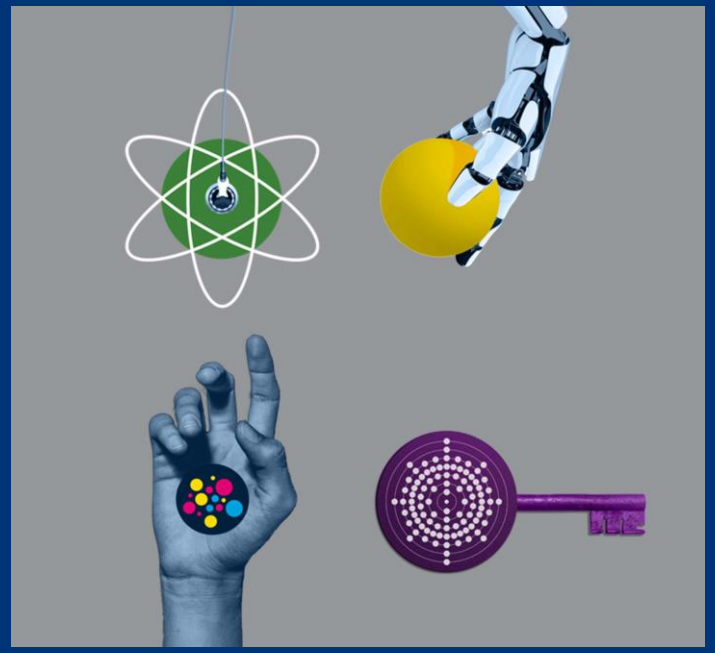


United Kingdom National Nuclear Laboratory

Nuclear Science to Benefit Society

Ask a Physicist, University of Warsaw, Warsaw, Poland

May 2025

Dr Iain Darby
Head of Strategic Research, UKNNL

Our mission

United Kingdom National Nuclear Laboratory

- United Kingdom National Nuclear Laboratory (UKNNL) is government's lead civil nuclear fission laboratory whose mission is twofold:

1. to enable and deliver nuclear outcomes for government, and
2. to support growth of the UK nuclear sector.

- *To achieve this mission, UKNNL will*
- *Be a custodian of national capabilities and infrastructure critical for national and energy security*
- *Become government's lead civil technical and strategic advisor for nuclear fuels and nuclear materials*
- *Carry out research to continue securing the safe operation of nuclear plants domestically and internationally*
- *Deliver practical nuclear research and enable decommissioning programmes*
- *Provide expertise and facilities to be a platform for the private sector to accelerate the deployment of technology to market*
- *Champion and nurture advanced nuclear skills*

“Our most important asset is our people”

1,600 People employed

13,000 Combined years of nuclear sector experience

500 Scientists

150 PhDs started in the last 5 years

370 Publications in the last 5 years

World-leading facilities

£1.5bn

The value of the nuclear facilities we manage

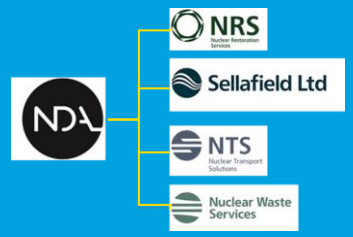
Four major change drivers for the UK nuclear sector

United Kingdom National Nuclear Laboratory

Advanced Gas – cooled Reactors (AGR) coming offline

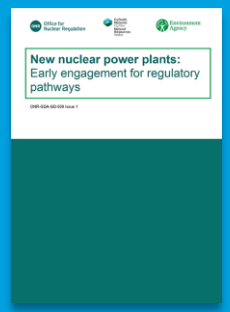
Decommissioning

(Nuclear Decommissioning Authority restructure, shift from AGR to PWR)



24GW Generating Capacity by 2050

(large, small and advanced reactors and associated fuel cycle)

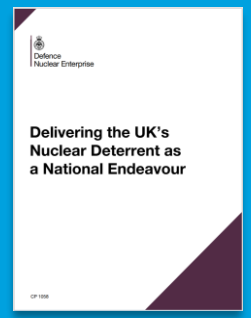


R&D Demand

(People, facilities, programmes)

Recapitalisation of the **Deterrent Programme**

(Defence Nuclear Enterprise)

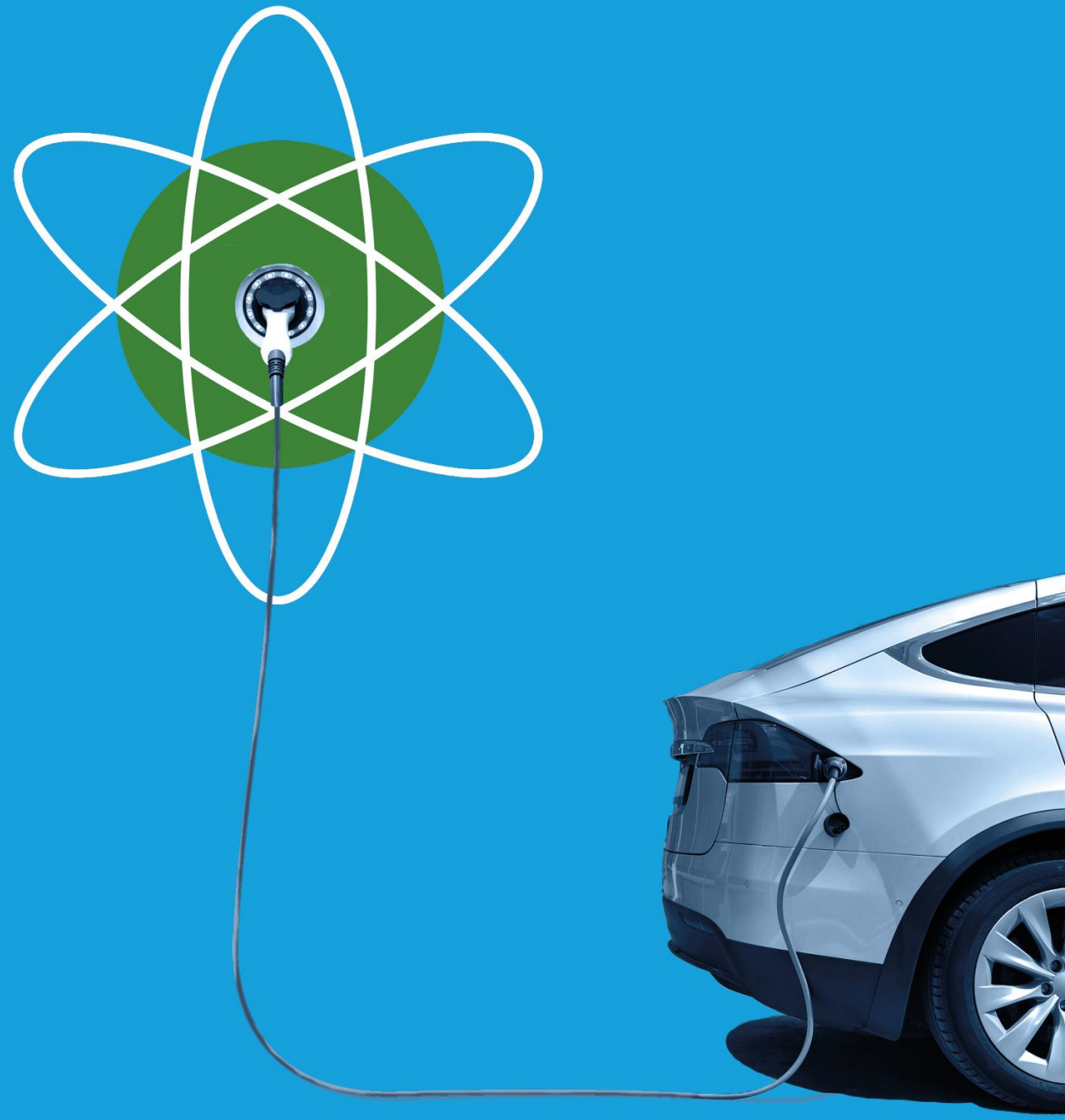


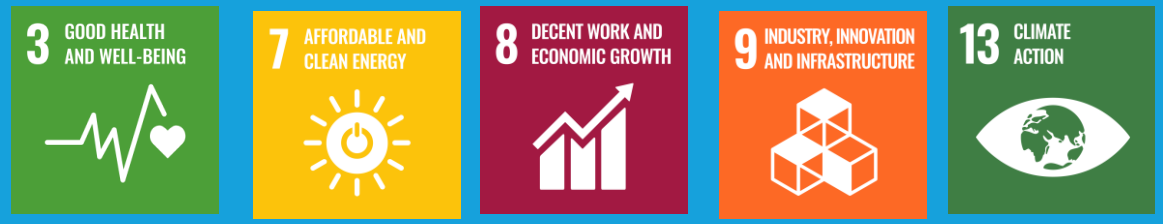
Emergence of **'new' Nuclear Applications**

(industrial heat, isotopes from 'waste', new therapeutics, space power)

Clean Energy

Securing the UK's place as a global leader in clean energy now and for the future, by developing and deploying advanced nuclear technologies

