European Partnership on Radioactive Waste Management

ICARUS – WP5
INNOVATIVE CHARACTERISATION TECHNIQUES FOR LARGE VOLUMES

Eros Mossini, Yevheniia Kudriashova, Bas Janssen, Jixin Qiao, José Luis Leganés Nieto
The ICARUS Coordination Team

Co-funded by the European Union under Grant Agreement n° 101166718

ICARUS OBJECTIVES

Further development, optimization and harmonization of innovative techniques for implementing the **radiological, physical and chemical characterisation of LLW/ILW-mixed waste** which could be critical for the safe implementation of radioactive waste management programmes, including destructive techniques (DT) on laboratory scale and its relation to non-destructive techniques (NDT) and scaling factors (SF) at the raw waste and package scale user cases.

- Identification of relevant **use cases** to develop cutting-edge techniques and methods for an industrial application.
- Development of characterization methodologies for **mixed wastes** as heterogeneous decommissioning, to acquire accurate radiological and chemical inventory necessary for defining pre-disposal management.
- Identification of most **relevant radionuclides**, including limitations and difficulties that remain for their proper characterisation.

ICARUS IMPACT AND INNOVATION: THE USE-CASES

Task 3 – **TL: Bas Janssen (NRG)**; co-TL: Ferdinando Giordano (CAEN), An Bielen (SCK CEN) – **218 PM**

- **1st use case**: to achieve fast and sufficiently accurate gamma activity distribution in large packages for industrial applications (decommissioning and ongoing operational processes, incl. mixed wastes as heterogeneous legacy waste).
  - development/optimisation/innovation of **improved NDT methods** and approaches for radiological characterization, incl. in-situ and remote characterization, gamma and neutron analyses.
- **2nd use case**: to improve/simplify the methods for physical-chemical properties and alpha emitters inventory compared to current expensive DT and high uncertainty SF methods in relevant industrial scenarios (decommissioning/operational processes).
  - development/optimisation/innovation of **improved NDT methods** for characterisation of physical-chemical properties and chemicals inventory to optimize waste segregation, treatment and conditioning and enhance pre-disposal safety.

ICARUS IMPACT AND INNOVATION: THE USE-CASES

Task 4 – TL: Jixin Qiao (DTU); co-TL: Marko Strok (JSI), Anumaija Leskinen (VTT) – **223 PM**

- **3rd use cases**: to improve sensitivity, accuracy, uncertainty and cope with expensive and time-consuming conventional radiochemical analysis for critical long-lived Difficult To Measure (DTM) radionuclides (C-14, Cl-36, Ca-41, Se-79, Zr-93, Mo-93, Tc-99, Pd-107, Cs-135, Cm-243, Cm-244) in relevant industrial scenarios (decommissioning/operational processes).
    - development/optimisation/innovation of **fast and cheap DTs** to characterise DTM radionuclides for which limitations/difficulties remain in the available characterisation techniques.

Task 5 – TL: José Luis Leganés Nieto (ENRESA); co-TL: Arturas Plukis (FTMC) – **72 PM**

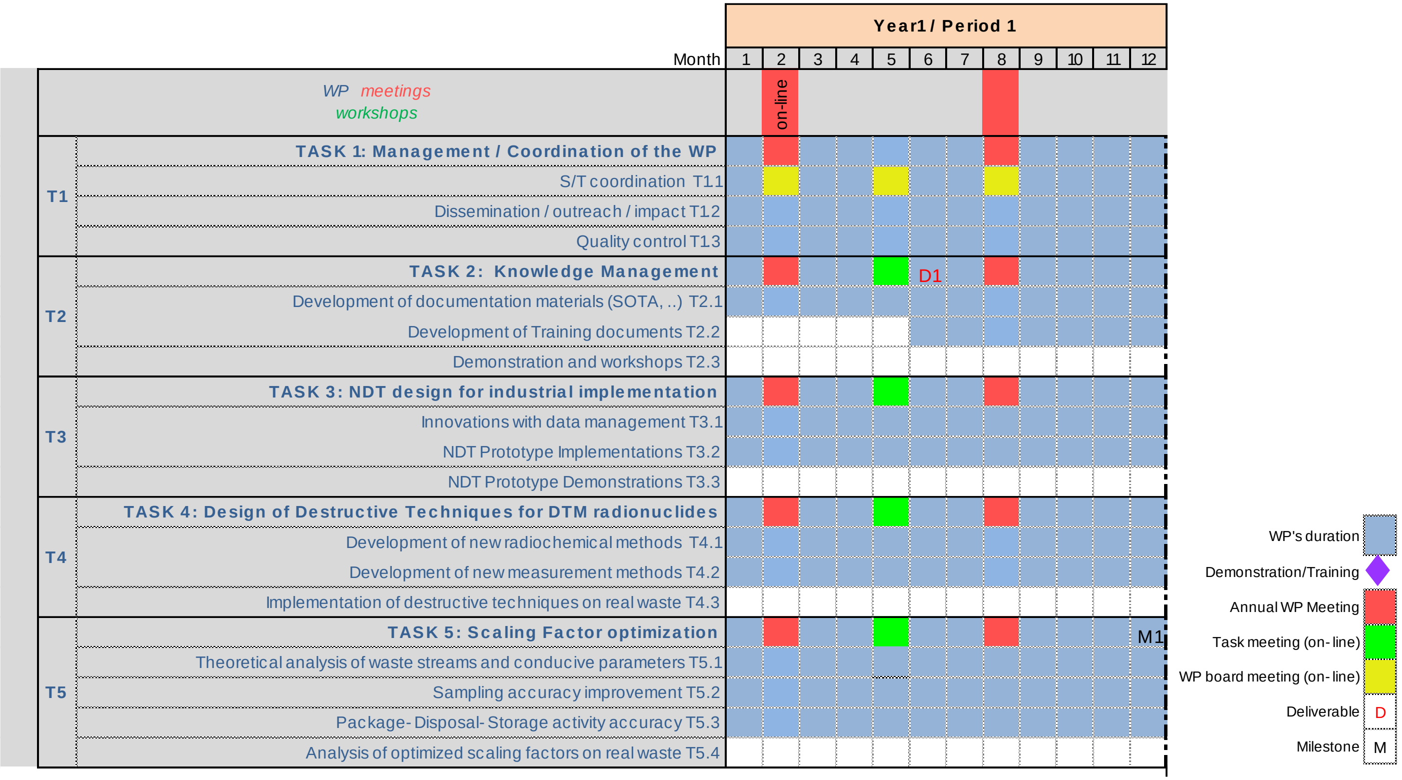
- **4th use case**: to lower the uncertainties and improve accuracy and reliability of SF methodology to meet ever stringent requirements set by national regulators for raw mixed waste.
    - development of innovative methods for the optimization and validation of SF methodology.

