# GIROSCOPE

## Guidance for Innovative Reactor Off-Site Consequences, Planned and Emergency

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on behalf of the GIROSCOPE team

PIANOFORTE EUROPEAN PARTNERSHIP FOR RADIATION PROTECTION RESEARCH
GIROSCOPE

**11th NERIS Workshop, 2025, September 29th, London, UK**

Co-funded by the European Union

# Background, scope and main goals

- GIROSCOPE project aims to investigate and address the gaps in knowledge, capability, and advice relating to environmental impact assessments (EIAs) and emergency preparedness and response (EP&R) for these new reactors.
- The project aims to identify the challenges posed such as
  - **unaccustomed source terms,**
  - **novel siting environments,**
  - **and societal perceptions,**

  and find solutions and develop recommendations to improve radiation protection advice.

# The GIROSCOPE Team

## GIROSCOPE brings together 12 institutions with broad expertise in EP&R

| | | | | | |
|---|---|---|---|---|---|
| **National Centre for Nuclear Research, NCBJ, Poland** | **Research Centre for Energy, Environment and Technology, CIEMAT, Spain** | **Norwegian University of Life Sciences, NMBU, Norway** | **Federal Office for Radiation Protection, BfS, Germany** | **University of Gothenburg, Sweden** | **Nuclear Protection Evaluation Center, CEPN, France** |
| Poland | Spain | Norway | Germany | Sweden | France |
| **Nuclear Safety and Radiation Protection Authority, ASNR, France** | **Canadian Nuclear Laboratories (CNL), Canada** | **Portuguese Environment Agency, APA, Portugal** | **UK Health Security Agency, UKHSA, United Kingdom** | **National Centre For Scientific Research Demokritos, NCSRD, Greece** | **NERIS platform** |
| France | Canada | Portugal | United Kingdom | Greece | |



Co-funded by the European Union

# Duration

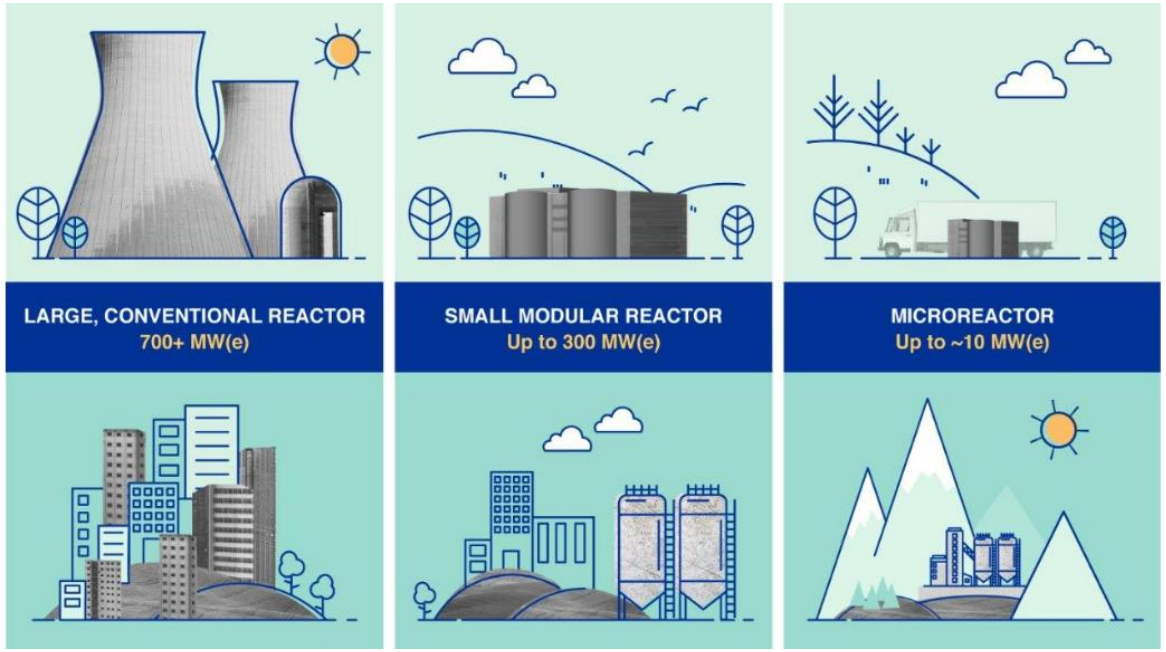
- Duration: 36 months -> start March 2025
  - WP1: Management, Dissemination, Translation (M1-M36)
  - WP2: Source Term Characterization For Novel Nuclear Reactors (NNRs) (M1-M30)
  - WP3: Modelling approaches for environmental transport of radionuclides from NNR technologies (M4-M30)
  - WP4: Framework For EIA And EP&R For NNRs (M2-M36)
  - WP5: Societal Perception Of NNR Technologies (M1-M36)

# GIROSCOPE WP2 objectives

- **WP2: Source Term Characterization For NNRs** (UGOT lead; NCBJ, NMBU, Bfs, CNL; **M4-M30**)
  1. Develop a methodology for source term characteristics for NNRs to scientifically support regulatory framework development, industry compliance, and protection of the public and environment.
     We consider three case studies (generic) :
     - **High-Temperature Gas-cooled Reactor** (HTGR-POLA- design at NCBJ ),
     - **Compact Molten Salt Reactors** (CMSR)-under development in Denmark, reactor driven ships in Norway
     - **Small Light Water Reactors** (SLWR)-planned in Swedish west coast by Vattenfall and Kärnfull Next AB
  2. Develop knowledge, skills, and capacity to prevent and/or manage and minimize the consequences of an NNR accident.

