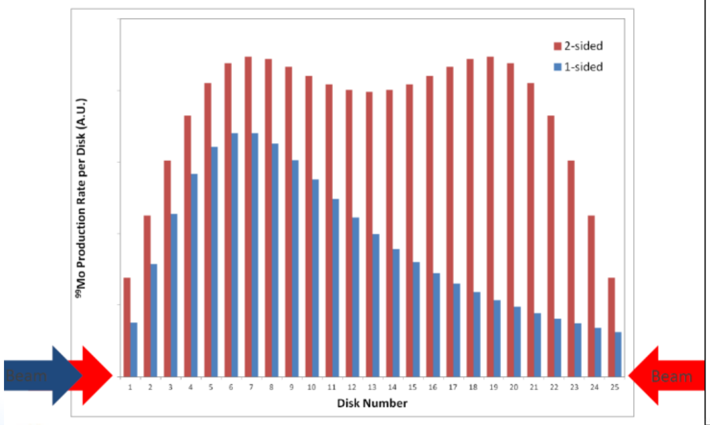
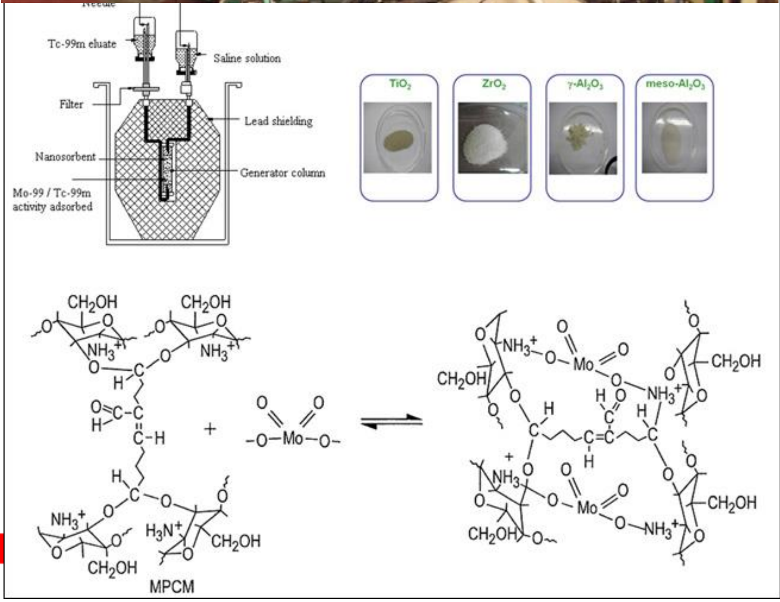
- First Meeting: December 2017
- 18 Approved Proposals
- Aimed as use of low specific activity Mo-99 for generator preparation and accelerator production of Mo-99 (Mo-100 (γ,n) reaction)
- Third RCM November 2021
- Publication to Follow



Two Sided Irradiation, 35 MeV Production





https://www.iaea.org/newscenter/news/new-crp-new-ways-of-producing-tc-99m-and-tc-99m-generators

TABLE 1. IAEA PUBLICATIONS RELATED TO Tc-99m RADIOPHARMACEUTICALS

***TRS = Technical Reports Series ; RRR = Radioisotopes and Radiopharmaceuticals Reports; NES = Nuclear Energy Series; Tec-Doc = Technical Document.**

Title	Date of publication	CRP code	Reference	Format*
Development of Kits for 99mTc Radiopharmaceuticals for Infection Imaging	2004	F22032	[18]	TECDOC
99mTc labelled peptides for imaging of peripheral receptors	2001	F22023	[19]	TECDOC
Labelling of Small Biomolecules Using Novel Technetium-99m Cores	2007	F22038	[20]	TRS
"Technetium-99m Radiopharmaceuticals: Manufacture of Kits"	2008	n.a.	[21]	RRS
Technetium-99m Radiopharmaceuticals: Status and Trends"	2010	n.a.	[22]	RRS
Non-HEU Production Technologies for Molybdenum-99 and Technetium-99m	2013	n.a.	[23]	NES
Cyclotron Based Production of Technetium-99m	2017	F22062	[24]	RRR
Feasibility of producing molybdenum-99 on a small-scale using fission of low enriched uranium or neutron activation of natural molybdenum (iaea.org)	2015	T12018	[25]	TRS
Development of 99mTc Radiopharmaceuticals for Sentinel Node Detection and Cancer Diagnosis	2015	F22045	[26]	RRS

A new IAEA TECDOC, *PROGRESS ON Tc-99m RADIOPHARMACEUTICALS (under preparation 2022)?*

Research Reactor Section Support for HEU Minimization

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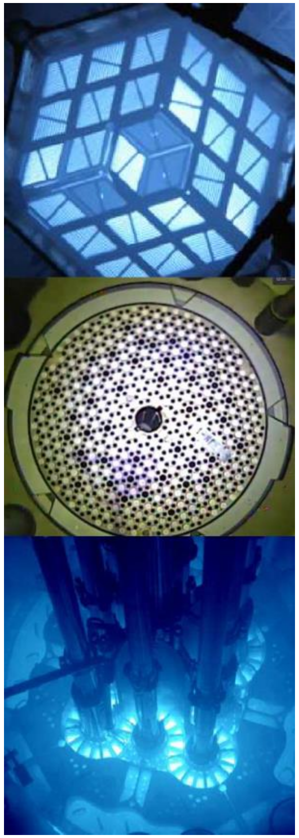


