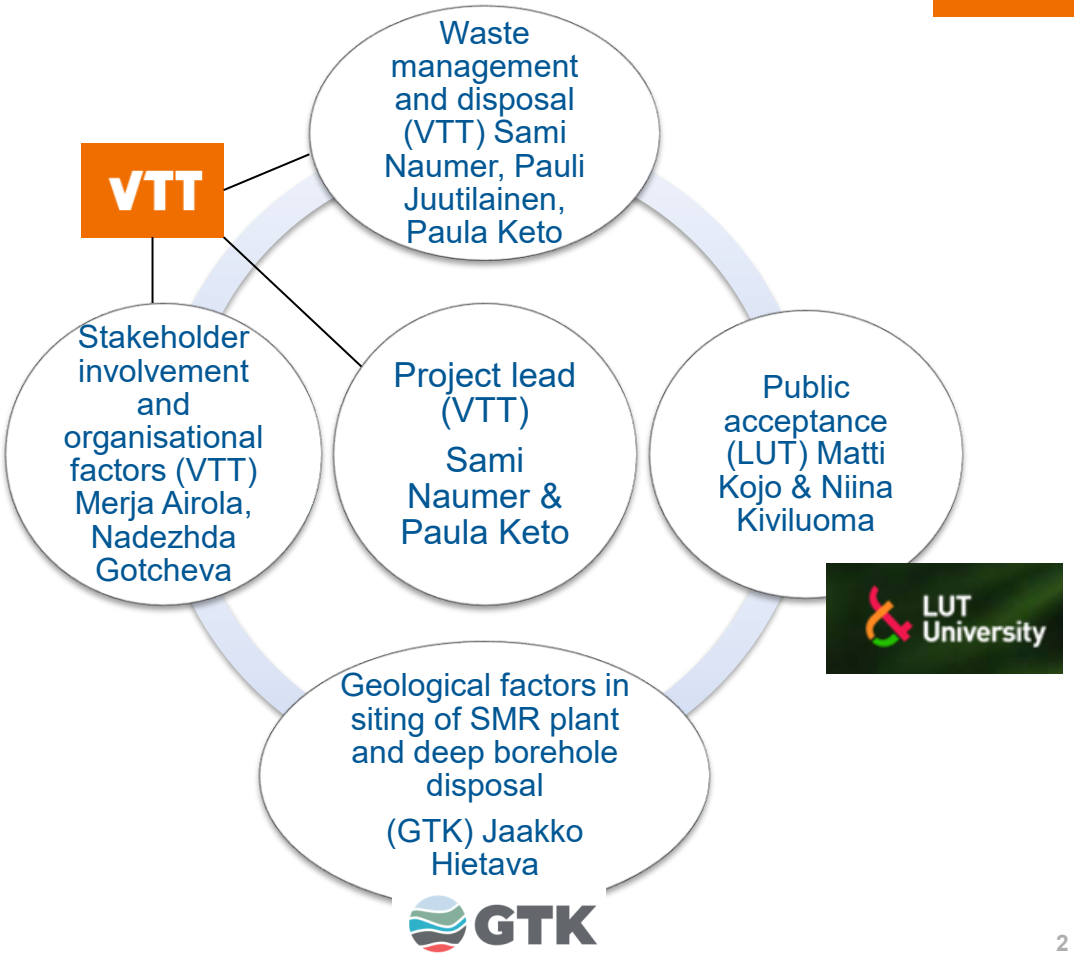
Lessons Learned from SAFER2028 SMR Siting and Waste Management Project

Paula Keto, Sami Naumer, Timothy Schatz, Nadezhda Gotcheva & Merja Airola (VTT), Matti Kojo (LUT), Jaakko Hietava (GTK)

17/10/2025 **VTT – beyond the obvious**

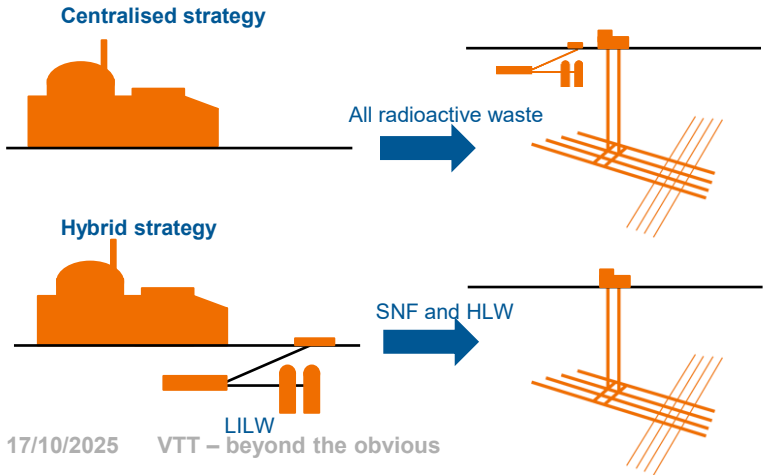
SMR Siting and Waste Management Project

- The overall objective is to support Finland in SMR deployment and in preparing for the SMR waste management.
- Links to international SMR waste management projects EURAD2 FORSAFF and NEA WIZARD