# Small Modular Reactors

- Advanced Reactors that produce typically up to 300 MW(e), built in factories and transported as Modules to sites for installation as demand arises




**Small**: in size, compared to traditional reactors.

**Modular**: factory-manufactured, installed onsite.

**Reactor**: energy generation via nuclear fission.

# Technology Categorization

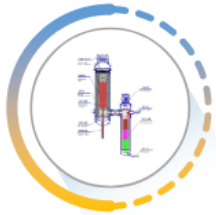
**Water Cooled (Land based)**
*PWRs, BWRs and HWR type SMRs*

**Marine-based Reactors**
*Mainly PWRs; Some are non-water-cooled reactors with capacity less than 100 MWe*

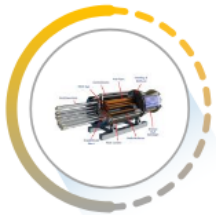
**Molten Salt Reactors**
*Can operate at high temperature under atmospheric pressure*

**SMR Technology Lines**

**Liquid Metal Cooled Fast Reactors**
*Better utilization of uranium resources with lower radioactive waste*



**High Temperature Gas Cooled Reactors**
*Suitable for cogeneration purposes due to high exit temperatures*

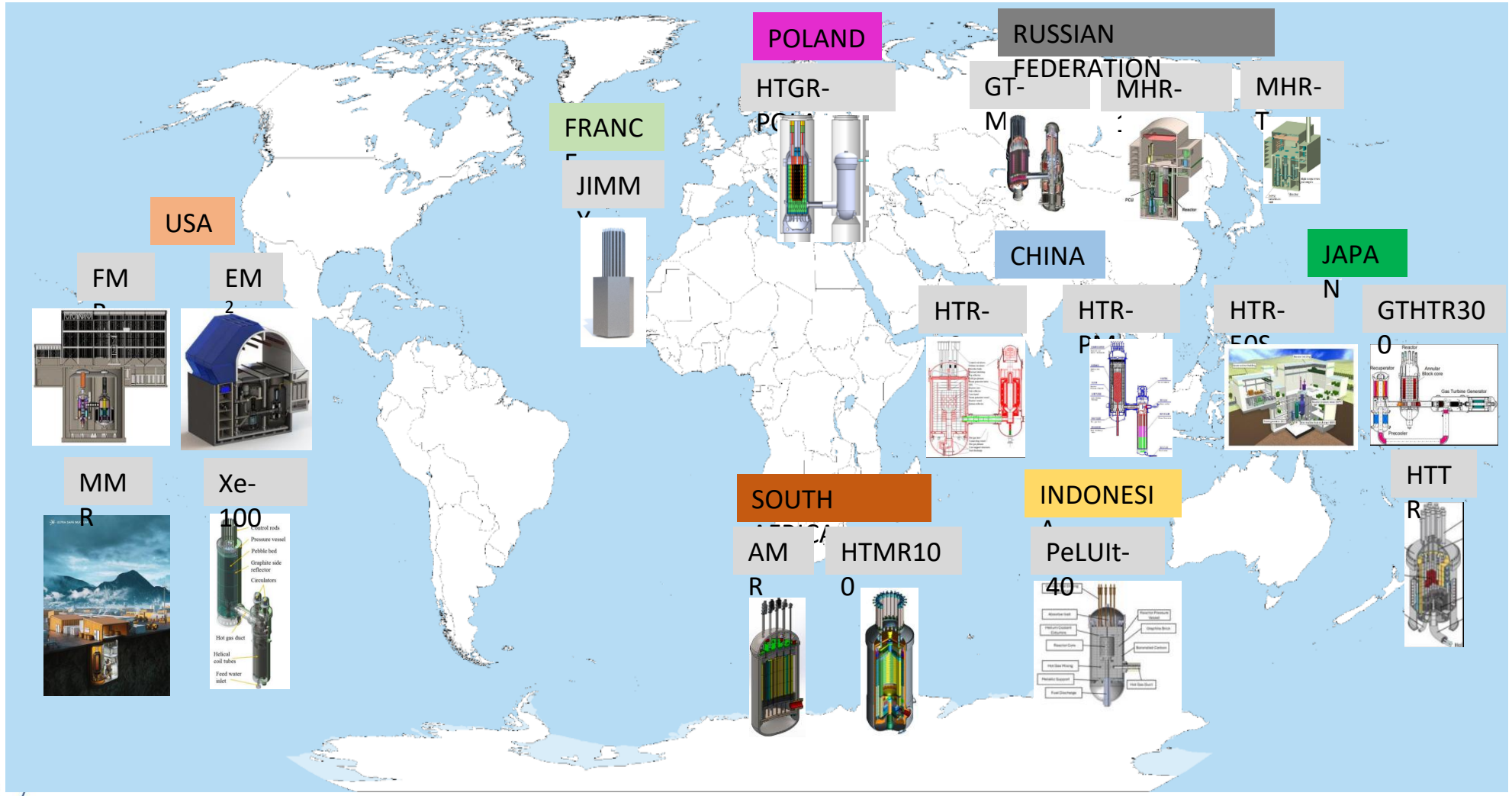


**Microreactors**
*A subset of small modular reactors with the power up to 10 MWe*

*Microreactors are intended for another niche market such as off-grid remote regions, small islands, and as power source for mining industries*

# IAEA: SMALL MODULAR REACTORS Catalogue 2024

*HTGRs under development and deployment*



# HTGR-POLA: reactor design developed by NCBJ

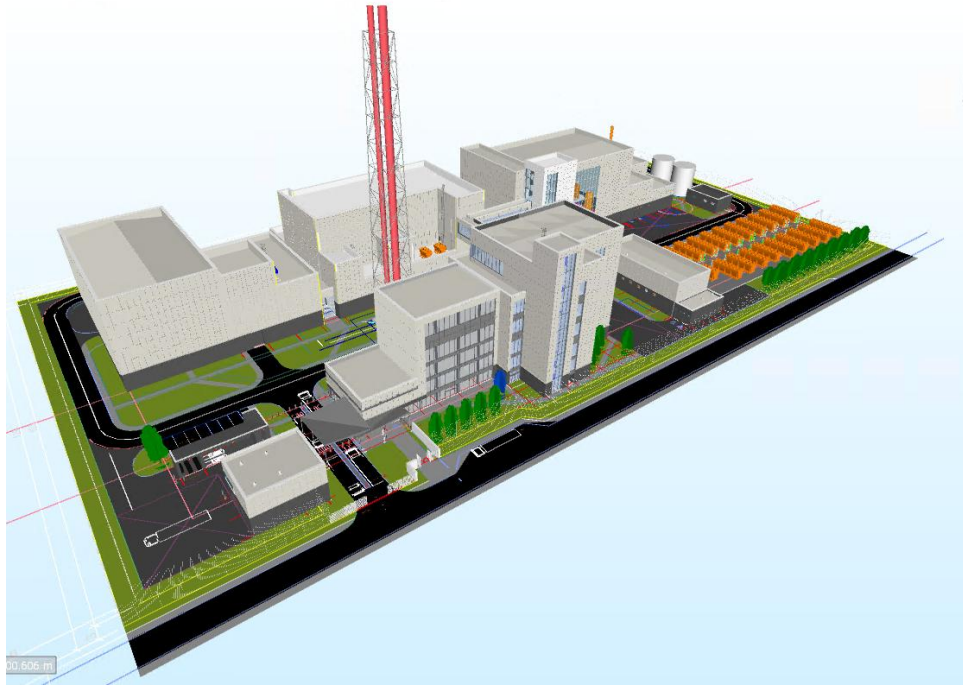
- Collaboration: **NCBJ – Japan Atomic Energy Agency (JAEA)**, with support: MHI, Fuji Electric, Toshiba ESS, ENERGOPROJEKT Katowice SA - **national project, 2021-2024**
- Small-scale, prismatic-type, helium-cooled, graphite-moderated research HTGR with a thermal power of 30 MWt
- Technology demonstrator for industrial applications, serving as a research tool, enhancing human resources, industry, and regulatory competencies
- HTGR-POLA combines elements from the GEMINI+ industrial reactor concept and the Japanese HTTR research reactor