30+ years of IAEA support on international efforts to reduce HEU in international civilian activities

We assist countries, upon request with

- Conversion to LEU
- New Fuel Specification and Procurement
- HEU Removals
- Non-HEU Mo-99 Production

Non-HEU Mo-99/Tc-99m Production

IAEA supports Member States to ensure sustainability of production of Mo-99/Tc-99m and other radioisotopes

Technologies:

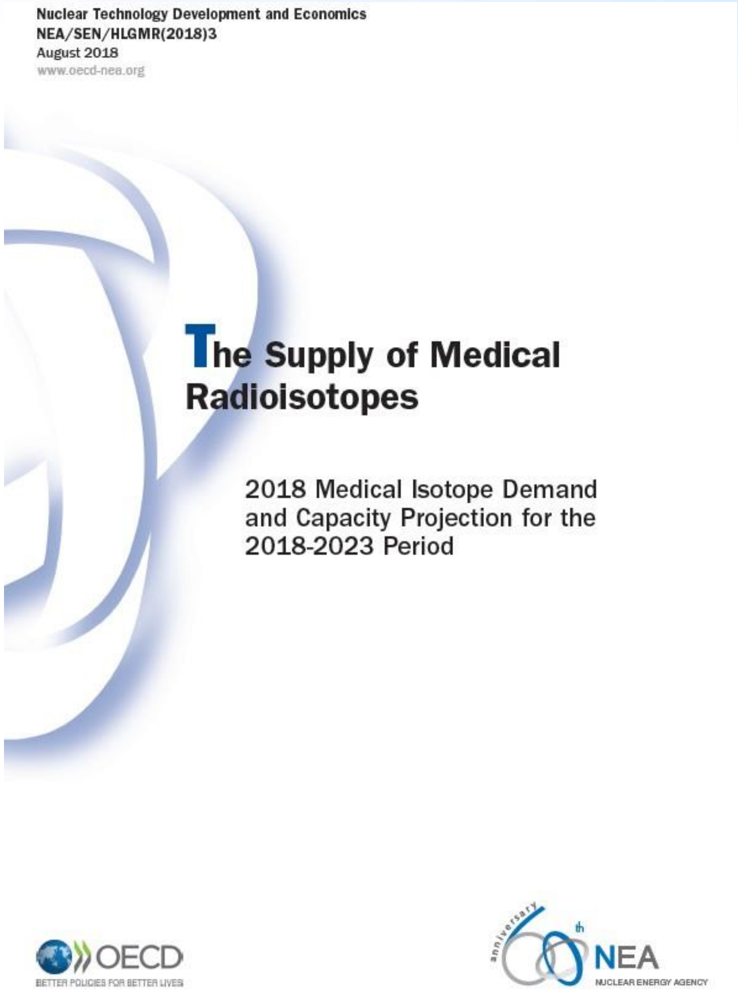
- Conversion of Major Mo-99/Tc-99m Producers – HEU to LEU targets
- Non-HEU Production of Mo-99 (Mo-98 activation)
- Accelerator-based alternatives to Non-HEU Production of Mo-99/Tc-99m

Production Support:

- 2018 OECD Isotope Supply Review
- 2018 and 2020 Technical Meetings on Global Capabilities for Production and Manufacture of Non-HEU Mo-99 Targets
- 2022 Technical Meeting on Management of Wastes / Residuals from Mo-99 Production
- Planned October 2022 Mo-99 International Symposium
- US Molybdenum-99 Program Support

OECD: 2018 Medical Isotope Supply Review

- Global Demand
- Irradiation Capacity
- Processing Capacity
- Supply


Nuclear Technology Development and Economics
NEA/SEN/HLGMR(2018)3
August 2018
www.oecd-nea.org