PARTNERS + END USERS

Good partners' mix for an **innovation-based approach** to address the **specific industrial needs**

T1: MANAGEMENT / COORDINATION OF THE WP

- Scheduling **Periodic TL meetings** (on-line) to monitor WP activities
  - Reporting (milestones/deliverables)
  - Disseminating (openaccess)
  - Achieving KPI targets
  - Implementing Data management
- Organizing **WP Kick-off meeting**
  8th November 8:30-12:30 (CET, on-line)
- Organizing **task periodic meetings**
- Organizing **WP annual meeting**



__1st year Milestones and Deliverables__

D5.1 SotA on innovative NDT, DT, SF for use cases (SSTC NRS, month 6)

M5.1: Identification of the most relevant radionuclides and WAC for SF (FTMC, month 12)

T2: KNOWLEDGE MANAGEMENT

Lead: SSTC NRS

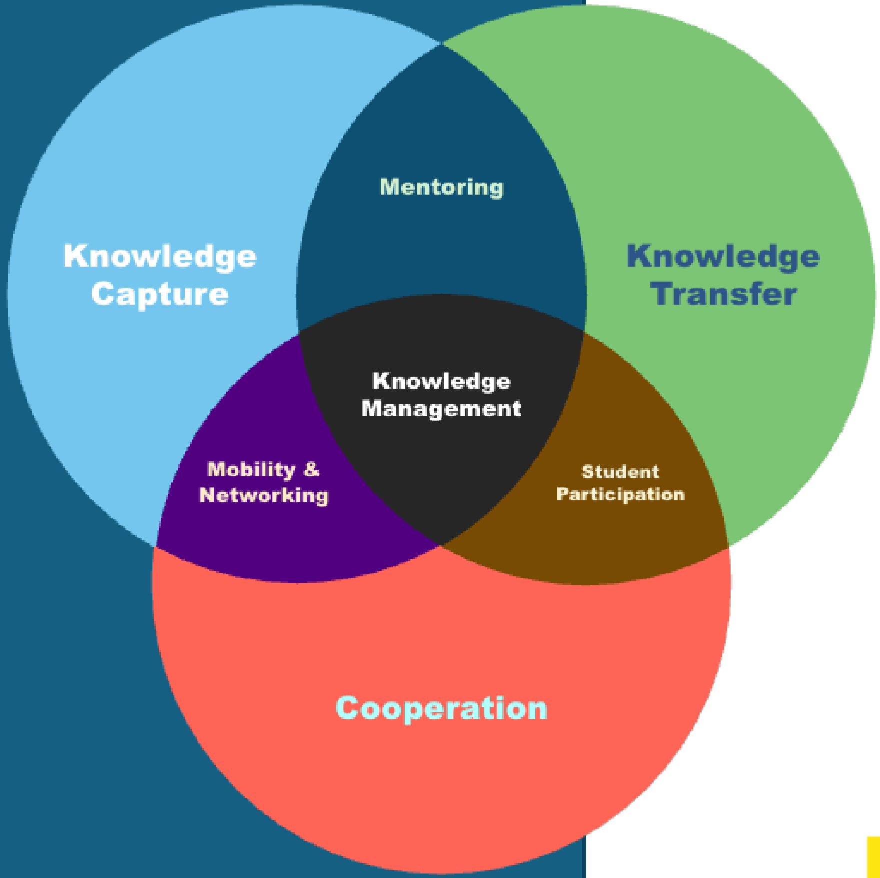
Duration: Months 1-60

Task Partners:

POLIMI, ENEA, UNIPI, ARAO, CAEN, NRG, ENRESA

Main Goals and Objectives

- **Capture knowledge relevant for ICARUS WP**
- **Contribute to knowledge transfer within EURAD-2 and beyond**
- **Organize cooperation on KM with other EURAD-2 parties**
- **Promote student participation in dissemination events and trainings**
- **Support mobility actions and networking activities**
- **Encourage mentoring initiatives**



T2: KNOWLEDGE MANAGEMENT

Subtask 2.1 Knowledge capture

Objective: Capture relevant knowledge prior to and during EURAD-2

Deliverables and Milestones:

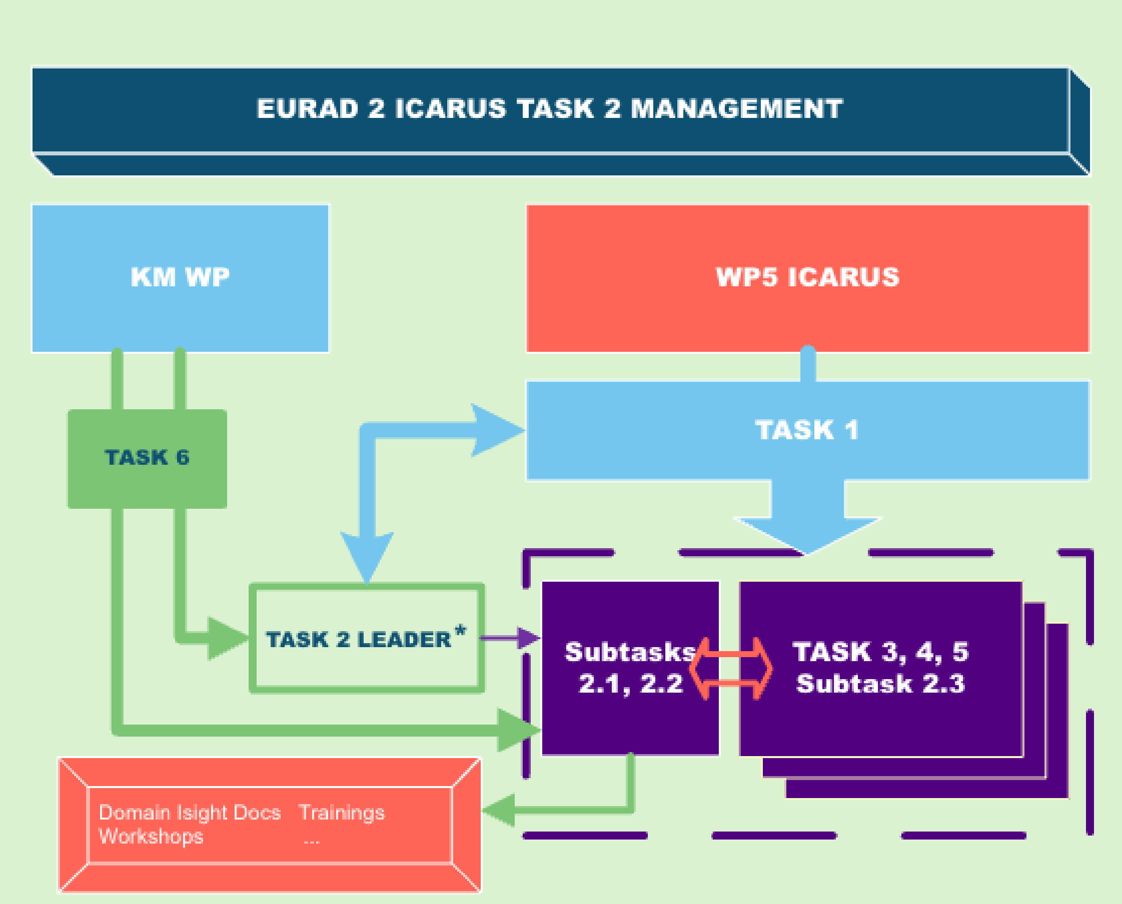
- **D5.1 SotA on innovative NDT, DT, SF for use cases (Month 6)**
- **+Specific documents to be identified in collaboration with WP2 KM**
- **D5.6 Extending the SotA on innovative NDT, DT, SF for current and new use cases (Month 57)**

Subtask 2.2 Knowledge transfer

Objective: Deliver specific activities to transfer knowledge

Deliverables and Milestones:

- **Specific activities to transfer knowledge to interested parties (for example, online training, face-to face-training, e-learning materials, workshops, posts for social media, summary sheets, videos, guidance)**
- **M5.5: Development of training material propaedeutic for the workshops (Month 40)**



***Task 2** leader is considered by WP2 KM as a knowledge management 'ambassador' and will be the contact point between ICARUS WP and WP2 KM.