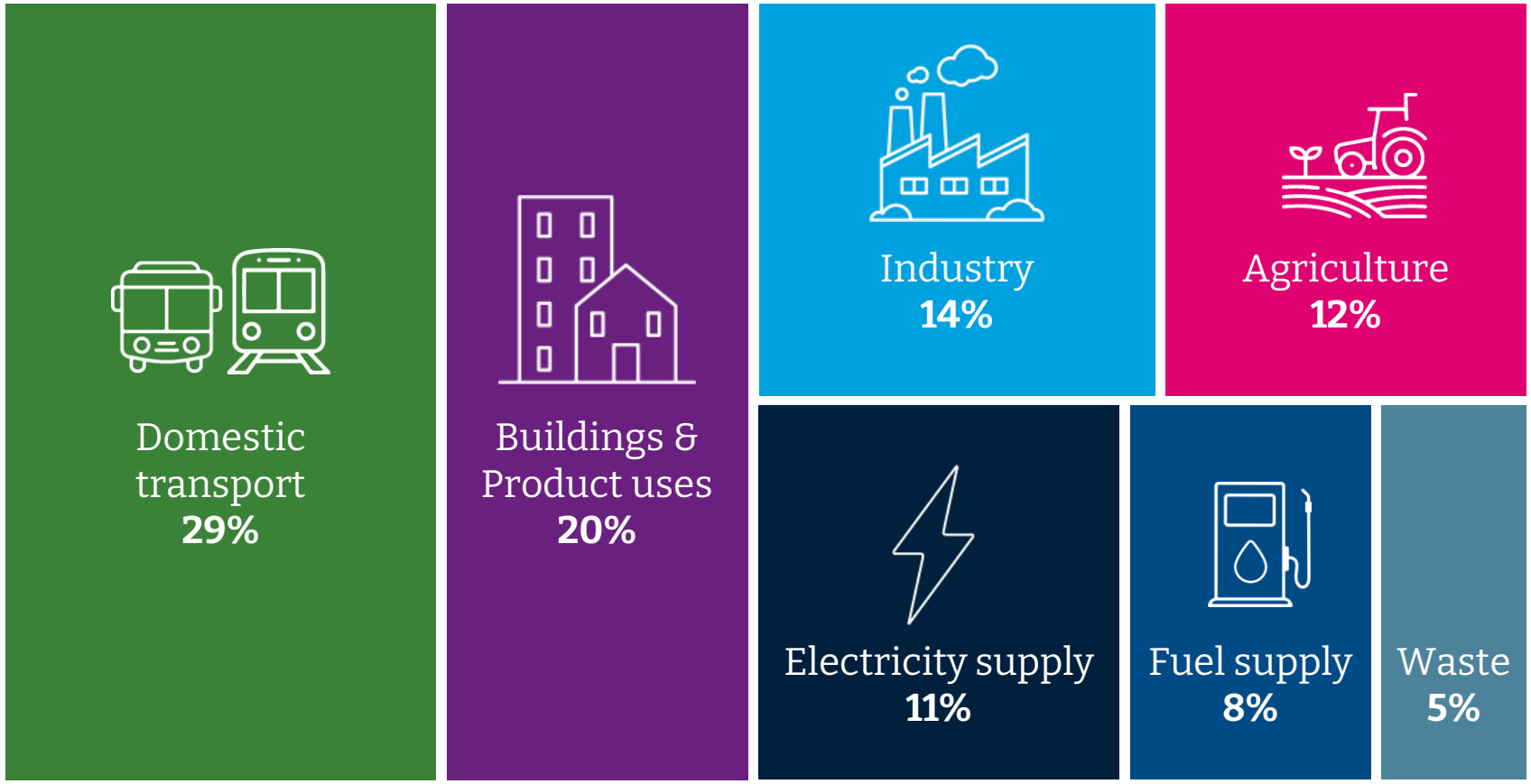


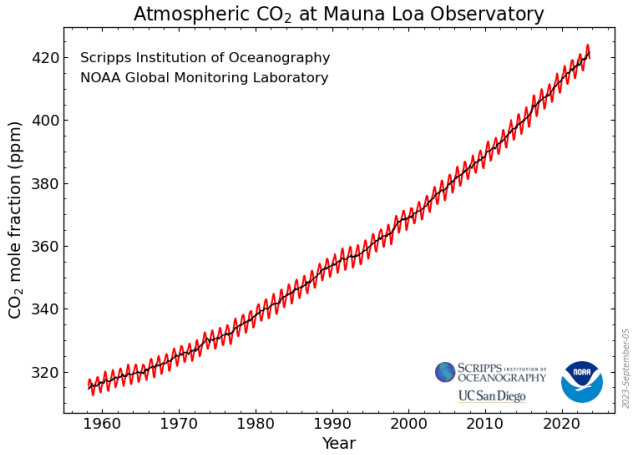


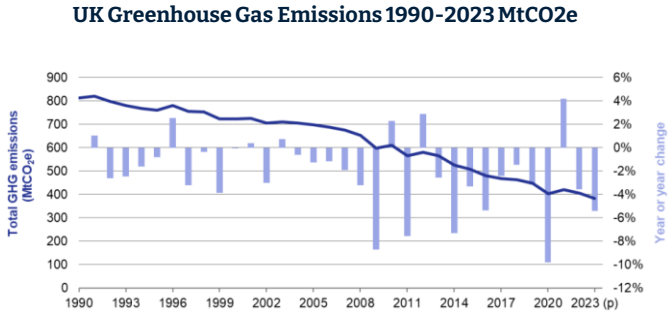
UK greenhouse gas emissions by sector
The problem statement