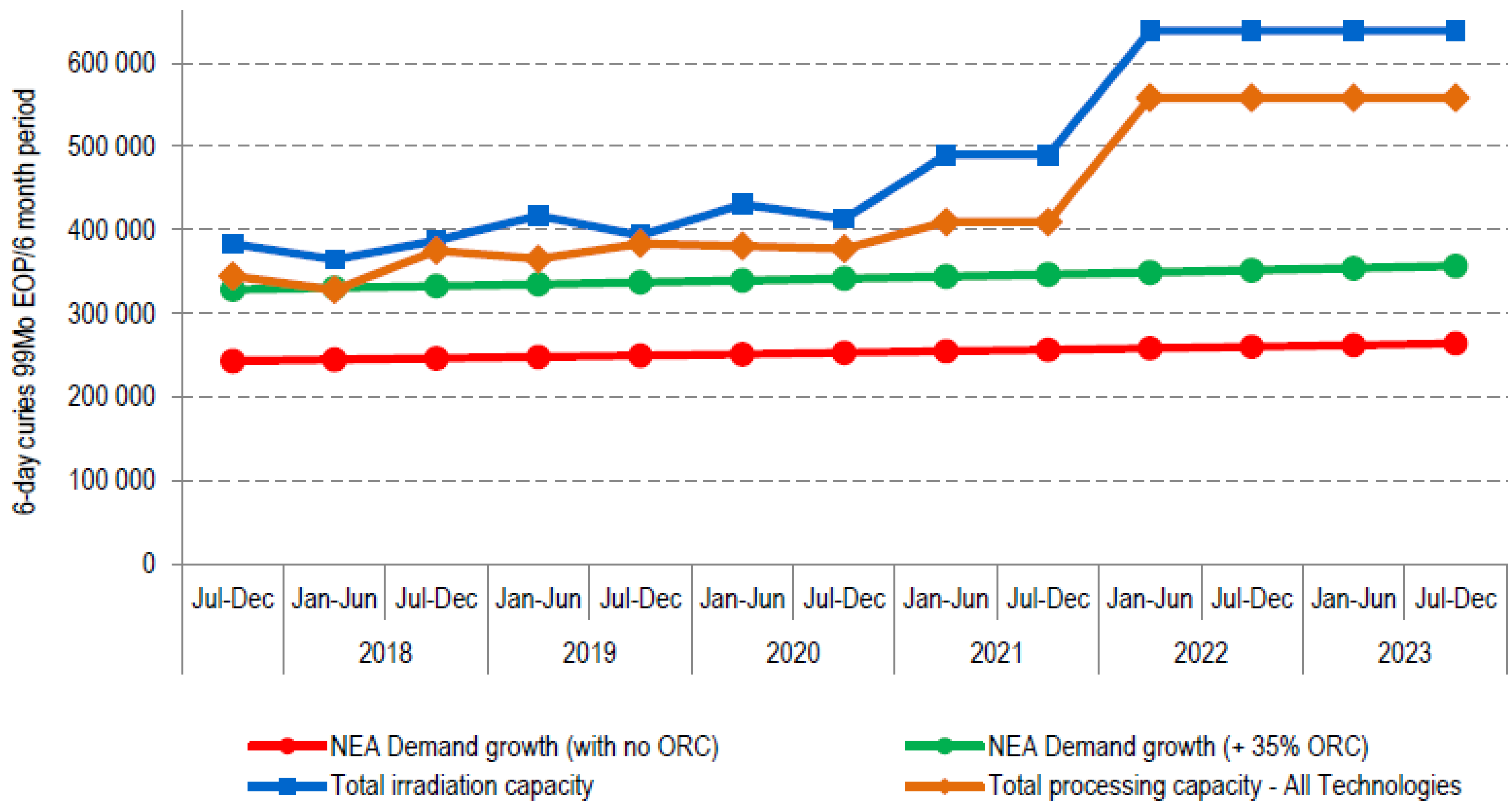
The Supply of Medical Radioisotopes

2018 Medical Isotope Demand and Capacity Projection for the 2018-2023 Period

OECD
BETTER POLICIES FOR BETTER LIVES

60th anniversary NEA
NUCLEAR ENERGY AGENCY

OECD: 2018 Medical Isotope Supply Review



OECD Key Takeaways, Current Status

- Positive developments with conversion to LEU and first licensing for alternative generators by NorthStar, SHINE
- Extended unplanned outage at NTP has pushed processing capacity below the NEA demand +35% outage reserve guideline
- Other Irradiators Have Stepped Up
- Supply situation will continue to require careful planning to minimize security of supply risks and react effectively in the event of unplanned outage