T2: KNOWLEDGE MANAGEMENT

•Subtask 2.3 – Demonstration and Workshops [POLIMI], [ENEA], [DTU], [JSI], [ENRESA], [FTMC], [CAEN] – 10 PM

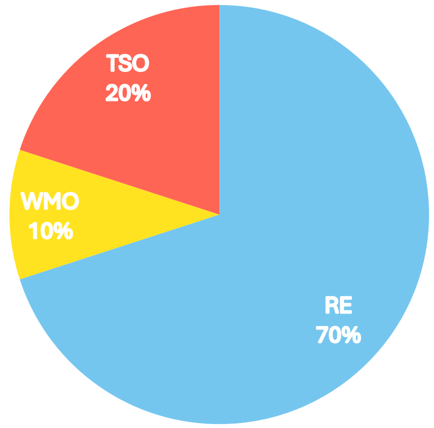
Objective: Utilize the material from T2.2 to conduct workshops and demonstrations, including NDT prototype training, a DT radionuclide workshop, and a workshop on SF in the decommissioning stage.

Deliverables and Milestones:

M5.7: Organization of practical demonstrations and workshops: report containing the information about the training sites, periods and draft agenda (Month 46)

D5.5: Report on practical demonstration of new NDT, DT, and SF (Month 54)

Subtask 2.3 colleges participation



Task 2 ICARUS KM Activities Timeline

T3: NDT DESIGN FOR INDUSTRIAL IMPLEMENTATION

TL: Bas Janssen (NRG); co-TL: Ferdinando Giordano (CAEN), An Bielen (SCK CEN) – **218 PM**

Partner (14)	Country (9)		
SCK CEN	Belgium	RE	
Tractebel	Belgium	AE	SCK CEN
ORANO	France	AE	CEA
NCSRD	Greece	RE	
NTUA	Greece	TSO	
ENEA	Italy	RE	
CAEN	Italy	AE	ENEA
UniPi	Italy	AE	ENEA
FTMC	Lithuania	TSO	
NRG	Netherland	TSO	
CIEMAT and LTPs	Spain	RE	
CSIC	Spain	AE	CIEMAT
SSTC NRS	Ukraine	TSO	
PSI	Switzerland	AP	

WMO	Waste Management Organization
TSO	Technical and Scientific Support Organization
RE	Research Entity
AE	Associated Entity
AP	Associated Partners
EUG	End Users Group

T3.1 Site integrated Data-management UniPI
[UNIPI, NRG, SCK CEN, TRACTEBEL, ENEA, CSIC, CAEN, NTUA, NCSRD]

T3.2 NDT Physical ENEA
[CSIC, SCK CEN, ENEA, TRACTEBEL, CIEMAT]

T3.3 NDT Radiation CAEN
[NRG, CAEN, UNIPI, FTMC, SSTC NRS, SCK CEN, CIEMAT, CSIC, NTUA, ORANO, NCSRD, ENEA]

T3.4 NDT Chemical SCK CEN
[TRACTEBEL, SCK CEN, PSI]

T3.5 Prototypes in Decom. approaches NRG
[NRG, CAEN, ORANO, UNIPI, FTMC, SCK CEN, NCSRD, ENEA, CIEMAT]

T3: NDT DESIGN FOR INDUSTRIAL IMPLEMENTATION

T3 NDT Design for industrial implementation NRG
[NRG, CAEN, SCK CEN]

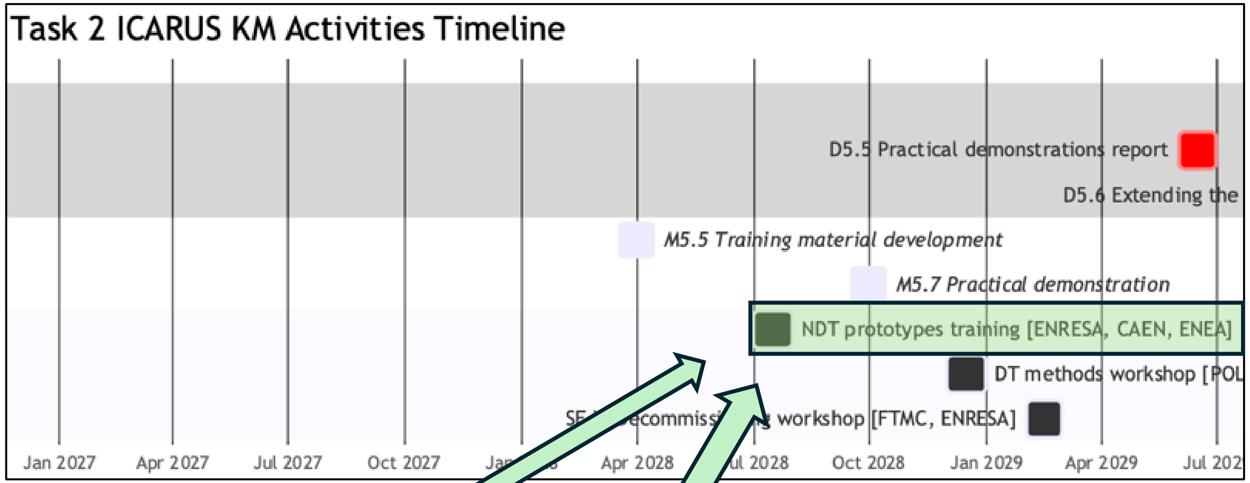
T3.1 Site integrated Data-management UniPI
[UNIPI, NRG, SCK CEN, TRACTEBEL, ENEA, CSIC, CAEN, NTUA, NCSRD]