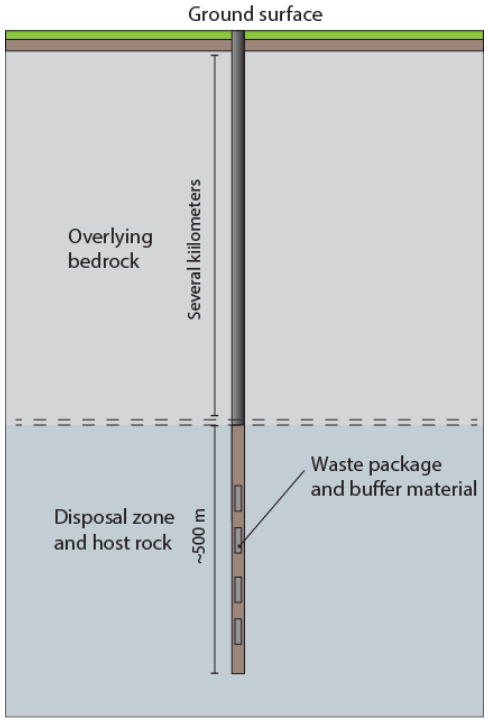


Waste management

- Topics:
  - SMR spent nuclear fuel characteristics and applicability of current management methods.
  - Waste management and disposal strategies and options.
  - Regulatory framework and licencing.



Local strategy / alternative disposal concept (DBD)



SMR SNF characterisation

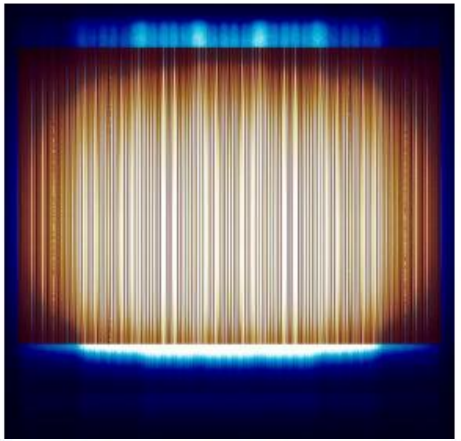
- Main research topics:
  - How do SNF characteristics of different LWR-SMRs with different burnups and enrichments differ from each other?
  - What is the impact of smaller core size on activation of materials and on the SNF?
  - How can neutronics calculations be made less computationally intense?

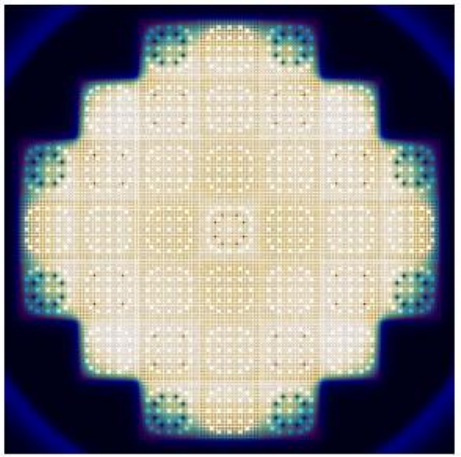
- SNF characterisation and canister loading investigated with:
  - Serpent, Ants, Serpent-Ants, both 2D and 3D calculations. Comparison between the different methodologies