US Molybdenum 99 Program

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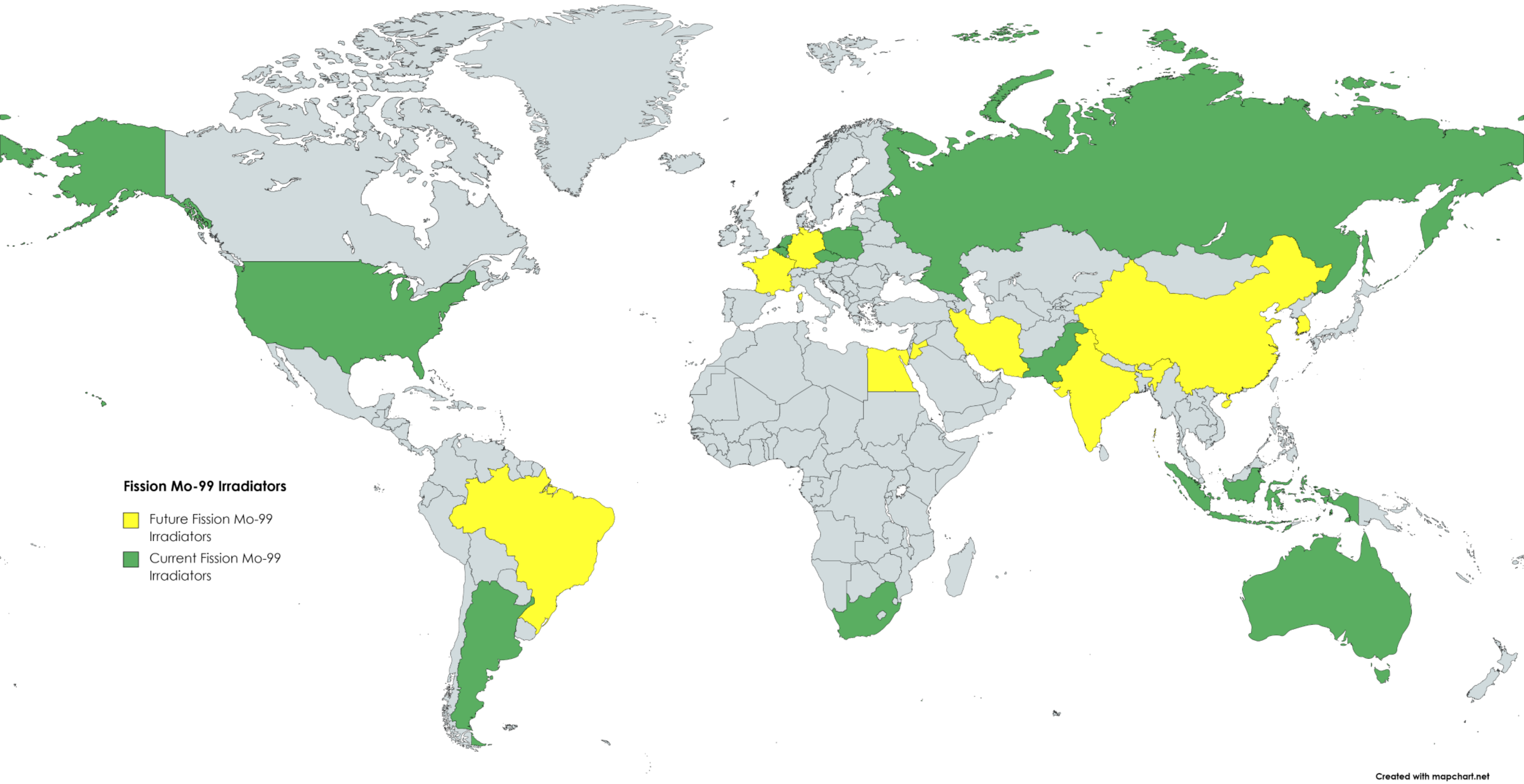
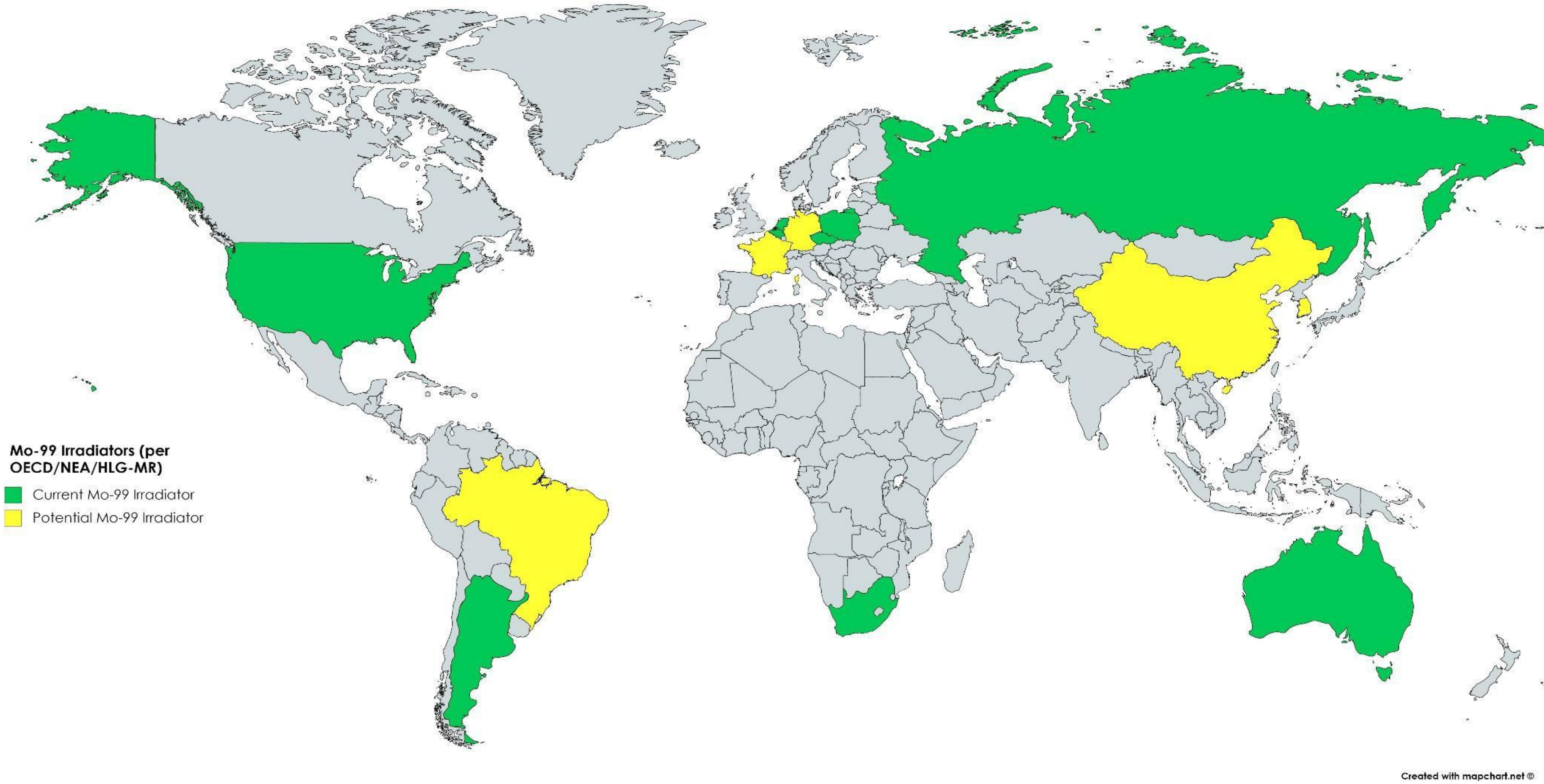
- Established by US Congress in Response to Shutdown of Maple Reactors in Canada
- Designed to Establish Commercial Supply of Non-HEU Based Mo-99/Tc-99m Production in the USA
- Cooperative Agreements Made with Three Companies
- Led to January 2022 End of US Exports of HEU for MIP