**HTGR-POLA – key mission objectives**

- Facilitate the licensing and demonstration path for commercial HTGRs
- Demonstrate and examine HTGR technology and practical application in an industrial environment;
- Support structural materials and TRISO fuel research
- Enhance safety assessment methods and tools
- Build competence in design, construction, operations, and training

# HTGR-POLA: Development Milestones

| | | |
|---|---|---|
| 2012 – 2019 | Preliminary studies and technological innovation | Complete |
| 2019 – 2021 | Pre-conceptual design phase and technology validation | Complete |
| 2021 – 2022 | Conceptual Design Phase | Complete |
| 2022 – 2024 | Basic Design Phase | Complete |
| 2025 – 2028 | Licensing Phase | Planned |
| 2025 – 2028 | Detailed Design Phase | Planned |
| 2029 – 2032 | Construction | Planned |
| 2033 | Commissioning | Planned |



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# Compact Molten Salt Reactors

- **Concept:** Modular reactors mounted on barges/ships, delivered as plug-and-play floating power plants
- **Fuel & Coolant:** Molten salt mixture, low-pressure, high-temperature, inherent safety
- **Output:** Typically 100–200 MWe per barge, scalable via multiple units
- **Mobility & Deployment:** Salt remains liquid under atmospheric pressure, no high-pressure explosion risk
- **Applications:** Electricity & industrial process heat (chemicals, steel, hydrogen), desalination, offshore industry supply
- **European Example**: Saltfoss (Seaborg) CMSR power barge project (Denmark)



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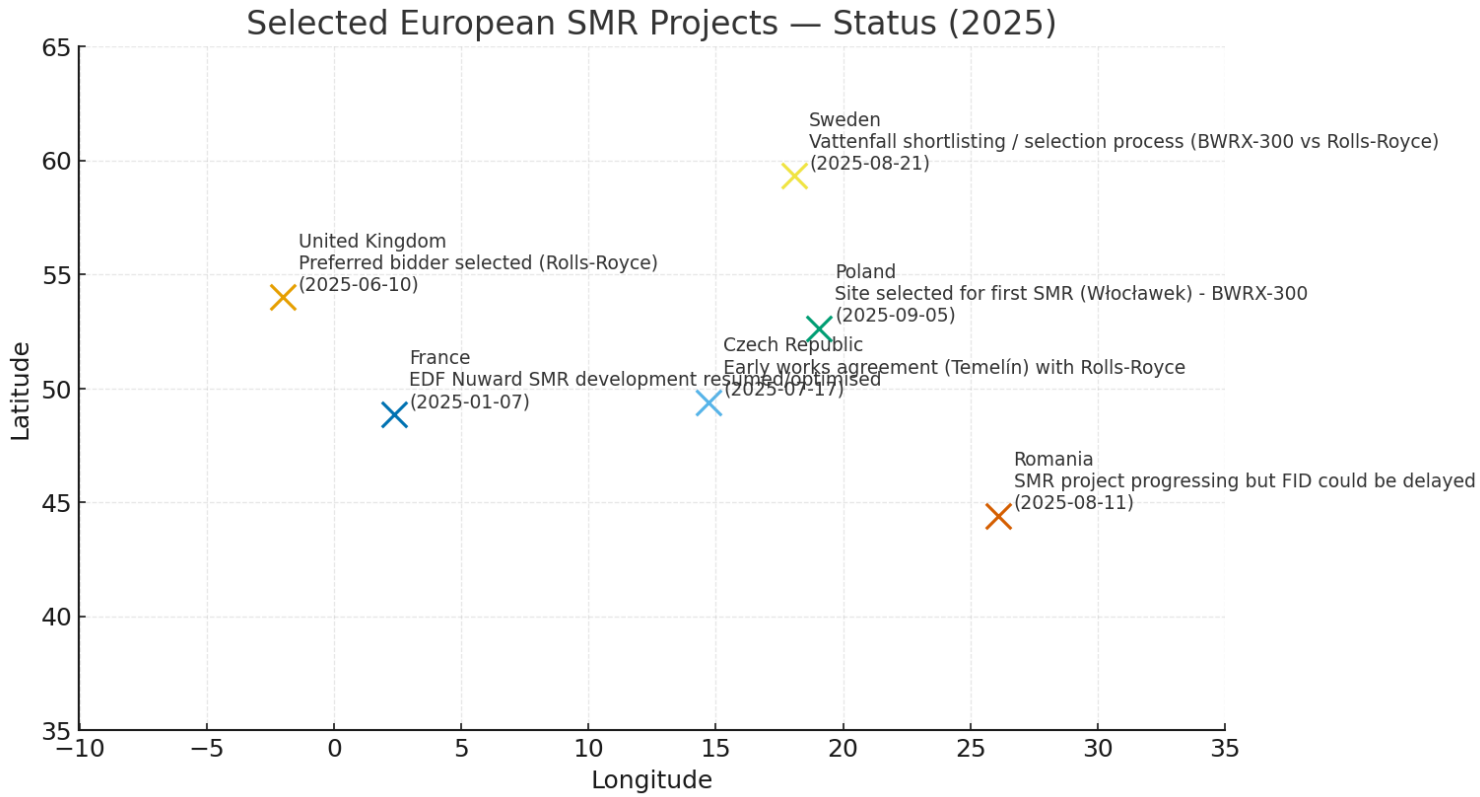
# Map – Selected European SMR Projects




Notes: markers show countries with notable SMR activity or agreements in 2025. Status captions are brief summaries.