T3.2 NDT Physical ENEA
[CSIC, SCK CEN, ENEA, TRACTEBEL, CIEMAT]

T3.3 NDT Radiation CAEN
[NRG, CAEN, UNIPI, FTMC, SSTC NRS, SCK CEN, CIEMAT, CSIC, NTUA, ORANO, NCSRD, ENEA]

T3.4 NDT Chemical SCK CEN
[TRACTEBEL, SCK CEN, PSI]

T3.5 Prototypes in Decom. approaches NRG
[NRG, CAEN, ORANO, UNIPI, FTMC, SCK CEN, NCSRD, ENEA, CIEMAT]



- **1st use case:**

To achieve fast and sufficiently accurate gamma activity distribution in complex large packages

- **2nd use case:**

To improve and simplify the inventory of physical-chemical properties and alpha emitters compared to current expensive DT and high uncertainty SF methods

T3.1: RAW WASTE MANAGEMENT INNOVATIONS WITH DATA MANAGEMENT FOR COMPREHENSIVE DECOMMISSIONING CHARACTERIZATION.

T3 NDT Design for industrial implementation NRG
[NRG, CAEN, SCK CEN]

T3.1 Site integrated Data-management UniPI
[UNIPI, NRG, SCK CEN, TRACTEBEL, ENEA, CSIC, CAEN,NTUA, NCSRD]

T3.2 NDT Physical ENEA
[CSIC, SCK CEN, ENEA, TRACTEBEL, CIEMAT]

T3.3 NDT Radiation CAEN
[NRG, CAEN, UNIPI, FTMC, SSTC NRS, SCK CEN, CIEMAT, CSIC, NTUA, ORANO, NCSRD, ENEA]

T3.4 NDT Chemical SCK CEN
[TRACTEBEL, SCK CEN, PSI]

T3.5 Prototypes in Decom. approaches NRG
[NRG, CAEN, ORANO, UNIPI, FTMC, SCK CEN, NCSRD, ENEA, CIEMAT]

- Developing site specific approach on waste management
- Using innovations that produce data in an automated, updated, and centralized manner
- Linking the SotA techniques to the applied use cases, site and techniques
- Use all the data available, including data processing
- Assessing the best techniques with all their data-streams
- Provide real-time info for automation
- Address innovation in the waste management approach before waste packaging.

T3.2, 3.3, 3.4: EXPLORING OPTIONS INTO NON-DESTRUCTIVE TECHNOLOGY (NDT) & PROTOTYPE IMPLEMENTATIONS FOR COMPREHENSIVE DECOMMISSIONING

T3 NDT Design for industrial implementation NRG
[NRG, CAEN, SCK CEN]

T3.1 Site integrated Data-management UniPI
[UNIPI, NRG, SCK CEN, TRACTEBEL, ENEA, CSIC, CAEN, NTUA, NCSRD]

T3.2 NDT Physical ENEA
[CSIC, SCK CEN, ENEA, TRACTEBEL, CIEMAT]

T3.3 NDT Radiation CAEN
[NRG, CAEN, UNIPI, FTMC, SSTC NRS, SCK CEN, CIEMAT, CSIC, NTUA, ORANO, NCSRD, ENEA]

T3.4 NDT Chemical SCK CEN
[TRACTEBEL, SCK CEN, PSI]

T3.5 Prototypes in Decom. approaches NRG
[NRG, CAEN, ORANO, UNIPI, FTMC, SCK CEN, NCSRD, ENEA, CIEMAT]

- NDT systems that are flexible, modular, and usable in-situ on the raw waste processing
- Further development to better suit the industrial applications
- Innovation in NDT on raw waste management
- Added value in a holistic waste management approach.
- Better knowing the waste matrix materials and density distribution
- More expensive detectors will be analyzed in comparison to cheaper and more robust ones
- Sensitivity analyses of critical parameters, allowing to focus all the experimental efforts

T3.3: PROTOTYPE IMPLEMENTATIONS OF NDT IN NEW DECOMMISSIONING APPROACHES FOR CASE 1 & 2

T3 NDT Design for industrial implementation NRG
[NRG, CAEN, SCK CEN]

T3.1 Site integrated Data-management UniPI
[UNIPI, NRG, SCK CEN, TRACTEBEL, ENEA, CSIC, CAEN, NTUA, NCSRD]

T3.2 NDT Physical ENEA
[CSIC, SCK CEN, ENEA, TRACTEBEL, CIEMAT]

T3.3 NDT Radiation CAEN
[NRG, CAEN, UNIPI, FTMC, SSTC NRS, SCK CEN, CIEMAT, CSIC, NTUA, ORANO, NCSRD, ENEA]

T3.4 NDT Chemical SCK CEN
[TRACTEBEL, SCK CEN, PSI]

T3.5 Prototypes in Decom. approaches NRG
[NRG, CAEN, ORANO, UNIPI, FTMC, SCK CEN, NCSRD, ENEA, CIEMAT]