United Kingdom National Nuclear Laboratory

2023 UK GHG emissions: 384.2 MtCO2e





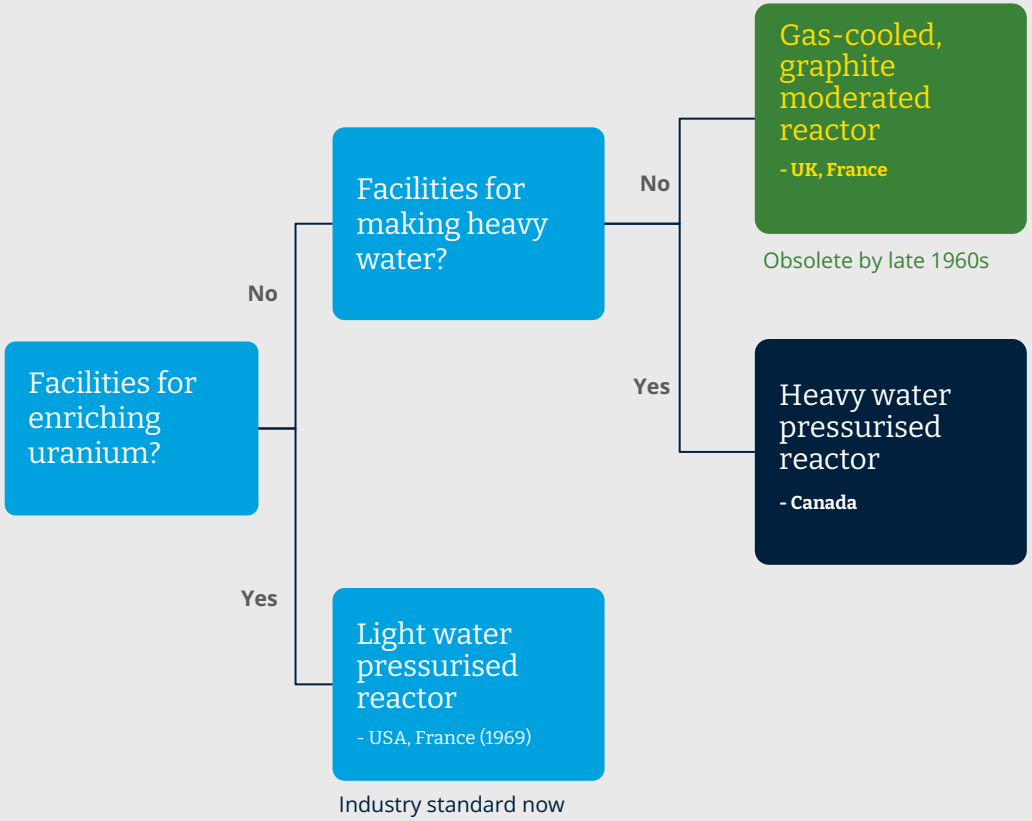


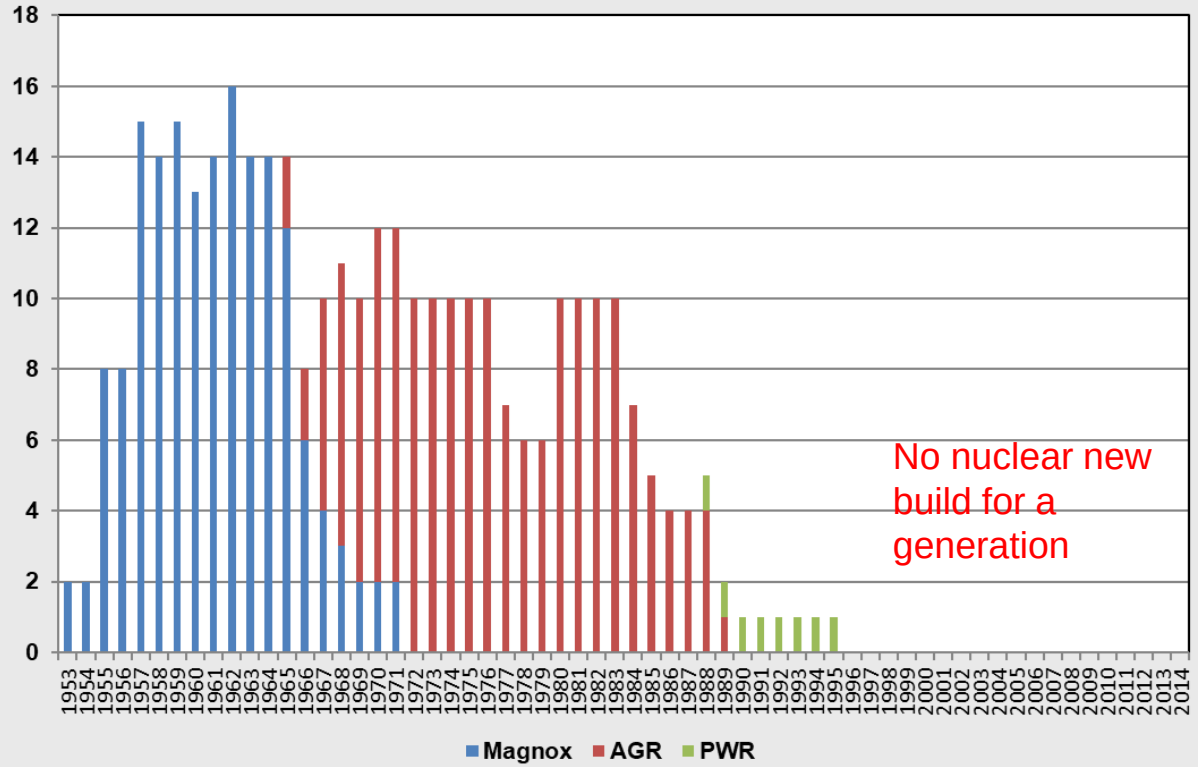
Source: 2023 UK Greenhouse Gas Emissions, provisional figures, Dept for Energy Security and Net Zero

UK power reactor construction
why gas cooled reactors?

United Kingdom National Nuclear Laboratory

Gas-cooled was only option for UK in 1950s
Nuclear reactor decision tree





DESNZ AMR RD&D programme

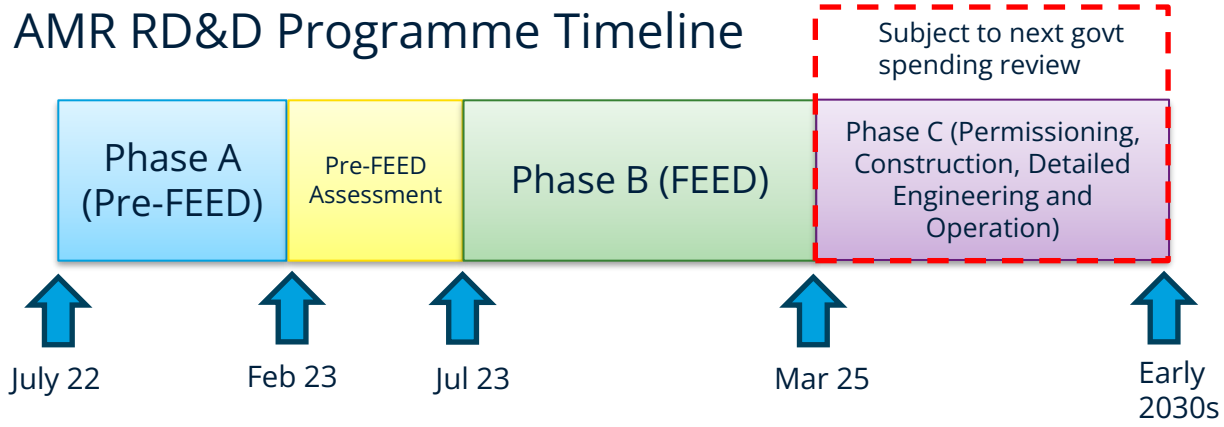
United Kingdom National Nuclear Laboratory

ADVANCED MODULAR REACTOR

Advanced Nuclear Reactors (AMRs) are reactors which use novel cooling systems or fuels and may offer new functionalities (such as industrial process heat). These reactors could operate at over 800°C and the high-grade heat could unlock efficient production of hydrogen and synthetic fuels.

We will provide up to £385 million in an Advanced Nuclear Fund for the next generation of nuclear technology aiming, by the early 2030s, to develop a Small Modular Reactor (SMR) design and to build an Advanced Modular Reactor (AMR) demonstrator.

AMR RD&D Programme Timeline



- Phase A Pre-Front End Engineering Design (FEED) studies were conducted for both Reactors and Fuels
- In July 2023 Phase B FEED grants with match funding UKNNL with JAEA were awarded :
  - £15m for UKJ-HTR reactor design
  - £16m for UK-CPF Step 1 to develop UK sovereign coated particle fuel supply

AMR Research, Development and Demonstration: Phase B (2023-2025): successful organisations - GOV.UK (www.gov.uk)

AMR RD&D Objectives

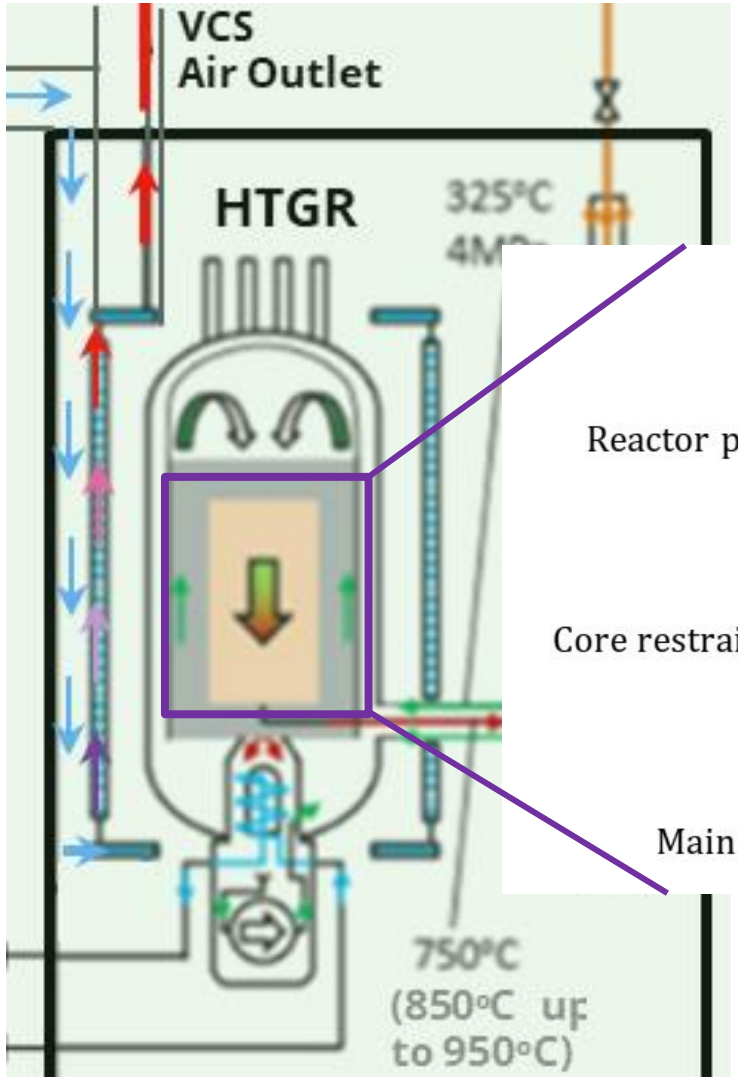
OBJECTIVE 2: Research and Development.
Identify what essential, 'no regrets' Technology Development (TD) activities need to be carried out in parallel with and as part of the development of the HTGR design to maintain the option of a Phase C schedule ending in the early 2030s