- Investigated SMRs:
  - LDR-50, NuScale, comparison to current operating NPPs

Results of SMR SNF characterisation

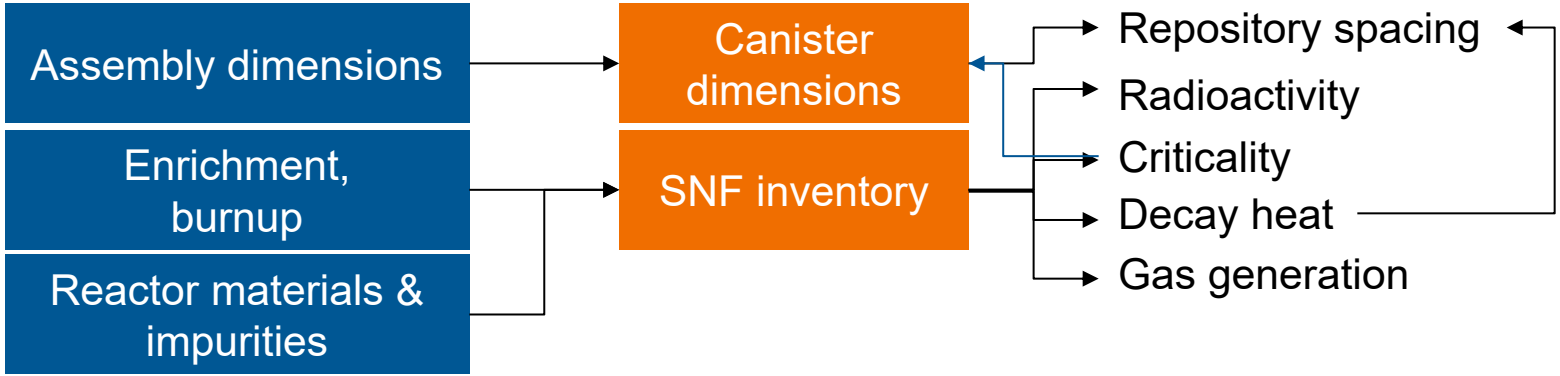
- SNF characteristics:
  - SNF properties with comparable burnups and enrichments do not significantly differ from conventional NPPs
  - With lower burnup, less fissile material is depleted, leading to lower radioactivity, and decay heat. May lead to criticality concerns! Vice-versa for higher burnups
- Smaller core size:
  - Few quantitative analysis carried out
  - Smaller core can lead to increased neutron leakage from axial ends. Possibly more activated materials and more LILW.
  - Smaller core size leads into a more varied axial burnup profile and higher peak burnups
- Computational aspects
  - Full core Serpent 3D calculations are most accurate, but require significant computational resources
  - 2D axial modelling is less intense, but does not capture all spatial phenomena, such as activation of structural parts, or end effects
  - Serpent–Ants full-core calculations are less intense than full core 3D calculations and results closer to full core Serpent calculations than 2D serpent calculations.





Applicability of SMR SNF to KBS-3

- Applicability of KBS-3 for SMR SNF and ATFs disposal assessed on a general level



- ATFs: multiple new cladding types, such as Zr alloys or ceramic materials, new core materials, improved UO_2
  - Less corrosion, less hydrogen production. However, disposal of ATFs should be quantitatively assessed. Dissolution rate / source terms, activation products (N → 14-C).
- Future: reprocessed SNF, new fuel types.

Renewal of Nuclear Energy Act (draft):

- Nuclear waste generated in connection with or as a result of use of nuclear energy in Finland shall be permanently disposed of in Finland (excluded minor amounts).
- Nuclear waste generated outside Finland cannot be disposed in Finland (exception small amounts).
- New options:
  - Re-use of materials.
  - Processing and long-term storage of the waste outside Finland is possible (large-scale).
  - Short term storage and processing of nuclear waste in Finland allowed, e.g. encapsulation.
- Plan how waste management will be executed is a requirement for the construction license.

Organisation models

License holder producing the waste in Finland is the party with the waste management obligation. Responsible for costs including also financial provision obligation and collateral security (vakuus).

Transfer of waste management obligation (Decision by TEM)

No transfer of the waste management obligation

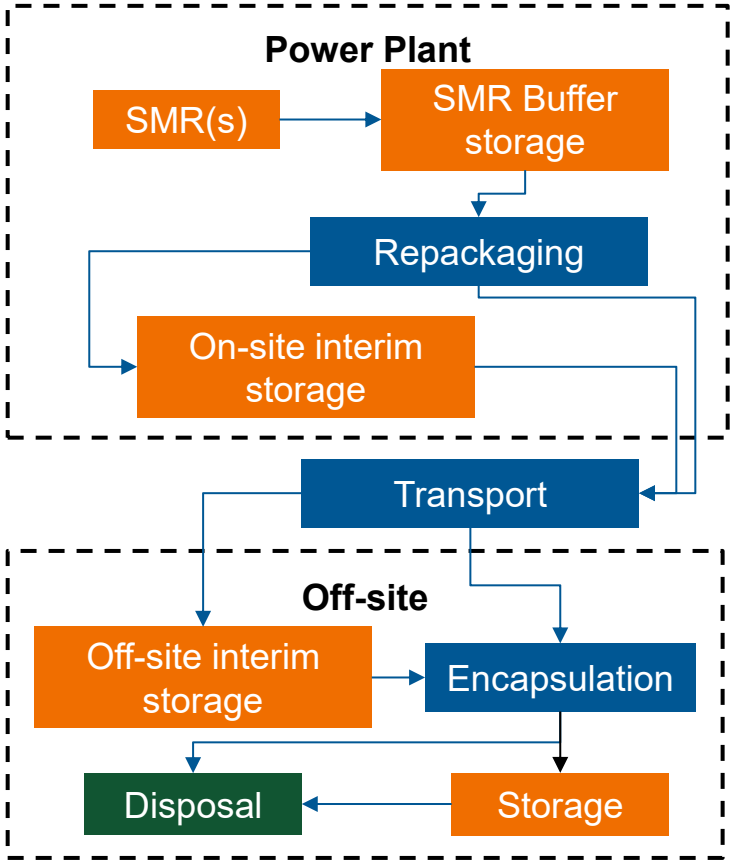
Service model:
Waste management and disposal by a company. Mutual understanding (agreements), ability, licenses, transfer of responsibility for safeguards and costs. Example: VTT/Fir1 LILW → Fortum