NIOWAVE	NorthStar MEDICAL RADIOISOTOPES, LLC	SHINE
Accelerator with LEU fission	Two technologies: ➢ Neutron capture with enriched Mo-98 targets ➢ Accelerator with Mo-100 targets	Accelerator with LEU fission

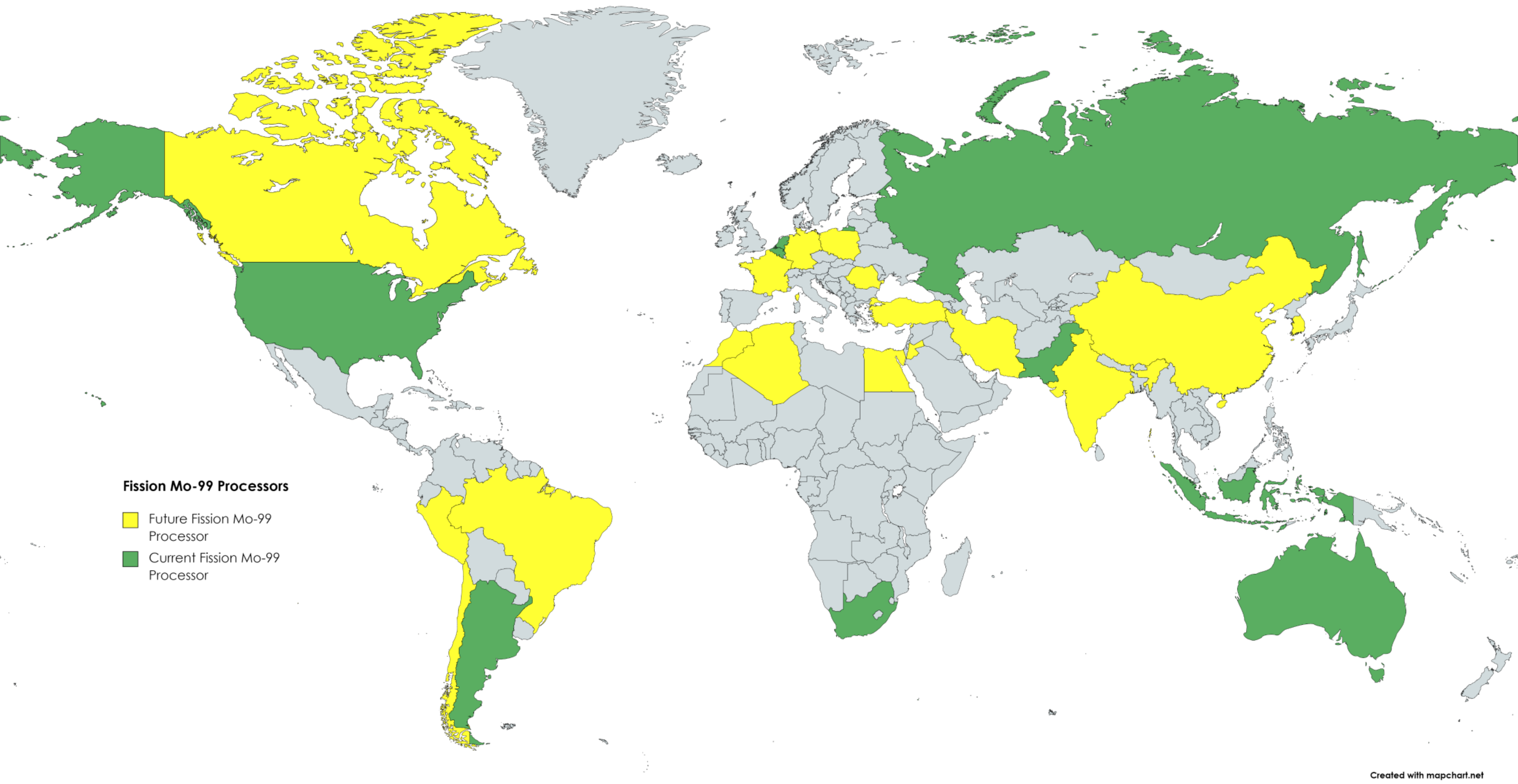
Fission Mo-99 Target Irradiators



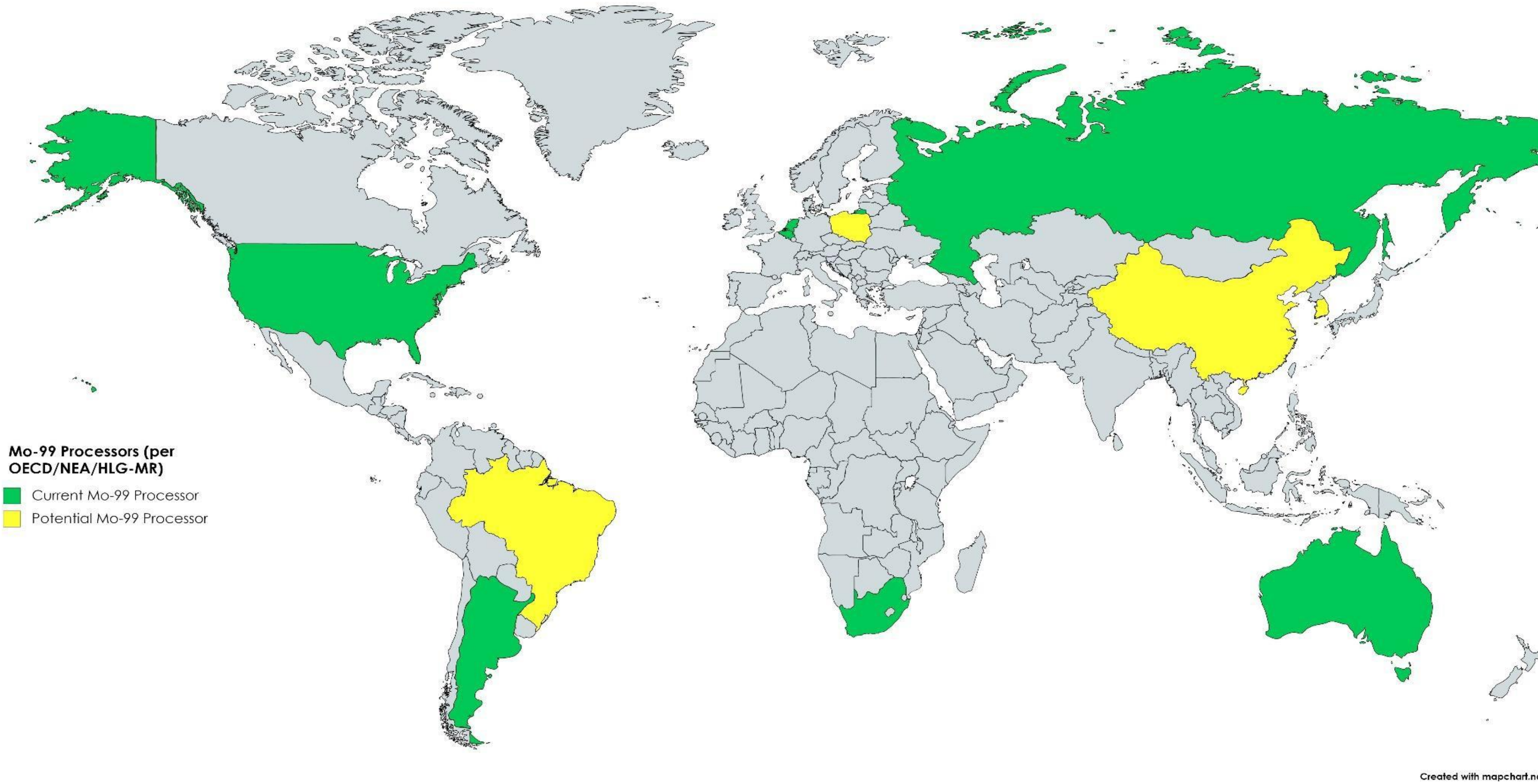
Fission Mo-99 Target Irradiators - 2018



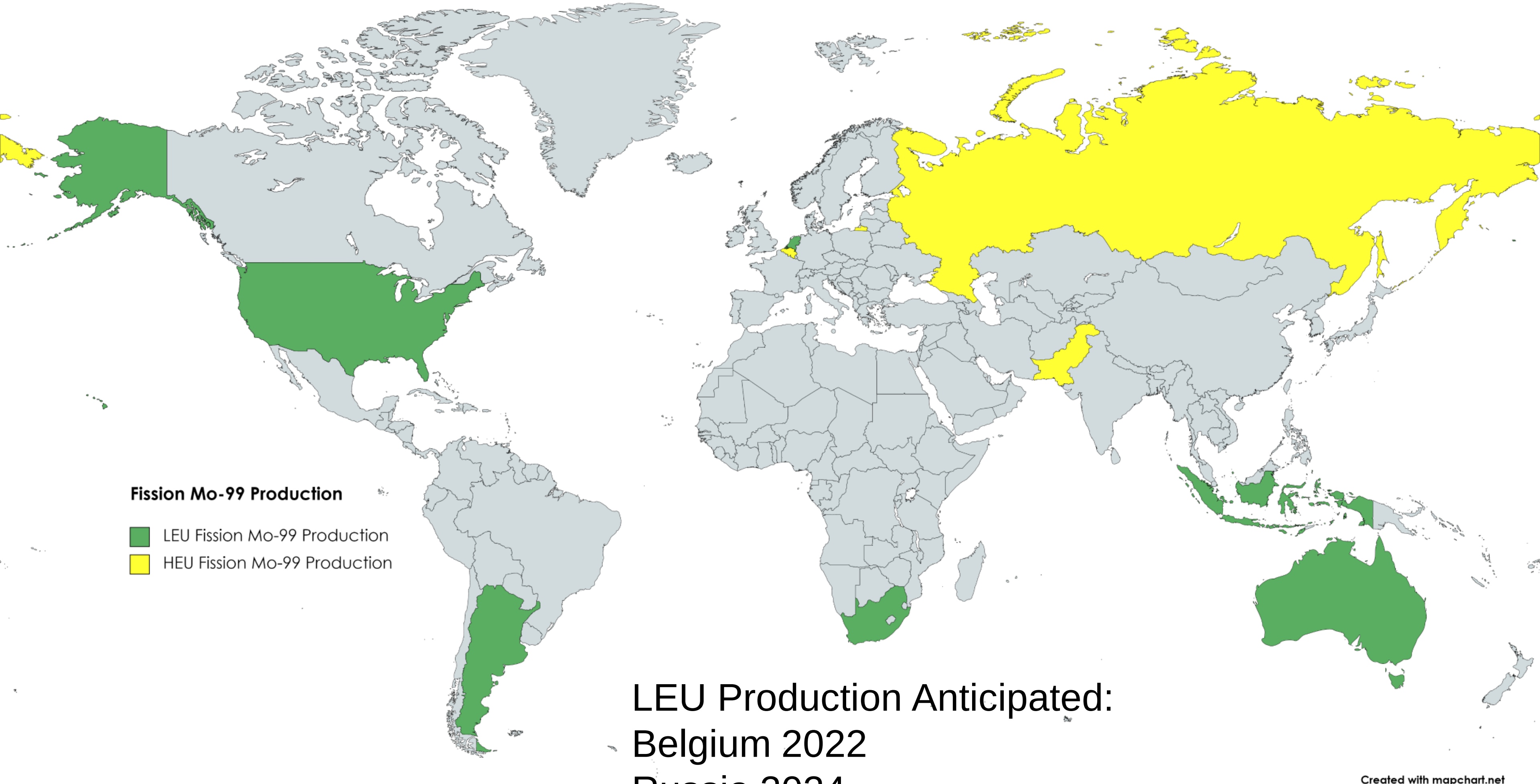
Fission Mo-99 Target Processors



Fission Mo-99 Target Processors - 2018

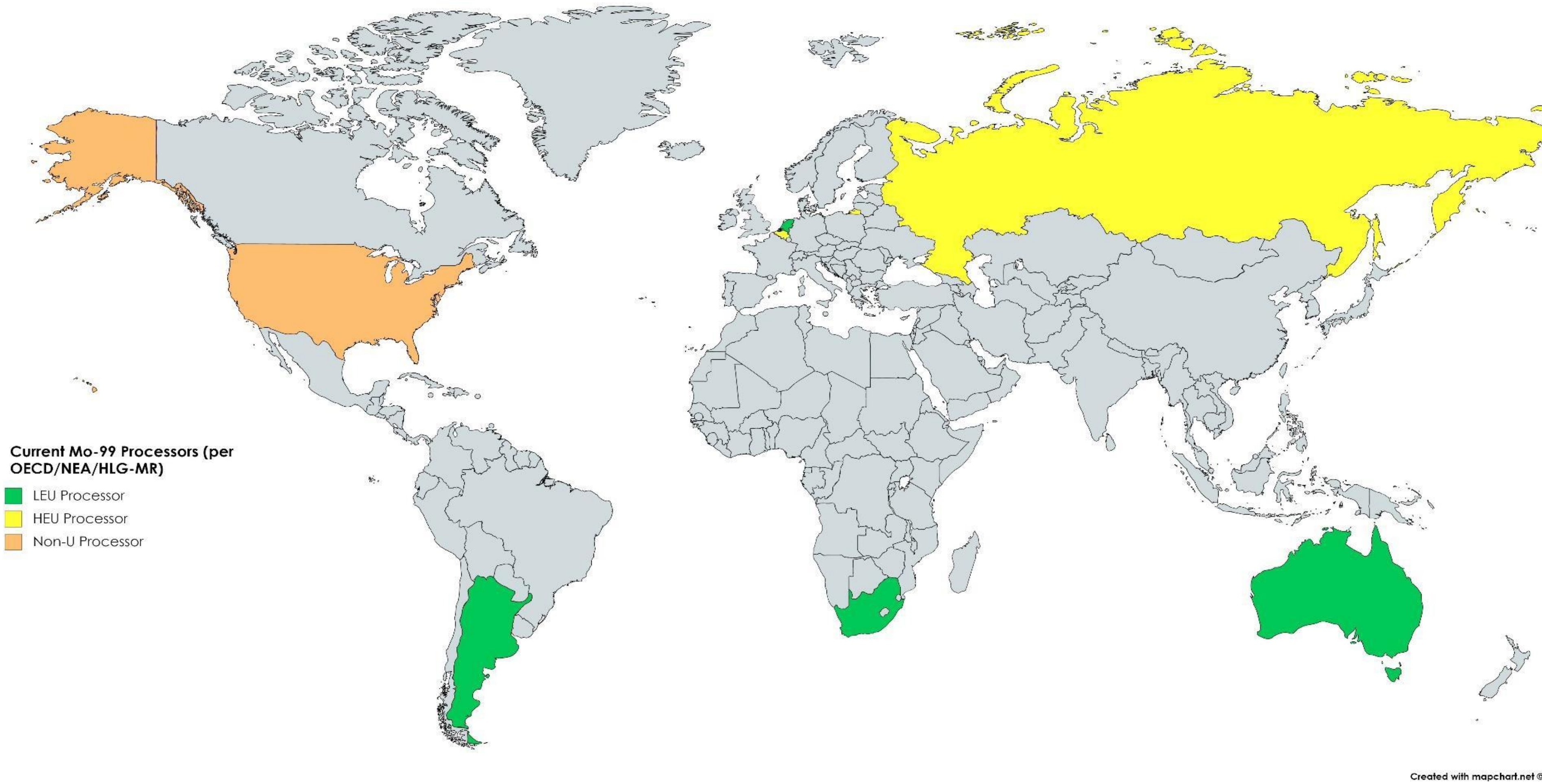


Most World Mo-99 Process Capacity Now non-HEU



LEU Production Anticipated:
Belgium 2022
Russia 2024
Pakistan – Under Study

Most World Mo-99 Process Capacity Now non-HEU - 2018



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IAEA CRP: Sharing and Developing Protocols to Further Minimize Radioactive Gaseous Releases to the Environment in the Manufacture of Medical Radioisotopes

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Coordinated Research Project (CRP)