UKJ-HTR technology development activities

United Kingdom National Nuclear Laboratory

Extending UK Graphite Experience to HTGRs

- Matrix Graphite Production
- Graphite Waste Management and Decommissioning



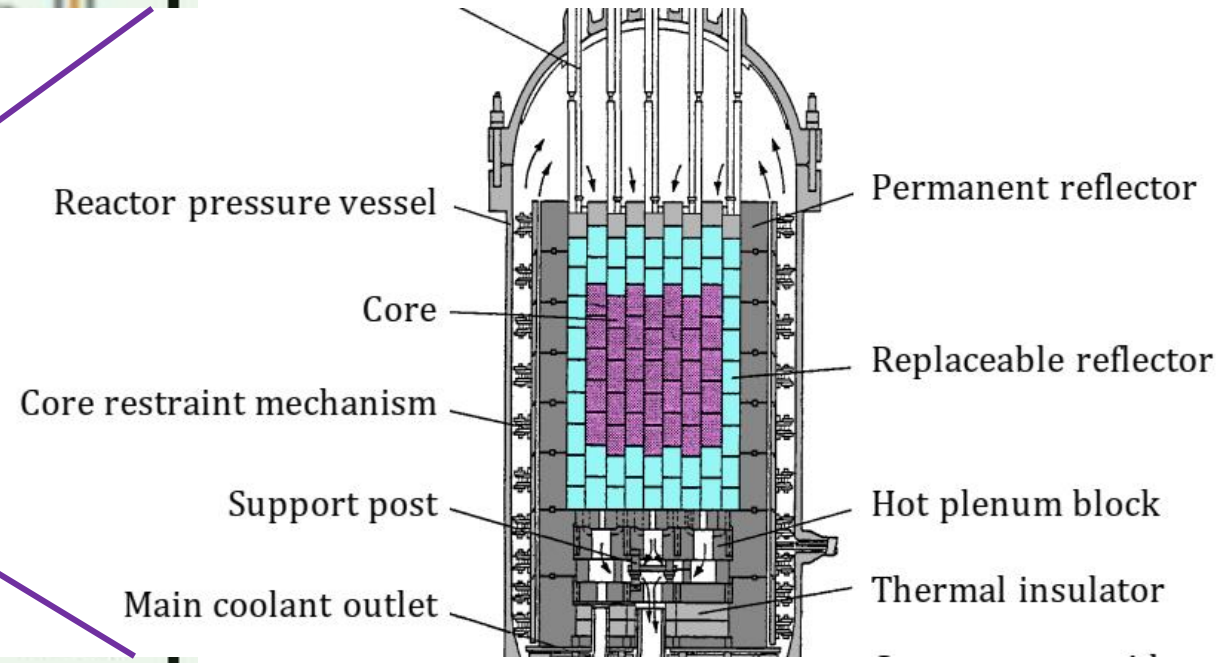


Figure Courtesy of JAEA

We need to electrify where we can: a UK example

United Kingdom National Nuclear Laboratory

This means electricity demand is set to at least double

We need to go from around **300** Terawatt hours (TWh) per year today

to between **600-900** TWh per year by 2050

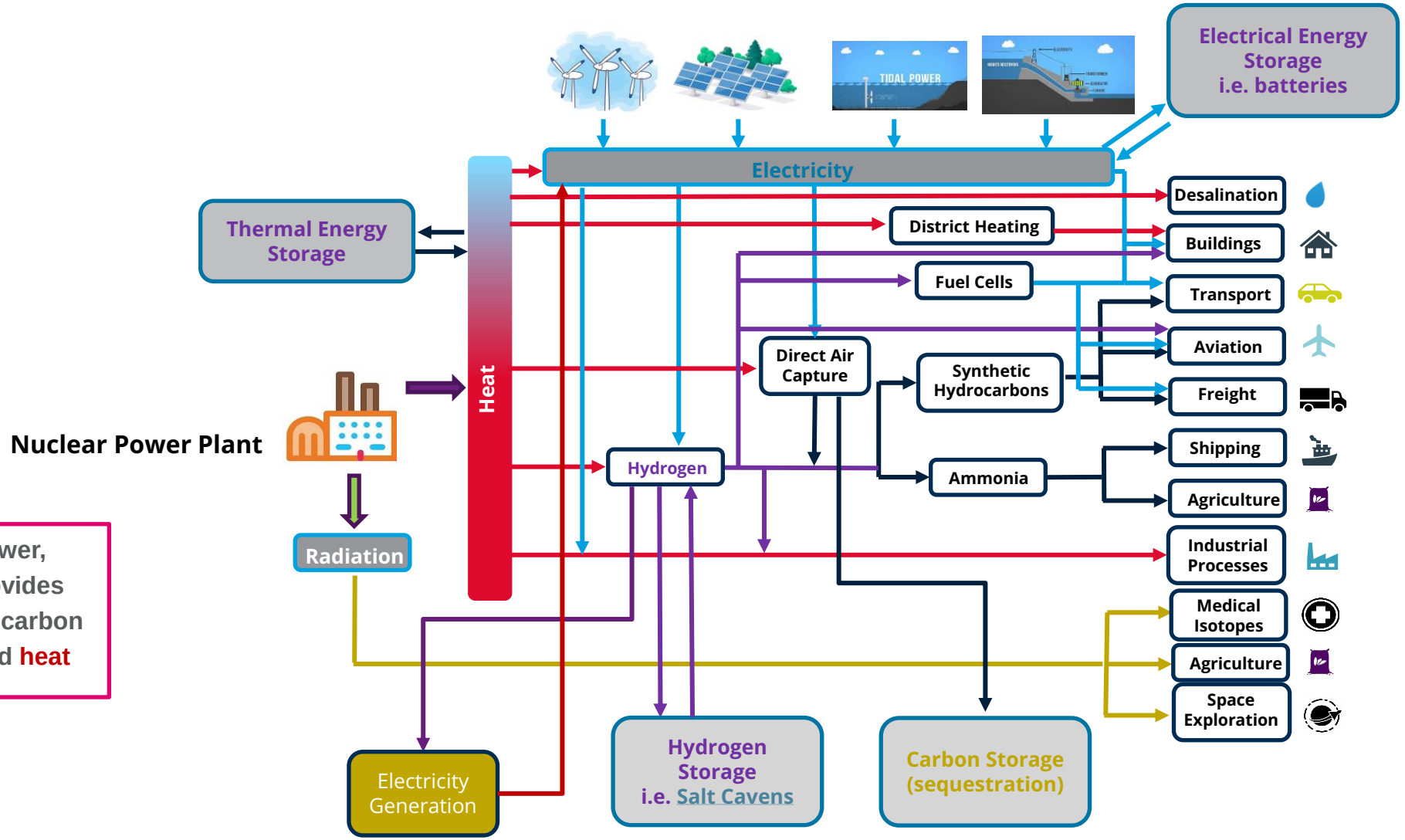
One Terawatt could power

10,000,000,000

100-watt lightbulbs

A hybrid energy system

United Kingdom National Nuclear Laboratory



Nuclear power, uniquely provides access to low carbon electricity and heat

Technical Papers and Academic collaborations

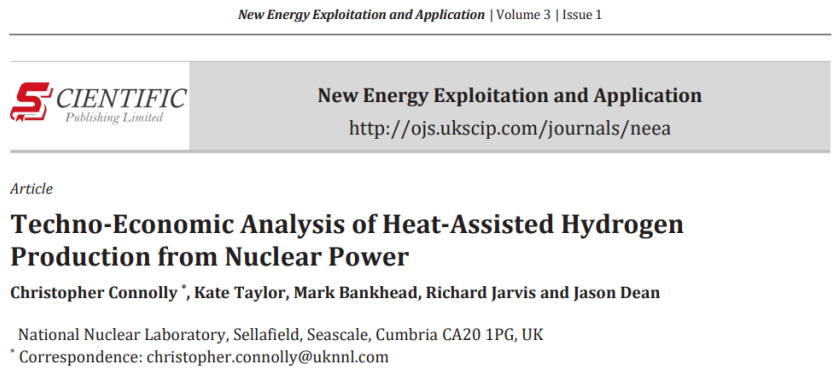
Techno-Economic Analysis of Heat-Assisted Hydrogen Production from Nuclear Power. Released in "New Energy Explorations and Applications"

United Kingdom National Nuclear Laboratory

Key Findings:

- **High Temperature Steam Electrolysis (HTSE) offers significantly greater efficiencies than liquid water electrolysis through coupling with nuclear heat.**

- **Nuclear coupled HTSE should be competitive with hydrogen generated from renewables** on a purely cost basis, without even accounting for the inherent advantages of a nuclear coupled technology (high scale & capacity factor, nonintermittent supply reducing buffer storage etc).



New Energy Exploitation and Application | Volume 3 | Issue 1

CIENTIFIC Publishing Limited

New Energy Exploitation and Application
http://ojs.ukscip.com/journals/neea

Article

Techno-Economic Analysis of Heat-Assisted Hydrogen Production from Nuclear Power

Christopher Connolly *, Kate Taylor, Mark Bankhead, Richard Jarvis and Jason Dean

National Nuclear Laboratory, Sellafield, Seascale, Cumbria CA20 1PG, UK
* Correspondence: christopher.connolly@uknnl.com

- **HTSE remains most promising to couple with nuclear energy for at least the medium-term future**, as thermochemical methods are unlikely to reach the market in a form where they could economically compete in this time period.

- **Beyond the 2040s**, with development of High Temperature Gas Reactors (HTGRs), and the parallel arrival of operational-scale thermochemical hydrogen production technologies, **thermochemical technologies could begin to compete with HTSE technology.**

Energy Systems Nexus

Collaborating for an integrated Net Zero future

CATAPULT Energy Systems

e·on

United Kingdom National Nuclear Laboratory

Bringing together the **most progressive and impactful industry players with some of the world's brightest minds** in energy systems.

Collaboratively defining, funding and delivering a whole energy systems-based R&D programme that will **enable industry to realise the massive opportunities in Net Zero**.