- Incorporate the potential added value.
- Different prototypes will demonstrate their feasibility
- They will represent in the model an added value
- Prototypes will be compared to reference systems
- Prototype candidates are modelled also with task 4 and 5
- Selection for their impact on show-cases
- Report on the advances of new Prototype devices for Non-Destructive characterization of waste

T3: GOALS FOR THE FIRST TWO YEARS:

- Assessment of the existing/available industrial communication standards;
- Organization of data based on methodologies and platforms;
- Implementation of the SotA techniques to identify the optimal current techniques and process for radiological characterization of large volumes of radioactive waste.
- Study of the physical constraints related with packages size, shape, and material, that affect the design of NDT solutions
- Assessment of the requirements using stakeholder collaboration and feedback for continuous innovation.
- Using the SotA techniques to identify proven NDT techniques that can be retro-fitted and combined
- Collaboration and on-going discussion with end-users and other interested partners, to focus on desired needs and innovation within use case 1 and 2.

eurad2

T4: DESIGN OF DESTRUCTIVE TECHNIQUES FOR DTM RADIONUCLIDES

This task focuses on development of sensitive and accurate techniques for completing the radiological inventory estimation of waste and packages by the quantification of long-lived DTM radionuclides usually present in low activity concentrations.

Task Partners: [DTU] [JSI] [SORC] [POLIMI] [ARAO] [RATEN] [VTT] [US] [SCK CEN] [CVUT] [IMT ATLANTIQUE] [ENEA] [CIEMAT] and [IFE]

Objectives:

- **Developing sensitive and reliable analytical methods to improve the detection limits and to replace the conventional expensive and time-consuming radiochemical analysis.**
- **The impact of radiochemical separation and purification will be focused on the effective removal of the interferences in the measurement of target radionuclides by radiometric or mass spectrometry methods.**

T4: DESIGN OF DESTRUCTIVE TECHNIQUES FOR DTM RADIONUCLIDES

4.1 Development of new radiochemical methods

- **Develop** rapid and effective methods to **extract** DTM radionuclides from the sample matrix and **purify** them from all interfering elements and isotopes. The **pure beta** (^{14}C, ^{36}Cl, ^{41}Ca, ^{79}Se, ^{93}Zr, ^{99}Tc, ^{93}Mo, ^{107}Pd, ^{135}Cs) and **alpha** emitting radionuclides (^{243}Cm, ^{244}Cm) are selected as DTM radionuclides in this work.

4.2 Development of new radiochemical methods

- **Test** and **compare** mass spectrometric and radiometric methods to find the optimum one with respect to detection limits, measurement time, as well as costs for analysis.

4.3 Implementation of destructive techniques on real waste

- **Validate**, **demonstrate** and **harmonize** the developed analytical methods for determination of DTM radionuclides by analysis of real waste samples from decommissioning or operation of nuclear facilities provided by project partners.

T4: DESIGN OF DESTRUCTIVE TECHNIQUES FOR DTM RADIONUCLIDES

Implementation plan (2024-25)

- **Focused radionuclides** by most partners: ^{36}Cl, ^{41}Ca and ^{99}Tc
- **Several other radionuclides** to be investigated by individual partners: ^{14}C, ^{79}Se, ^{107}Pd, ^{93}Mo and ^{93}Zr
- **Sample types**: stainless steel, graphite, concrete, resin
- **Measurement techniques focused**: LSC, ICP-MS and AMS
- Performance criteria: **simplicity** of the method, **applicability** (sample types, measuring technique)
- **Working groups** for specific radionuclides or measuring techniques are under development.

T5: SCALING FACTOR OPTIMIZATION

Researching ways to refine the Scaling Factor Approach

- T5.1: Theoretical analysis of waste streams and identification of conducive parameters.
  - Scaling Factor theoretically determined vs. empirically determined.
  - Identifying conducive parameters that influence the model.
- T5.2: Sampling design for accuracy improvement: trueness/precision.
  - Improving precision and reducing bias.
  - Grouping data.
  - Manner of sampling.
- T5.3: Package-Disposal-Storage activity accuracy.
  - From model estimation to package and Storage/Disposal estimation.
  - Sample support vs. package support.
- T5.4: Analysis of optimized scaling factors on real waste
  - Multiple Key Nuclides, KN.
  - Ratios among DTM and further KN analysis.

T5: SCALING FACTORS DEFINITION

Finding correlation between Difficult to Measure isotopes, DTM, and Easy to Measure, ETM (Key Nuclides)