# GIROSCOPE WP2 tasks

- **Task 2.1 Understanding NNR Characteristics** (NMBU lead, NCBJ, UGOT, CNL)
  - This task aims to **identify unique design features** of selected NNRs to estimate source terms for **normal operation and accident conditions**

  **2.1.1 Identify possible operating configurations** of HTGR, CMSR, and SLWR reactors,

  Considerations include:
    - Systems
    - Interface requirements
    - System interactions
    - Different fuel components
    - Coolant materials  etc. (NCBJ Lead, UGOT, CNL)
- …

# GIROSCOPE WP2 tasks

- **2.1.2 Identify reactor design characteristics**, e.g.,
  - Fuel
  - Coolant type
  - Core configuration
  - Core damage development
  - Retention of radionuclides in the primary coolant system
  - Performance of means of confinement
  - Other release sources:
  - Graphite oxidation
  - Molten salt loss of chemical retention
- Containment systems on radionuclide behavior post-accident
- Additional factors affecting radionuclide transport and environmental release etc. (NMBU lead, NCBJ, UGOT, CNL)

# GIROSCOPE WP2 tasks

- **Task 2.2 Source Term Assessment - Identification of New Potential Release Pathways (UGOT lead, NCBJ, CNL)**
  - This task will estimate the source terms of HTGR, CMSR, and SLWR for normal and accident conditions and identify distinct mechanisms/pathways for radionuclide release into the environment. Identified radionuclides and their quantities will be used as input for the assessment of their environmental impact (WP 4)
  - **2.2.1 Comprehensive state-of-the-art review of the suitability of existing codes and input parameters** needed to estimate annual and accidental releases for HTGR, CMSR, and SLWR
  - **2.2.2 Development/improvement of selected computer codes**. Inventory of fission products and other radionuclides in the core. Specific HTGR, CMSR, and SLWR fuel designs will be used

# GIROSCOPE WP2 tasks

- **Task 2.3 Database Establishment** (Bfs lead, NCBJ, UGOT)
  - A database containing estimated source terms for selected NNRs, accounting for potential uncertainties in release scenarios, will be established.

# WP2: Milestones Achieved and Preliminary Results

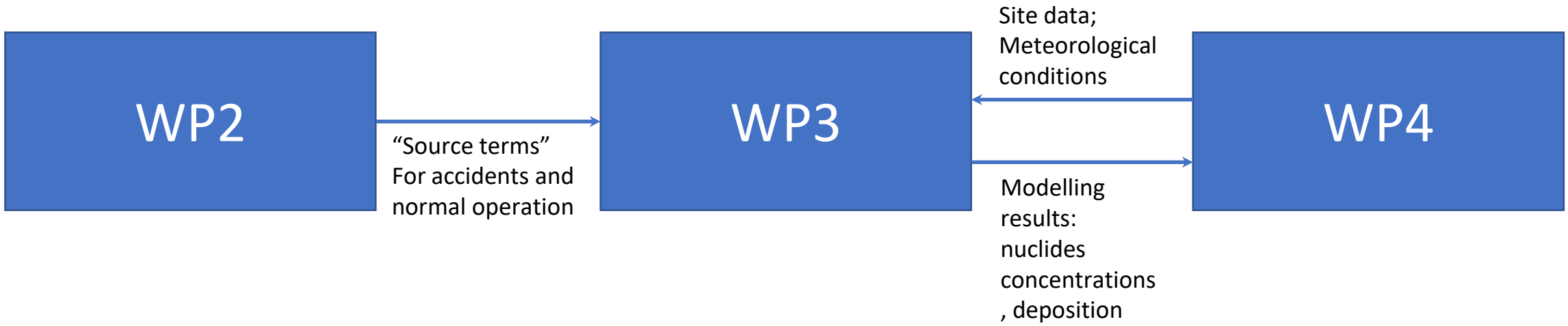
- **Database of source terms**
  - accident scenarios for SLWR and HTGR (Canada, CNL).
  - source term for annual releases and fluctuations from SLWR in Sweden.
  - ongoing modelling in Poland and in Sweden for accident scenarios for HTGR-POLA and SLWR Rolls-Royce preferred in Sweden
  - under development the source term for CMSR accident and normal operation



# GIROSCOPE WP3 objectives

- **WP3 Modelling approaches for environmental transport of radionuclides from NNR technologies**
  (NCSRD lead; NCBJ, CIEMAT, UKHSA, Bfs, IRSN, APA, CNL; **M4-M30**)
  1. Define requirements for radionuclide atmospheric transport modelling across various NNR types and scenarios for EP&R
  2. Develop a framework and novel approaches (e.g., AI) for atmospheric transport modeling in EP&R and routine EIA.
  3. Benchmark models using experimental data and simulate NNR accident scenarios to assess radiological consequences.
  4. Compare new and existing atmospheric dispersion models for normal operational discharges.

# WP3 in GIROSCOPE data flow



# WP3 – special emphasis / novel elements

- Particularities of the NNRs siting : small scale computational domain, detailed topography and geometry, proximity to urban or industrial sites
- Dispersion modelling of nuclides from NNR accident scenarios and routine operation discharges
- Use and benchmarking of atmospheric dispersion modelling approaches fitted to the particular project requirements
- Multiple accident scenarios, multiple siting cases, multiple modelling systems

# WP3 – on going activities

- Task 3.1: Review and identification of new modelling and data requirements
  - D3.1 Report on new modelling requirements, led by ASNR, to be delivered on M10 (December 2025)
    - 1st version of the report already available, in consultation with the partners for completion
  - Compilation of information on atmospheric models / modelling systems to be employed by the GIROSCOPE partners (model types, spatial and temporal scales, nuclides, I/O requirements, etc.)

# WP3 – future activities

- Task 3.2: Carry out modelling systems developments (where necessary), set up of suitable modelling frameworks, consider novel modelling approaches, based on conclusions from T3.1 (M10 – M16)
  - *D3.2 Report on concept development for small-scale atmospheric transport modelling, led by NCBJ, do be delivered on M17*

# WP3 – future activities

- Task 3.3: Computational simulations using the tools from Tasks 3.1 and 3.2
  - T3.3.1 Model validation with experimental data → *D3.3, report, ASNR, M24*
  - T3.3.2 Simulations of radiological consequences from NNR accident scenarios → *D3.4, report, NCSRD, M31*

    (i) one source term from WP2 applied on location and weather conditions of the experimental case from all partners

    (ii) source terms from WP2 applied on NNR locations and weather conditions from WP4 according to each partner interests