The ES Nexus membership will :

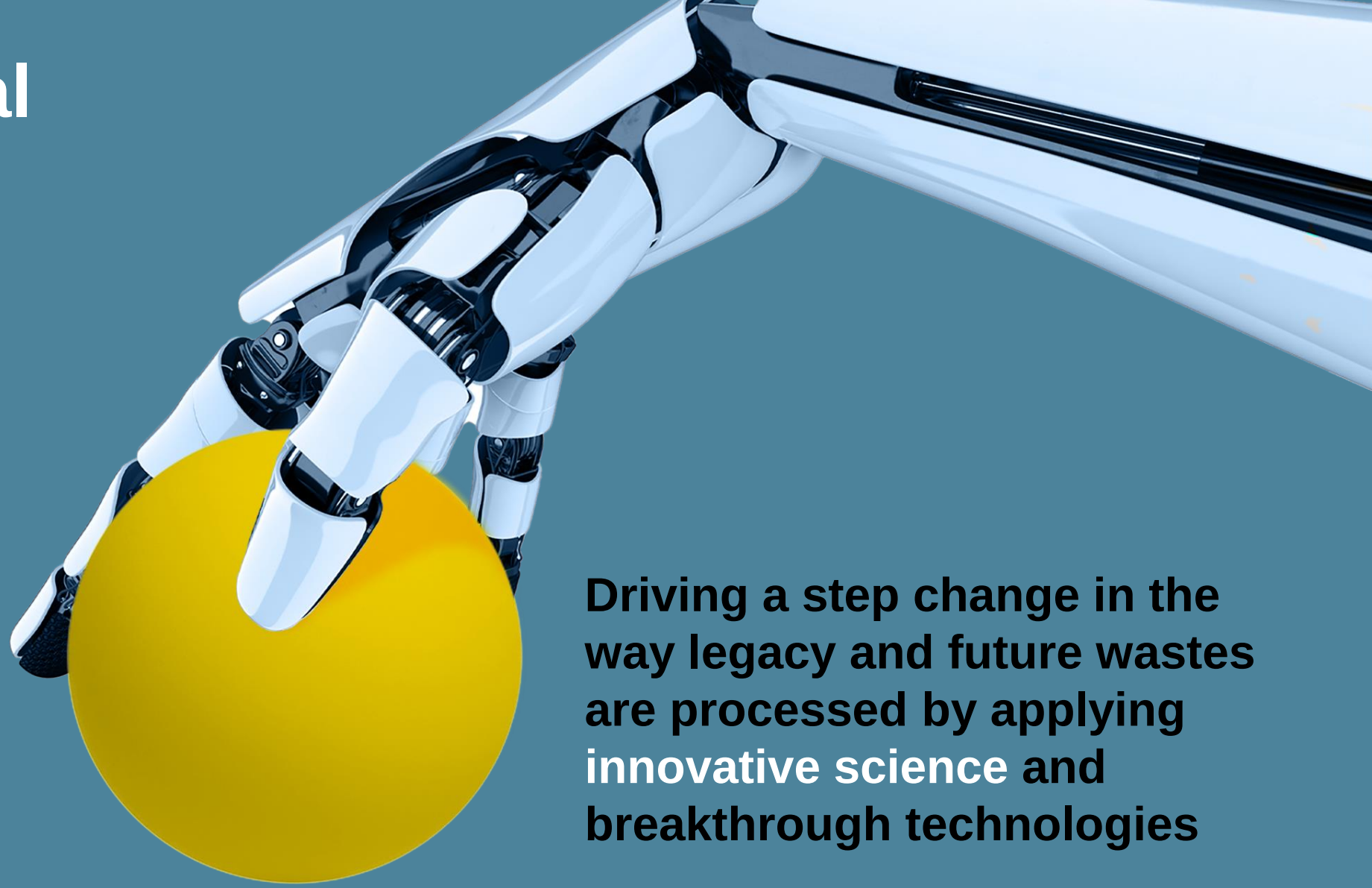
Define...
...the only industry-led whole energy system R&D programme with £1-1.5m annual budget.

De-risk...
...investment decisions and identify opportunities from Net Zero.

Drive...
...the wider Net Zero agenda with a unified industry perspective.

Find out more on our launch event video

Environmental Restoration

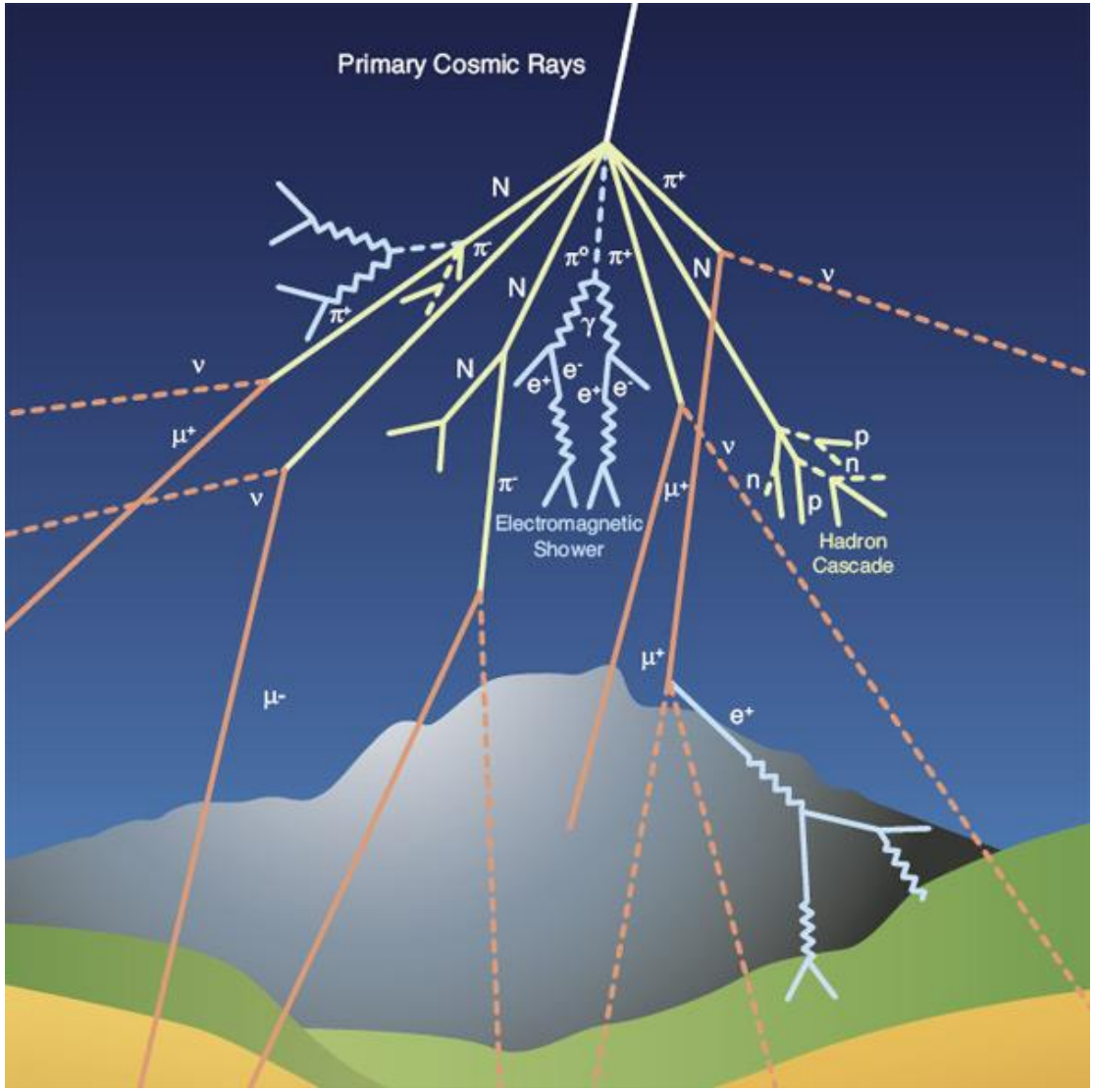


Driving a step change in the way legacy and future wastes are processed by applying innovative science and breakthrough technologies