- CRP on Sharing and Developing Protocols to Further Minimize Radioactive Gaseous Releases to the Environment in the Manufacture of Medical Radioisotopes, as Good Manufacturing Practice

- Request received from Australia, Belgium, the Netherlands, Republic of Korea, and the USA in May 2014

- Request proposed the IAEA initiate a CRP on the topic of technologies to reduce emissions from medical isotope production facilities

- Research Coordination Meetings Held in 2015, 2017, and 2018

SPECIFIC RESEARCH OBJECTIVES

- To identify the steps and factors of the MIP process that need proper gaseous emission monitoring and trapping, including those radioisotopes coming from the fission of Uranium.
- To evaluate the impacts of emissions on health and safety and on the international and national monitoring of nuclear explosions without affecting production capabilities by using ATM.
- To validate ATM and quantify the uncertainty based on MIP stack data and monitoring data.
- To develop research activities focusing on efficient methods of treatment and process of the radioactive gaseous emission to the atmosphere (plant operation, gas trapping and decay time) that could mitigate the radioactive gaseous emissions.
- To evaluate and develop stack measurement systems for radioactive gases and explore data exchange methodologies and formats.

Recommendations From the Final Report

- CRP showed that the cooperation between IAEA and CTBTO is productive and should be continued
- New adsorption materials and mitigation technologies should be further explored, in combination with modelling adsorption/desorption cycles to allow cost and space efficient systems for reducing emissions, potentially in a new CRP
- Further study of global medical isotope production which can lead to potential releases impacting treaty verification (e.g. radio Xe & I)
- Collection and sharing of data such as
  - Stack monitoring and environmental monitoring
  - Atmospheric dispersion and transport modelling
- Study on worldwide background levels of I-131

Proposed Contents for the Guidelines

- Introduction
- Origin of Radioactive Gaseous Emissions
  - Xe, Kr, I
  - Fission process: dissolution, purification, waste treatment
- Trapping/Delay – Technology for New and Existing Facilities
  - Noble Gases
  - I-131
- Stack Monitoring
  - Detectors, efficiency, resolution, detection limits
  - Fixed and mobile
  - Data Sharing with CTBTO
- Monitoring Stations
- Transport Modelling – Validation of ATM
  - Near range (installation)
  - Long range
- Recommended Emission Values (safety and background)

Current Status

- The work performed during this CRP will be shared and made accessible to Member States beyond those involved in the CRP
- Draft of Publication is Expected early 2023
- Depending of Format, Publication is Expected in 2024-25

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Thank you!