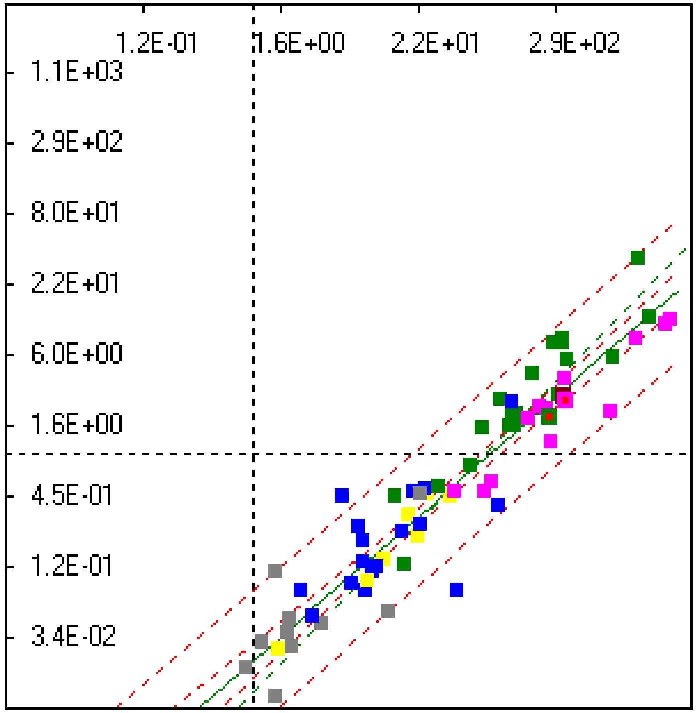
Key Nuclides (K.N.):

- Gamma emitter easily detected for any gamma spectrometry
- Relatively long lived (60Co and 137Cs)

Difficult to Measure Isotopes and K.N.:

- Activation Products (AP), or Fission Products (FP)
- Similar solubility
- Similar transport process

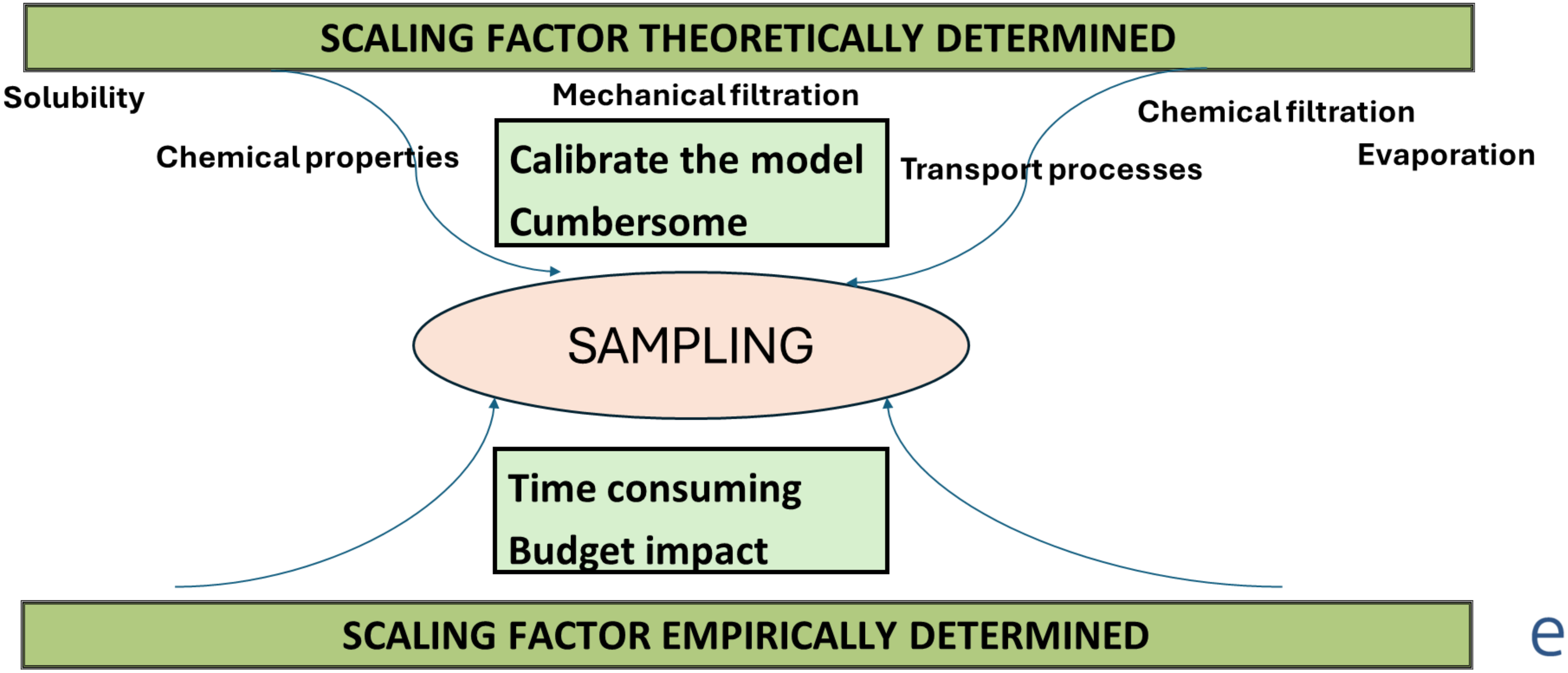
1) ISO 21238 “Scaling factor method to determine the radioactivity of low and intermediate-level radioactive waste packages generated at nuclear power plants”
2) IAEA TECDOC NW-T-1.18 “Determination and Use of Scaling Factors for Waste Characterization in Nuclear Power Plants”