12 RESPONSIBLE CONSUMPTION AND PRODUCTION

Cosmic ray muons

United Kingdom National Nuclear Laboratory

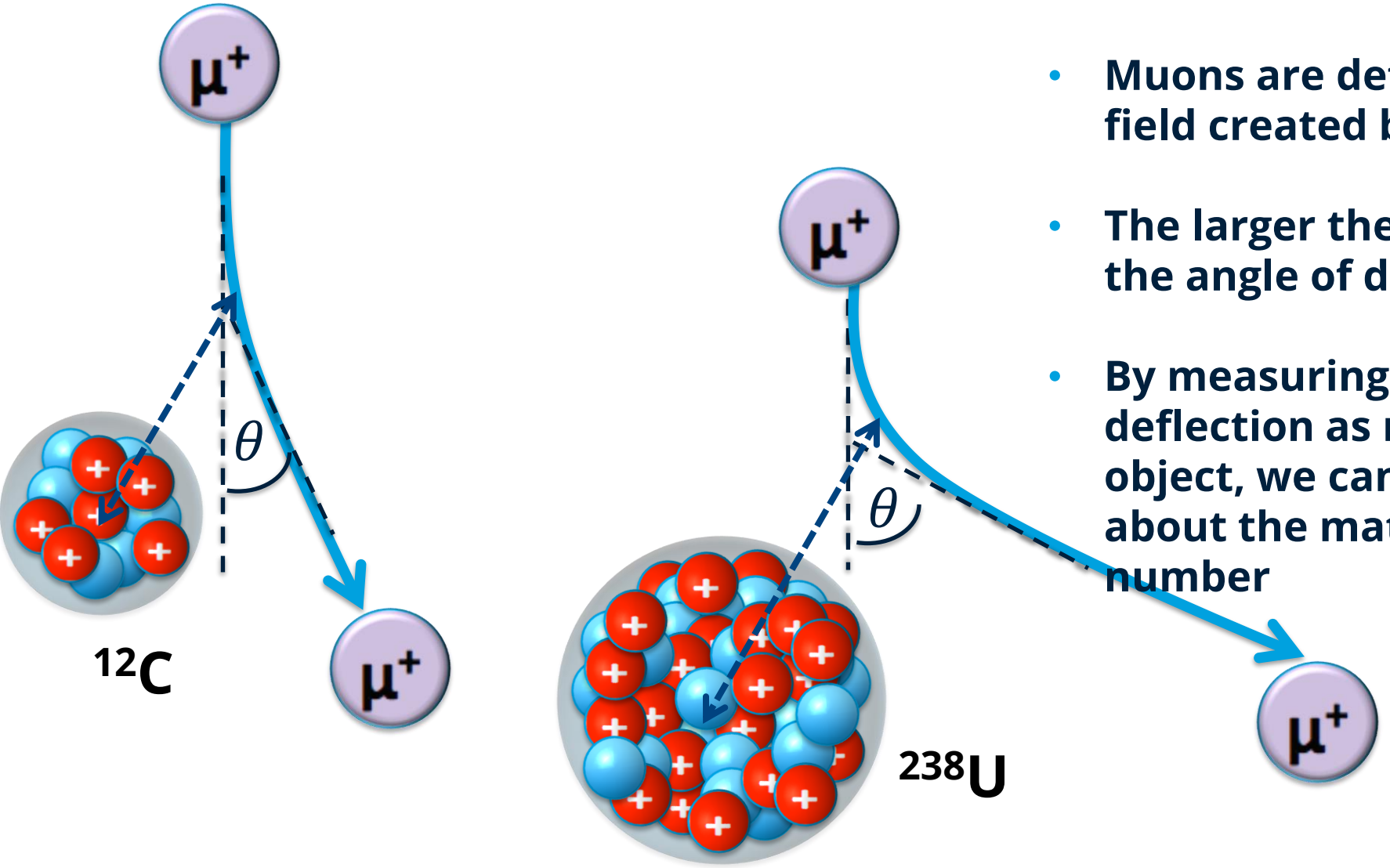


LEPTONS

≃0.511 MeV/c²	≃105.66 MeV/c²	≃1.7768 GeV/c²
−1	−1	−1
½	½	½
e	μ	τ
electron	muon	tau
<1.0 eV/c²	<0.17 MeV/c²	<18.2 MeV/c²
0	0	0
½	½	½
νe	νμ	ντ
electron neutrino	muon neutrino	tau neutrino

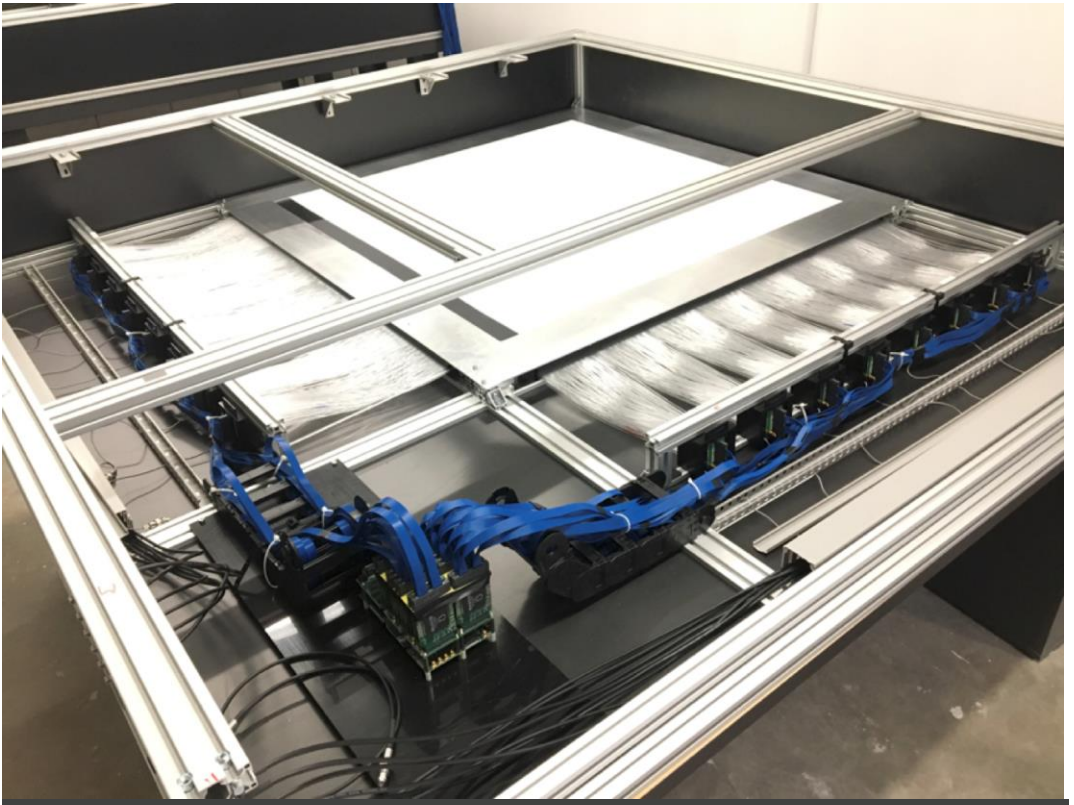
Muon scattering tomography

United Kingdom National Nuclear Laboratory

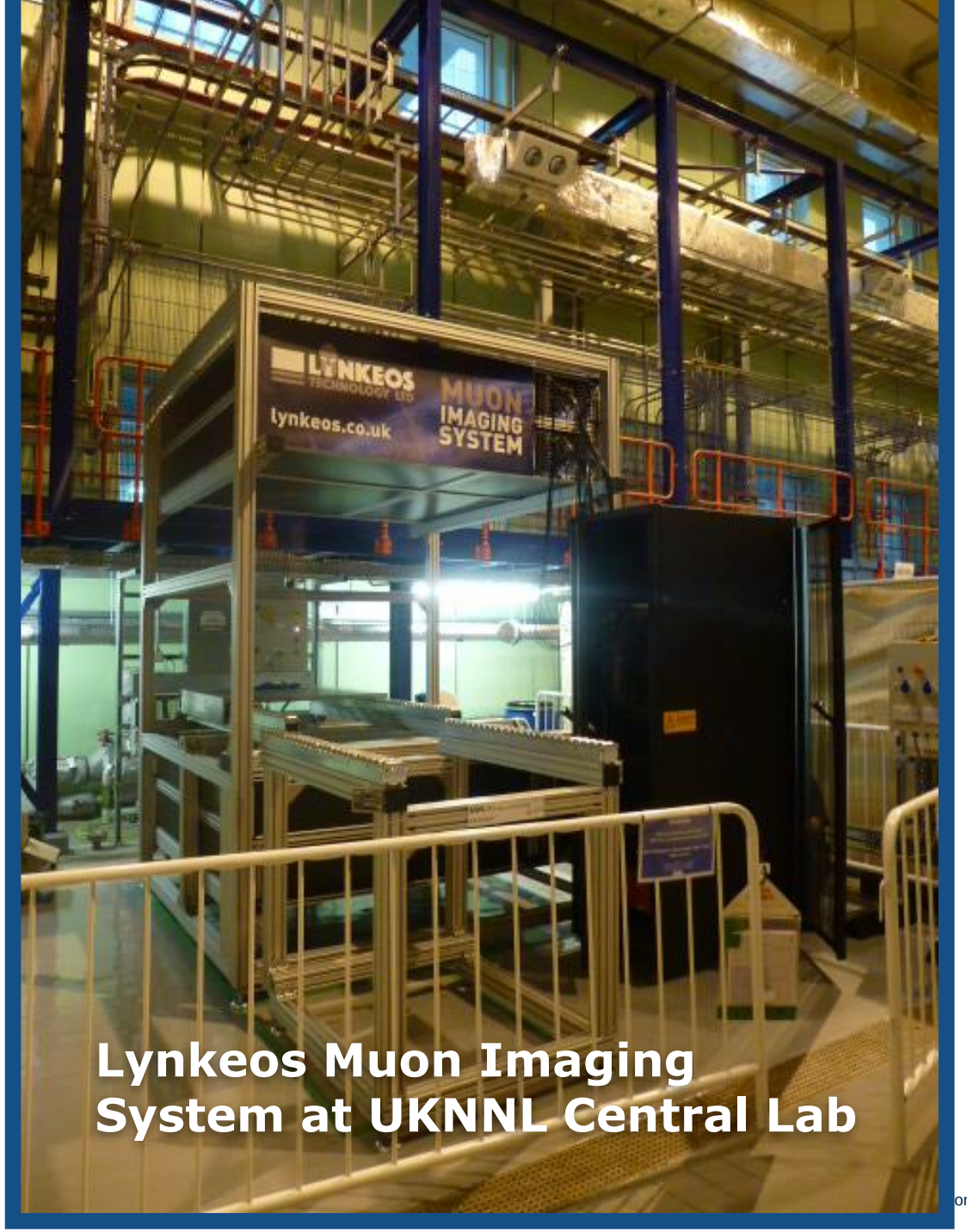


- Muons are deflected by the electric field created by atomic nuclei.
- The larger the nucleus, the greater the angle of deflection.
- By measuring the angles of deflection as muons pass through an object, we can infer characteristics about the material's density and Z-number

Muon detection



- Four modules measure the muon tracks: two above the object of interest and two below.
- 1024 scintillating fibres per module in an x-y grid, give muon hit coordinates,
- Muon trajectories and scattering angles calculated from the hits.