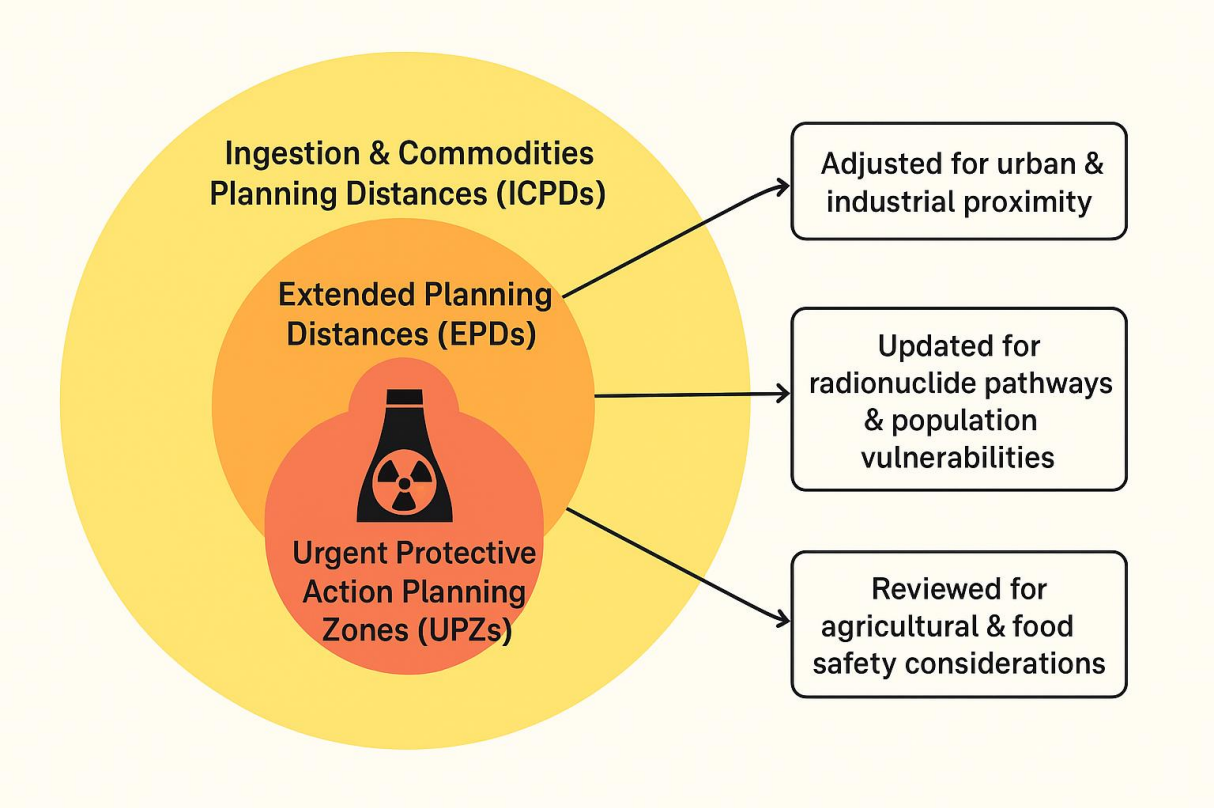
    (iii) new models / methods applicable for normal operations compared to existing modelling techniques

    Results from (i) and (ii) will be passed on to WP4 to draw recommendations on protective actions

# GIROSCOPE WP4 objectives

- **WP4: Framework For Environmental Impact Assessments (EIAs) and Emergency Preparedness and Response (EP&R) For NNRs**
  (NCBJ lead; NCSRD, CEPN, NMBU, CIEMAT, UKHSA, Bfs, IRSN, APA, CNL; **M2-M36**)
  a) Compile data on potential NNR locations based on institutional proposals and recommendations.
  b) Revise protective action zones based on WP3 data, dose limits, and IAEA guidelines:
     a) Adjust Urgent Protective Action Planning Zones (UPZ) boundaries for urban and industrial proximity.
     b) Update Extended Planning Distances (EPDs)for radionuclide pathways and population vulnerabilities.
     c) Review Ingestion and Commodities Planning Distances (ICPDs) for agricultural and food safety considerations.
  c) Develop EIA recommendations for NNR under normal and emergency conditions.
  d) Prepare a comprehensive report summarizing methodologies, findings, and WP4 recommendations.

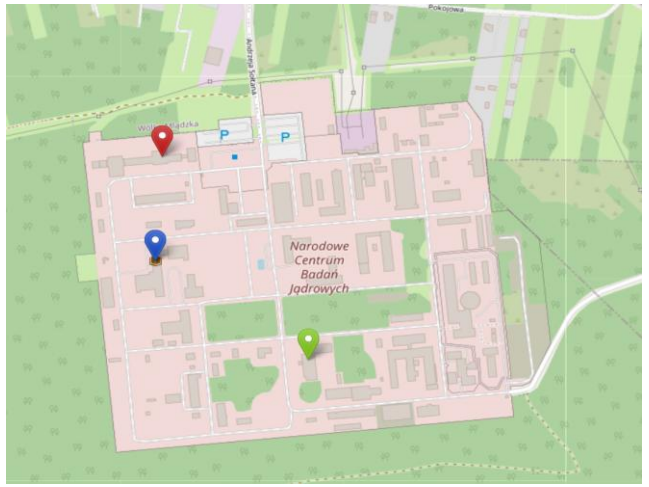
# Protective action zones




- A concentric diagram illustrating the types of radiological protection planning zones and the aspects being updated.

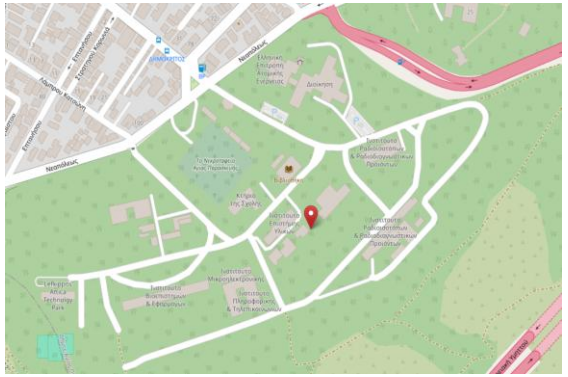
# Location: Otwock-Świerk (Poland)

- Institution: NCBJ
- Coordinates: 52.1231, 21.3405
- Character: research, forested, distant from urban areas
- Planned reactor: HTGR-POLA (30 MWt)
- Purpose: chemical processes, electricity generation, hydrogen production
- Key aspects:
  - Existing MARIA research reactor
  - Large campus with laboratories and facilities
  - Reactor design: helium coolant, TRISO fuel, inherent safety
- Available data:
  - 3D model of buildings + SHP terrain (~700 × 700 m)
  - Meteorology (Warsaw-Okęcie, 2013–2022