- Geometric Mean, Arithmetic Mean, Log-Linear Regression
- Collection of samples
- Manner of sampling as critical aspect
- Time Consuming, High budget

T5.1: THEORETICAL ANALYSIS, IDENTIFICATION OF CONDUCIVE PARAMETERS

Partners T5.1: INGECID, SSTC NRS, **FTMC**, TRACTEBEL, SKB



eurad2

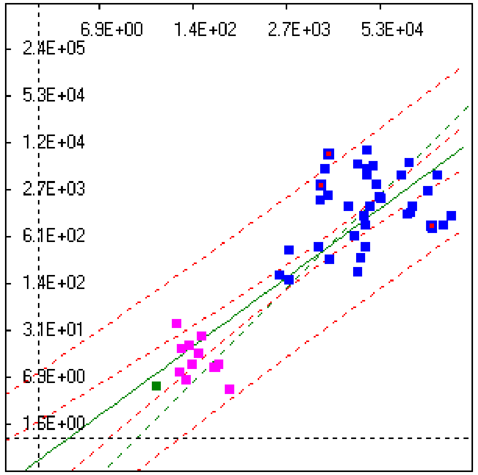
T5.2/T5.3: SCALING FACTOR TRUENESS - PRECISION IN SAMPLES / PACKAGES

Partners T5.2: INGECID, SSTC NRS, **FTMC**, TRACTEBEL

- Scaling factor uncertainty and bias improvement
- Package uncertainty and bias improvement

Partners T5.3: **INGECID**, UNIVERSITY OF PISA, SSTC NRS

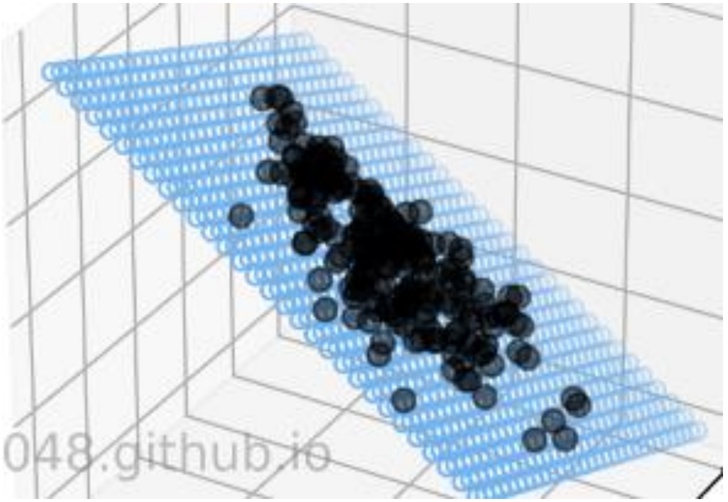
- Normally U_{SF} is directly applied to packages
- Normally bias is not taken into account

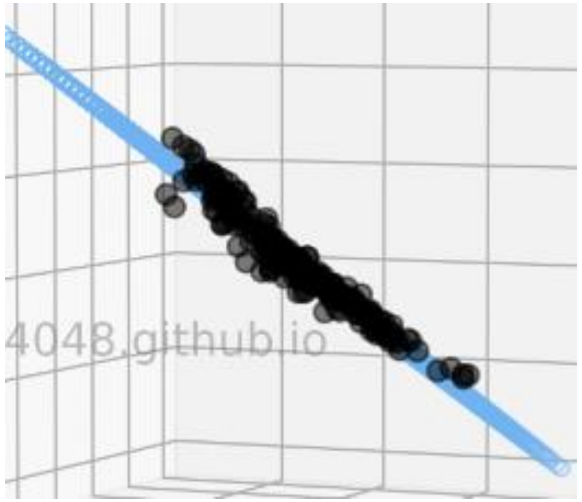


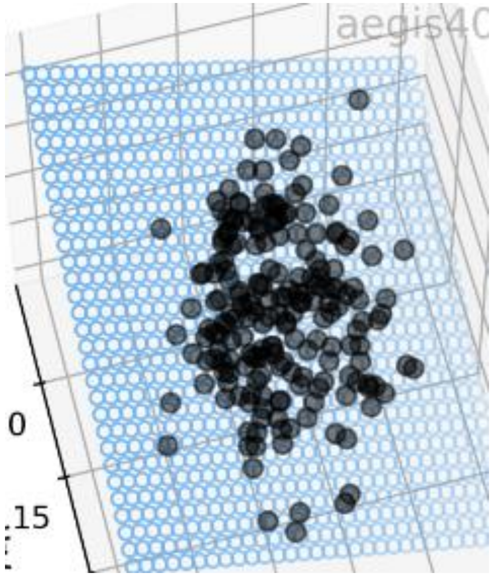
T5.4: ANALYSIS OF OPTIMIZED SCALING FACTORS ON REAL WASTE

Partners T5.4: **ENRESA**, SSTC NRS, ARAO, FTMC, ENERGORISK, SCK CEN, SORC, TRACTEBEL, ENEA

- Collecting **real samples** and applying the refined methodology.
- Multiple Key Nuclides.
- Correlation among DTM and further KN adjustment.







Thank you for your attention!

Any questions?