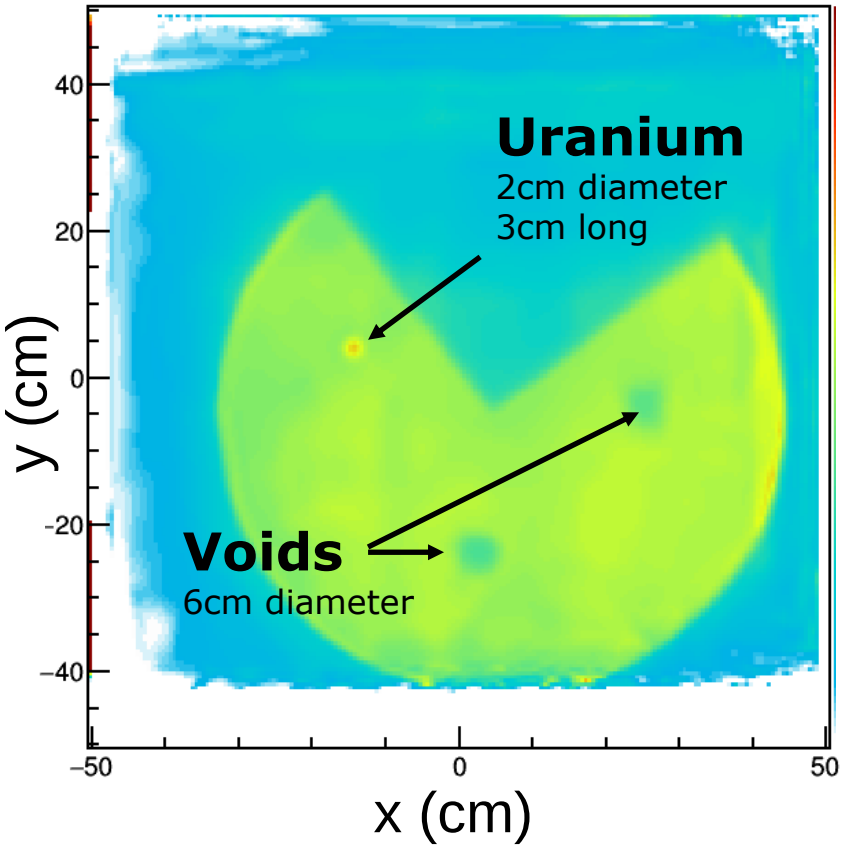
Lynkeos Muon Imaging System at UKNNL Central Lab

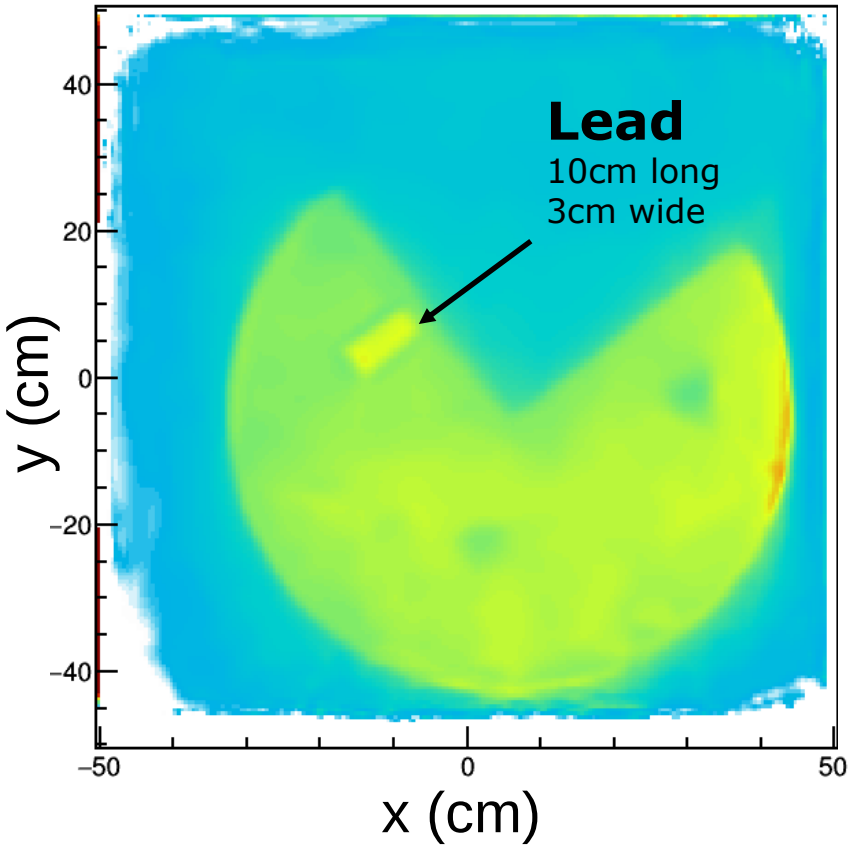
United Kingdom National Nuclear Laboratory

LYNKEOS TECHNOLOGY LTD

Imaging an ILW drum

*Mahon, D. et al., 2018, "First-of-a-kind muography for nuclear waste characterisation", Phil. Trans. R. Soc. A, **377**, 0048*



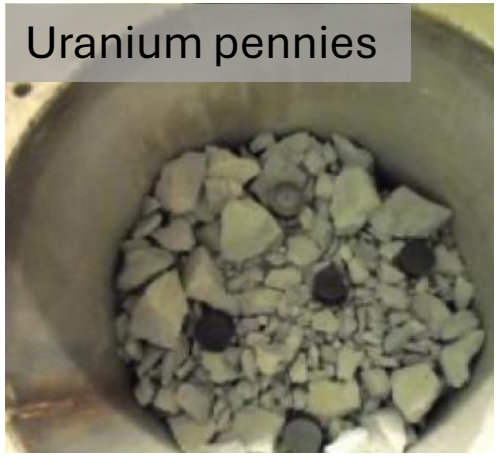


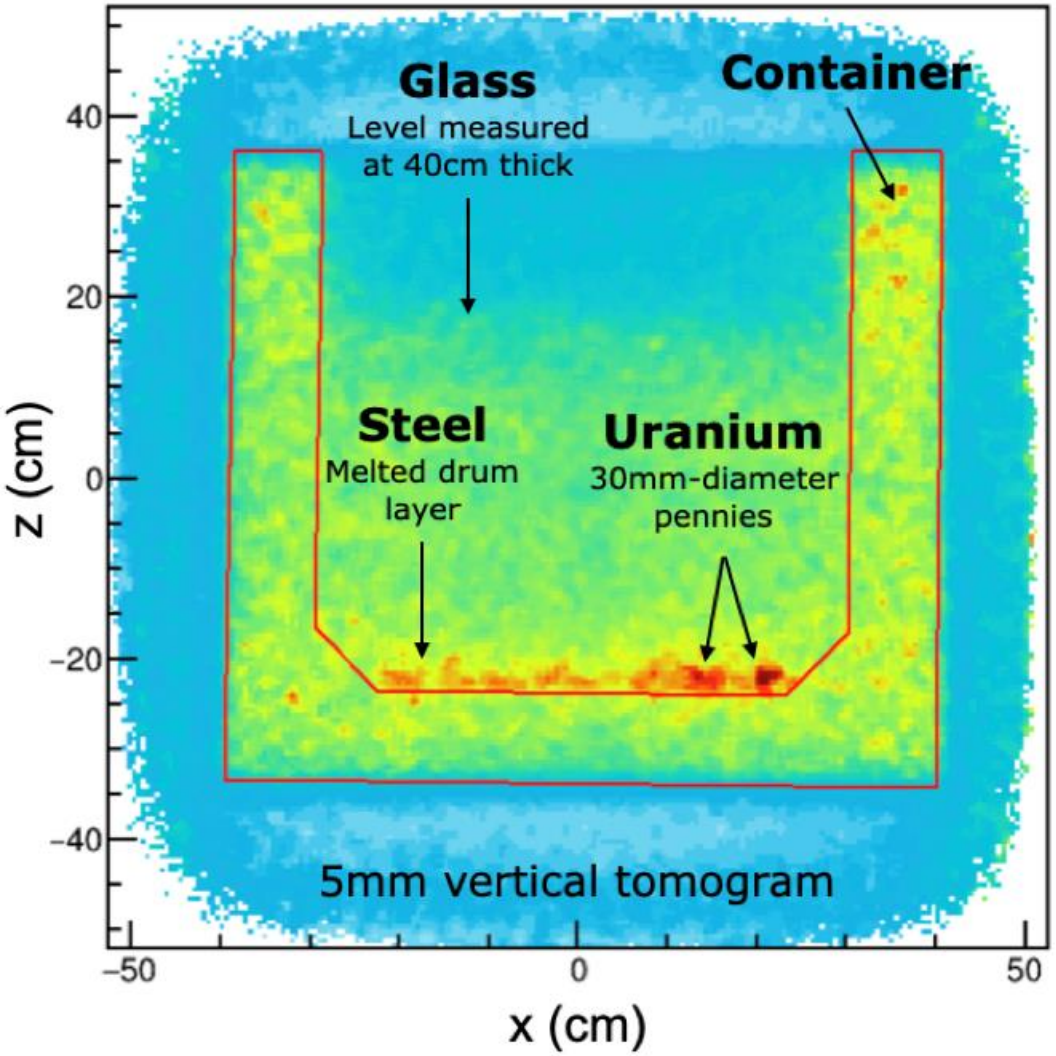
Imaging of a vitrified waste package

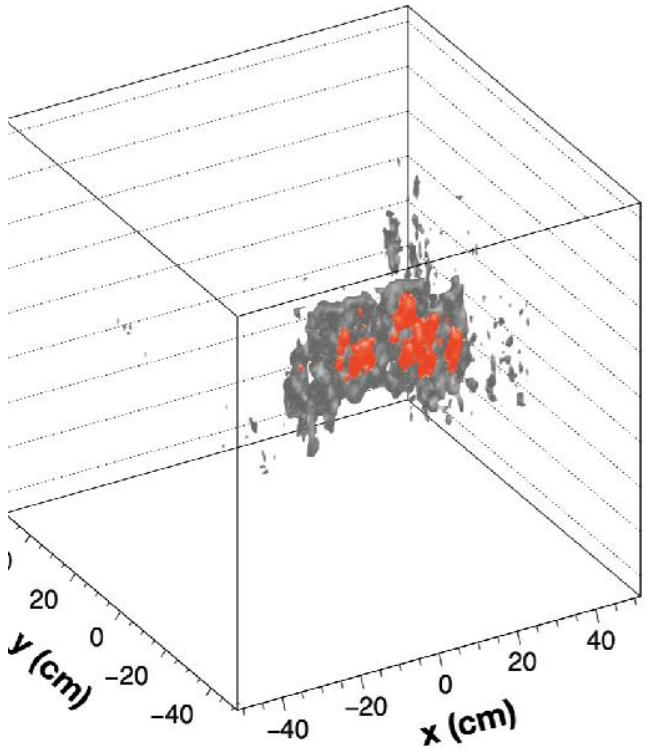
United Kingdom National Nuclear Laboratory