# Location: Aghia Paraskevi, Athens (Greece)

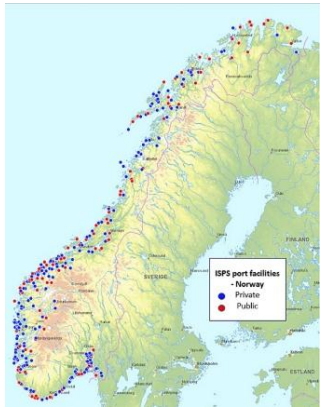
- **Institution**: NCSRD "Demokritos"
- **Coordinates**: 37.9972, 23.8196
- **Character**: suburban/research, complex terrain, near city
- **Planned reactor**: none (existing GRR-1 research reactor)
- **Key aspects:**
  - ~400–500 m from residential area
  - Reinforced concrete reactor hall (5 storeys)
  - Urban proximity → airflow & building wake effects important
- **Available data:**
  - Terrain model used with JRODOS MPP
  - WRF model (v3.4, v3.5)
  - Measured data from 5 stations: wind, stability classes, precipitation



# Location: Aure & Heim (Norway)

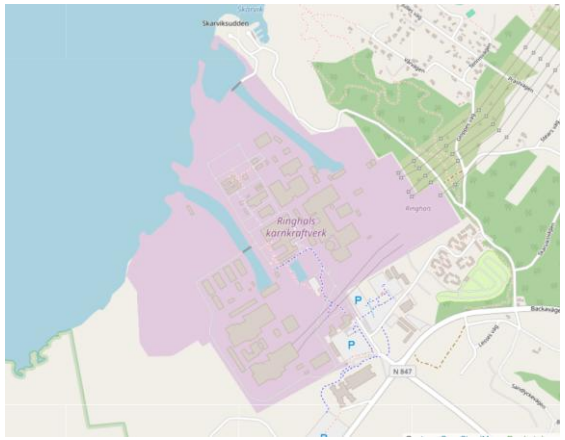
- **Institution**: Norsk Kjernekraft
- **Coordinates**: 63.4179, 8.7680
- **Character**: coastal/industrial, energy production oriented
- **Planned reactors**: several SMRs (~12.5 TWh total)
- **Key aspects:**
  - Candidate site: **Taftøy Industrial Park**
  - Officially included in EIA studies
  - Designed to provide stable, large-scale electricity
- **Available data:**
  - Meteorology from MET Norway
  - Source terms to be developed by NNRC
- **+ Location: Ship**
- Character: mobile/maritime, industrial seaports
- Planned reactors: Kairos (USA), Thorium CMSR (Molten Salt Reactor)
- Purpose: nuclear marine propulsion
- Meteorological datasets provided by MET Norway

https://www.world-nuclear-news.org/articles/norwegian-town-initiates-nuclear-plant-zoning-work



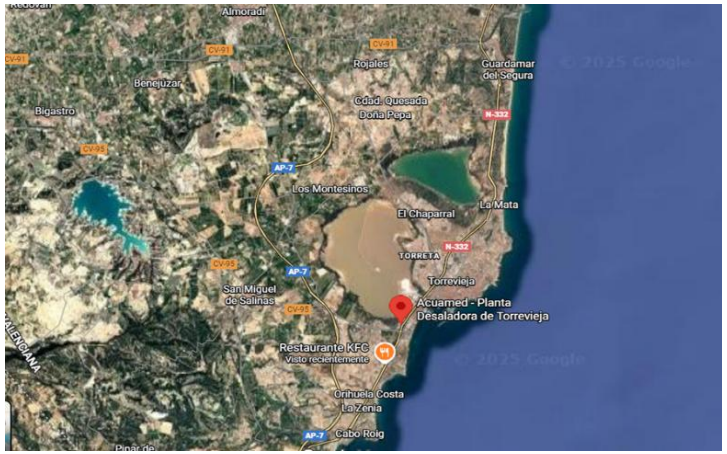

# Location: Ringhals NPP, Värö Peninsula (Sweden)

- **Institution**: Vattenfall
- **Coordinates**: 57.2597, 12.1108
- **Character**: existing nuclear facility, coastal, industrial
- **Planned reactors**: Rolls-Royce SMR, GE Hitachi (under evaluation)
- **Key aspects:**
  - Established nuclear site with existing reactors
  - Close to Gothenburg (~65 km)
  - Existing radioactivity monitoring at the site
- **Available data:**
  - Terrain model (SHP)
  - Full meteorological dataset maintained on site



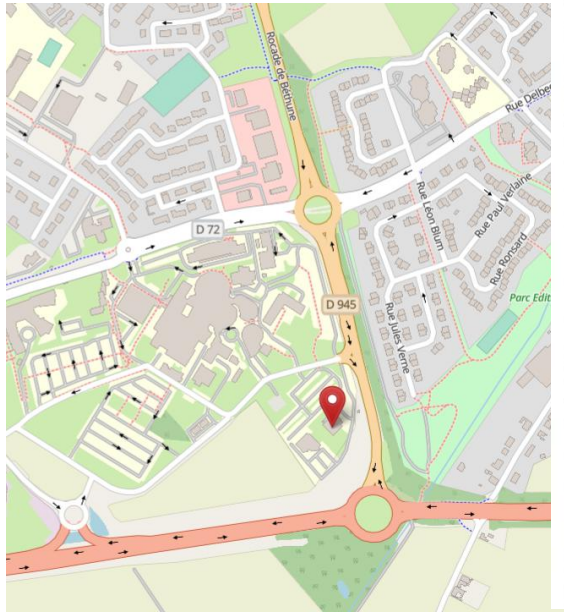

# Location: Torrevieja Desalination Plant (Spain)

- **Institution**: CIEMAT
- **Coordinates**: 37.9692, –0.7071
- **Character**: coastal, industrial, near urban area & protected ecosystems
- **Planned reactor**: none officially (academic/hypothetical)
- **Purpose**: support energy demand for desalination processes
- **Key aspects:**
  - One of Europe's largest desalination facilities
  - Semi-arid Mediterranean climate (<300 mm rainfall/year)
  - Within 30 km: **15 Natura 2000 sites** (wetlands, marine habitats)
  - Region heavily urbanised, dependent on tourism and water management
- **Available data:**
  - Meteorological stations from **MASTRAL project**
  - National datasets: **AEMET**
  - Prognosis/reanalysis: **HARMONIE model**, NOAA NOMADS
  - 3D building model needed for dispersion