Steel cannister

Uranium pennies







Steel

Uranium

Health and Nuclear Medicine

Benefitting healthcare by advancing nuclear medicine in medical research and the treatment and diagnosis of conditions

EU-SECURE project

United Kingdom National Nuclear Laboratory

SECURE partners are working on **S**trengthening the **E**uropean **C**hain of s**U**pply for next generation medical **R**adionuclid**E**s

A major contribution from **EURATOM Research and Innovation Actions with 18 EU partners. UKNNL is the sole accredited partner from the UK** involved in this international project.

SECURE objectives:

- Develop a framework of guidance and recommendation for medical radioisotope production
- Exploring optimal production routes for existing and new isotopes for nuclear therapy and diagnostics
- Demonstrating cases for addressing issues in upscaling and sustained isotope production

This project has received funding from the Euratom research and training programme 2021-27 under GA No 101061230

Funded by the European Union

UKNNL's involvement in EU-SECURE project

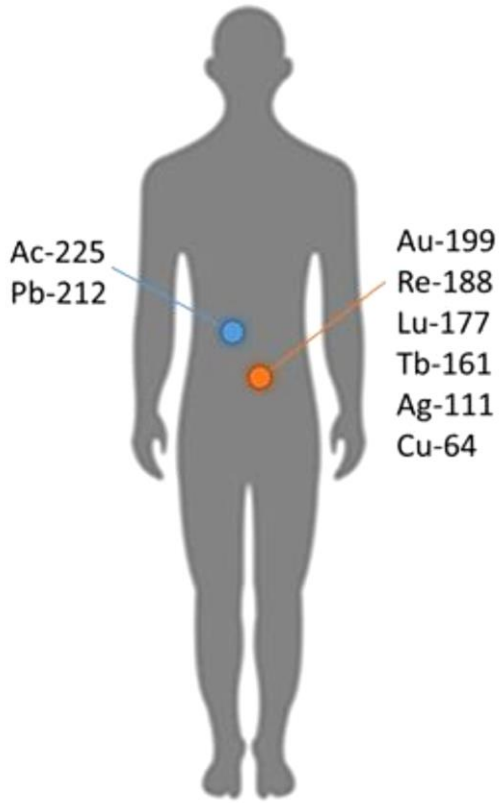
United Kingdom National Nuclear Laboratory

UKNNL provides in-depth studies on the following topics for the SECURE project. The aim is to make a major contribution to the sustainability of medical isotope production and its safe application in Europe.

EO1: Development of **innovative routes of production of therapeutic and diagnostic radionuclides in the EU**, looking into reactor-based and alternative methods, including accelerator-based as well as separation / purification methods, also taking into account waste management options (EURAD), nuclear security and proliferation concerns.

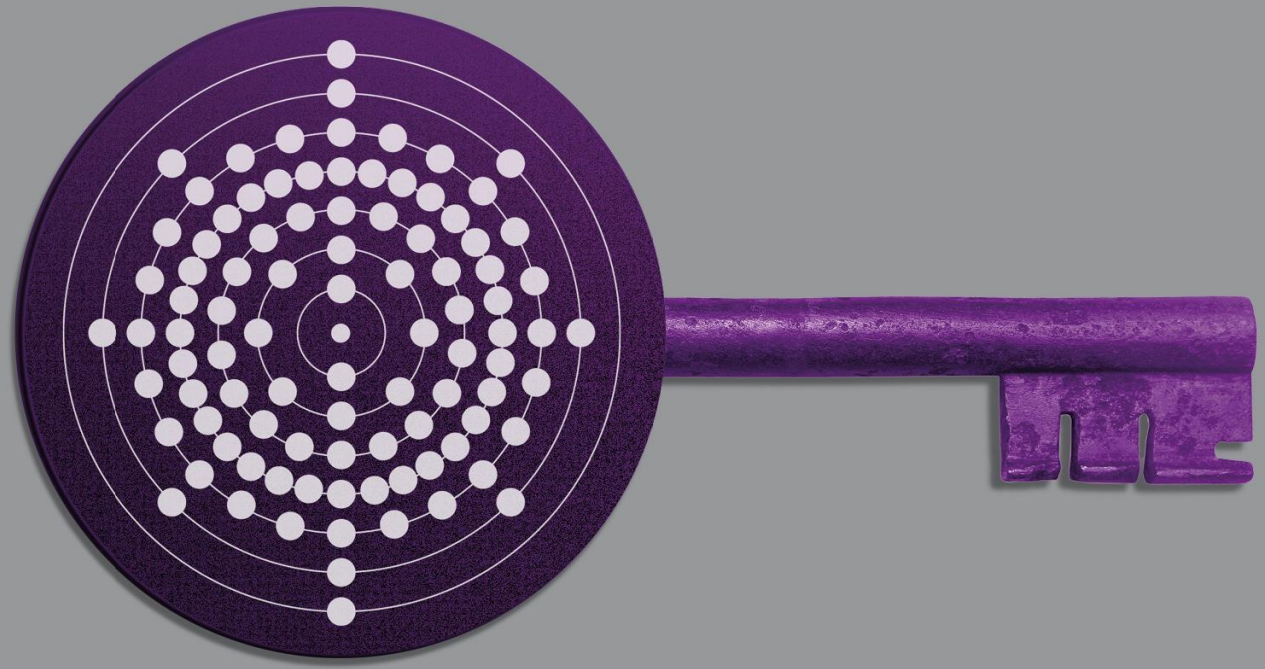
EO2: Development of **optimised irradiation targets**, that are interchangeable to allow use within the whole EU supply network, and prioritising production with raw and source materials which are available and sustainable for the EU.

EO4: Development of r**ecommendations for implementing clinical trials involving radiopharmaceuticals in the EU**, including the development of individual/specific organ dosimetry for the therapeutic applications (in target and non-target tissues).

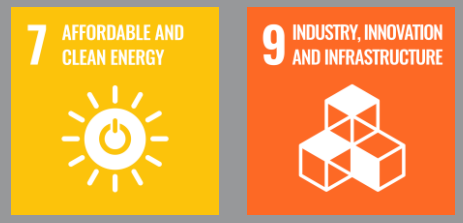


Blue: alpha emitting materials
Orange: beta emitting materials

Security and Non-Proliferation



Facilitating the global deployment of vital nuclear technologies by protecting nuclear materials, sites and technology



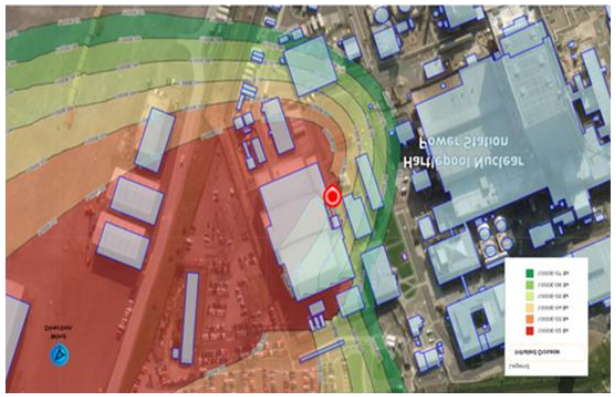
Nuclear safety modelling

United Kingdom National Nuclear Laboratory

UKNNL Safety and Engineering Assessment (SEA) team have been working alongside Riskaware, a company specialising in real time incident modelling software.

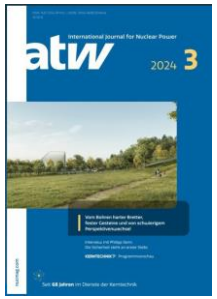
This work has expanded the capability of Riskaware's existing Urban Dispersion Modelling (UDM) software, which previously only modelled chemical releases, to now also integrate a new radiological dispersion modelling capability.

This software will provide unique capabilities in modelling radiological and chemical releases. This will increase the accuracy of assessments, remove unnecessary pessimisms (and costs) and enhance stakeholder confidence.



Various RiskAware UDM outputs showing hypothetical radiological and chemotoxic releases

Howard Chapman (3rd left) and Stephen Lawton (6th left) at Riskaware during a development workshop



Paper: Dynamic Dispersion Modelling to Enable Informed Decision Making in a Modern Nuclear Safety Case
Authors: H. Chapman, J. Hargreaves, S. Lawton (UKNNL), R. Gordon, T. Culmer (RiskAware)
JournaL ATW - International Journal for Nuclear Power
Link: https://www.yumpu.com/en/document/view/68694930/atw-international-journal-for-nuclear-power-032024

Science and technology is, and always has been, the beating heart of UKNNL