# Beuvry Hospital Cyclotron (France)

- **Coordinates**: 50.51404° N, 2.67255° E
- **Character**: peri-urban, medical/industrial facility,
- **Purpose**: medical radioisotope production, atmospheric dispersion research
- **Key aspects:**
  - Cyclotron building: **21.5 × 24 m**, height 8.5 m
  - Discharge stack: **10.2 m high**, curved outlet, 45° downward jet, ejection ~6 m/s
  - Mixed environment: rural (south) + urban/hospital/housing (north)
  - Very near-field environment includes **hedges (15–20 m), vegetation, road, nearby buildings**
  - Complex stack geometry induces **turbulence & divided plume flows**
  - **Available data:**
- **Two experimental campaigns** (15–17 Oct 2019, 10–12 Dec 2019)
  - Helium tracer releases (flow 2.4–5.5 g/s, 8–10 min duration)
  - Atmospheric transfer coefficients (ATC) derived
- **Meteorological monitoring:**
  - Young ultrasonic anemometer (wind speed/direction at 11.8 m, 10 Hz sampling)
  - Watchdog station (temperature, pressure, solar radiation at 1.5 m)
  - Stability classification: **Pasquill–Turner class** (from wind & radiation)

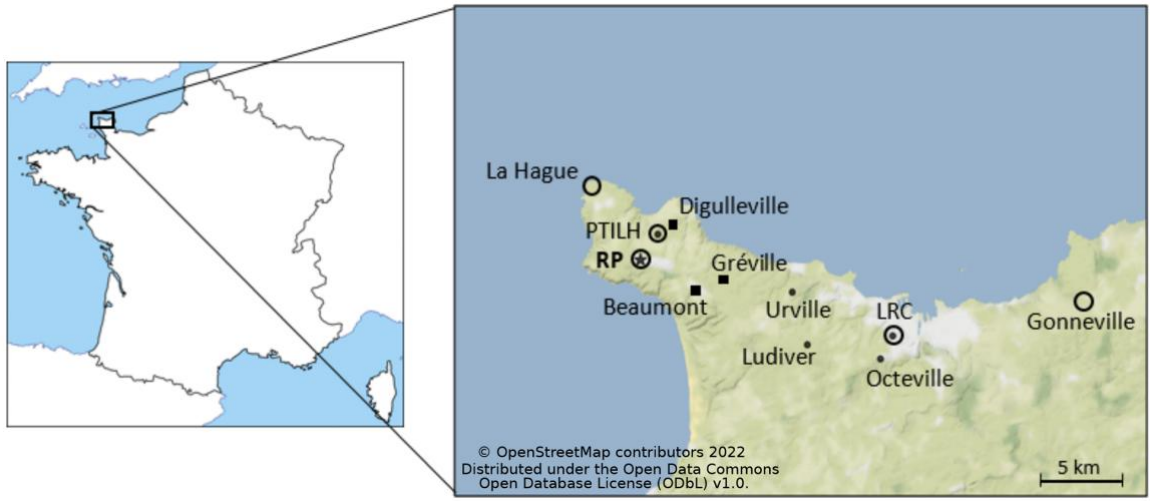




Laguionie, P., Connan, O., Tien, T. L., Vecchiola, S., Chardeur, J., Cazimajou, O., ... & Maro, D. (2022). Investigation of a Gaussian plume in the vicinity of an urban cyclotron using helium as a tracer gas. *Atmosphere*, *13*(8), 1223.

# La Hague Reprocessing Plant (France)

- **Coordinates:** 49.67705° N, 1.87941° W
- **Character:** Coastal, industrial nuclear reprocessing facility
- **Purpose:** Reprocessing of spent nuclear fuel, atmospheric dispersion studies of 85Kr
- **Key aspects:**
  - Production units: **UP2-800** & **UP3**
  - Stacks: 100 m high, 200 m apart
  - Intermittent 85Kr releases: 30–45 min bursts, ~10 min intervals without release
  - Long periods without releases possible (hours to weeks)
  - Releases can occur from **one or both stacks simultaneously**
  - Annual releases (2019–2021): 294–379 PBq/yr
  - Continuous measurement time step: 10 min, **uncertainty ~10%**
- **Meteorological monitoring / environment:**
  - Near-field environment: coastal, low vegetation, some buildings
  - Wind direction crucial for observed 85Kr events
  - Continuous air measurements at 8 nearby stations (IRSN & Orano): 1 min (IRSN) / 10 min (RP)
  - Ideal tracer: inert, long half-life (10.7 yrs), negligible wet/dry deposition




El-Ouartassy, Y., Korsakissok, I., Plu, M., Connan, O., Descamps, L., & Raynaud, L. (2022). Combining short-range dispersion simulations with fine-scale meteorological ensembles: probabilistic indicators and evaluation during a 85 Kr field campaign. *Atmospheric Chemistry and Physics*, *22*(24), 15793-15816.

# WP4 Milestones - Summary

- **Locations**: diverse environments – forest, rural, urban, industrial, maritime
- **Key inputs**: meteorological data + 3D/terrain models for EP&R & EIA
- **Important aspect**: selected sites represent the **variety of meteorological and climatic conditions across Europe** (Mediterranean, continental, Nordic), enabling robust scenarios for dispersion modeling and emergency planning

- **Next steps:**

1. Review of **national regulatory frameworks** and **nuclear safety authority recommendations** for calculating **emergency planning zones and emergency planning distances**

1. Definition of **institutional responsibilities** – assigning which organizations will simulate which cases

# GIROSCOPE WP5

## SOCIETAL PERCEPTION OF NNR TECHNOLOGIES

**M1-M36**

Lead by NMBU
Contributors: NCBJ, CEPN, CIEMAT, UGOT, BfS, APA, CNL

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# WP5 Objectives

Analyse stakeholder perceptions of NNR to

better understand the issues underlying public trust and acceptance,

respond to evolving community needs and concerns,

adjust communication and risk management strategies

Develop education and outreach materials

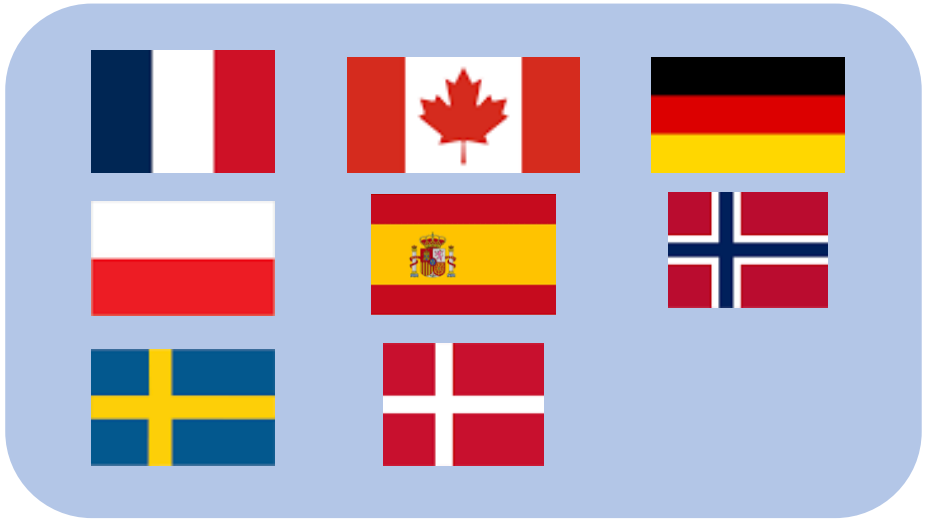
# **Task 5.1** Mapping Societal Aspects of NNR Technologies (UGOT lead, NMBU, M1-12)

Aims to

- review existing **knowledge** surrounding the potential **siting and development** of NNR (literature-based )
- identify **key factors** for the planned **stakeholder engagement and dialogue activities** linked to the project case studies.


M5.1 Mapping Societal Aspects of Novel Nuclear Reactor Technologies - Literature review ongoing (complete for M12)

# **Task 5.2** Stakeholder Engagement and Co-expertise Dialogue (NMBU lead, CEPN, CNL, UGOT, CIEMAT, NCBJ, BfS; M11-30)



Several stakeholder engagement activities

**Harmonise the approaches**, to ensure that even if different methods are used, **similar issues are addressed** (societal, environmental, economic and security) to better understand commonalities and differences.

M5.2 Stakeholder Engagement and Co-expertise Dialogue - preliminary summary of national stakeholder engagement activities: ongoing and planned (M24)

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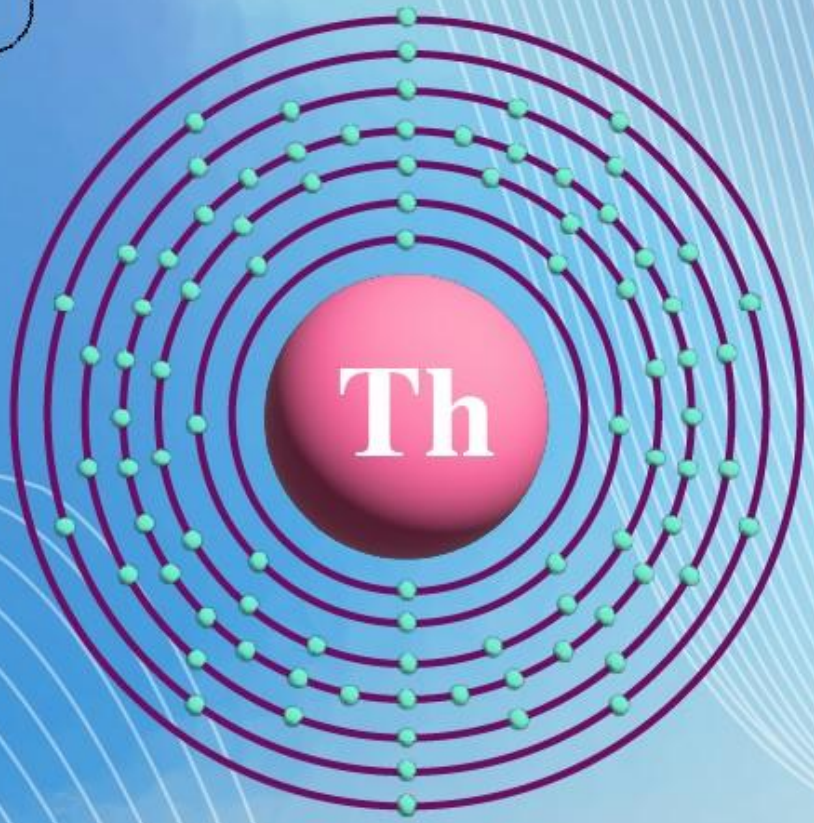
# NUCLEAR NORWAY: SHOULD THORIUM BE PART OF THE DEAL?

**June 11, 2025 9:00 AM – 6:00 PM,**
**The Norwegian Academy of Science and Letters**



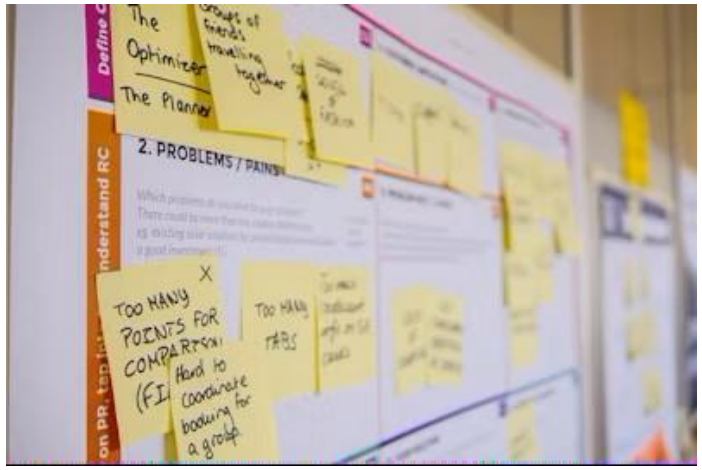
# **Task 5.3** Education and Training (NMBU lead, UGOT, CEPN, NCBJ; M1-36)

- consolidate work on education and training
- development of teaching and training material
- inclusion of MSc, PhD and Post Doc students

M5.4: Summary of Education and Training Activities (M18, 30)

# **Task 5.4** Recommendations for Outreach, Education, and Communication (CEPN lead, NMBU, APA, CNL, CIEMAT, UGOT, BfS; 19-32)

- Consolidate the results of the stakeholder dialogue exercises
- Develop recommendations for addressing the societal perception of NNR
- Present and discuss final recommendations with the project international stakeholder panel
- Key findings and recommendations will also be included in education and training activities.




M5.3: Draft of outreach recommendations (M30)
M5.5: International workshop (M32)
D5.1 Addressing Stakeholder Concerns in Outreach, Communication and Education for Next-Generation Nuclear Technologies (NMBU, M36)

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# Thank You



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