Ownership model:
Waste management and disposal by a company (partly or entirely) owned by the license holder. Example: Posiva.

License holder model License holder takes care of the waste itself. Example: LILW disposal in VLJ

Centralised waste management

- Remaining uncertainties for different type SMR reactors concerning centralised waste management:
  - Interim storage capacity and cooling times at the SMR plant before transport is possible.
  - Interim storage types:
    - Wet storages currently in use.
    - SMR vendors also plan to use dry storage.
  - Transports casks & safety during transport.
  - LILW interim storages at the site and transport.
  - Societal acceptability of transport and interim storages at the SMR plant site and at the centralised waste management site. *Acceptance from the community remains as a requirement!*
  - Use of new processing options and disposal concepts?
  - Is it a viable business and a risk worth taking if organised as a service?



Other organisational aspects and stakeholder involvement

- Safety oversight of organisational, management and leadership aspects in the SMR lifecycle
  - Key human organisational factors include nuclear-qualified personnel, construction of new nuclear projects, readiness of domestic supply chains etc., needed for building the required human and organisational resources and infrastructure
  - Role of human and organisational factors has been limited in discussion for SMRs. Further work is needed on organisational design models, enhancements to technical competency in regulatory regimes, optimising SMRs for human interaction (design around human and organizational capabilities and limitations).
    - With reduced staffing levels and advanced automation, integrating Human and Organisational Factors in SMRs design and whole lifecycle is becoming increasingly critical.
- Preliminary roadmap has been created addressing societal engagement issues.

COMING UP in 1/2026: A compact SMR guide for cities / municipalities "*Pikkuopas kaupungeille*", covering land-use planning, licensing, stakeholder and public engagement, waste-management etc.


LUT
University
LAND
OF THE
CURIOUS

LUT work on residents' opinions on SMR waste management and disposal

- *Kojo, M., et al. (2024) Residents' opinions on the options for managing nuclear waste from SMRs. The case of four largest cities in Finland. International Conference on the Management of Spent Fuel from Power Reactors. IAEA. Conference Proceedings. Paper No 79. 10-14 June 2024. Vienna, Austria. (accepted, presented in June 2024, forthcoming in 2025)*
- In Finland, a number of cities, including notably those in the Helsinki metropolitan area, have proposed small modular nuclear reactors (SMRs) as a means of decarbonizing district heating. The current plans are mainly based on light-water reactor technology. Other designs are considered for industrial use.
- Among the many issues to be addressed before SMRs can become a reality is the management of spent nuclear fuel (SNF).
- The paper explores the opinions of residents in the Helsinki metropolitan area on selected nuclear waste management options.
- These include disposal in a centralized national nuclear waste repository, SNF disposal in the municipality hosting an SMR, and exporting the SNF abroad.

Research questions

- Our research questions are:
- (1) What are residents' opinions on the safety of final disposal of SNF from SMRs?
- (2) How do safety opinions differ by background variables (gender, age, and political party affiliation)?
- (3) What are residents' opinions on the options for managing waste from SMRs and how do they differ by gender?
- (4) How do residents' transportation risk perceptions differ by gender?
- (5) How does trust in actors differ by gender? Opinions were asked about the following NWM options:
  - a) disposal in a centralized national nuclear waste repository,
  - b) disposal in the municipality hosting an SMR, and
  - c) exporting the SNF abroad.

Resident survey

- A resident survey was conducted to find out respondents' attitudes towards the introduction of small nuclear power plants in Finland and in their own municipality. In addition, the **questionnaire** covered various topics related to small nuclear power, including those concerning the management of the SNF from possible small reactors.
- The survey was answered by 2104 Finnish-speaking residents aged 18-75 in **Helsinki, Espoo, Vantaa, and Tampere**.
- Of the respondents, 46.9% were male and 51.4% female, 1% were of other genders and 1.1% did not wish to indicate their gender.
- The data was collected as a web-based survey for Innolink's consumer panel between November and December 2022, with a margin of error of 2.1%.

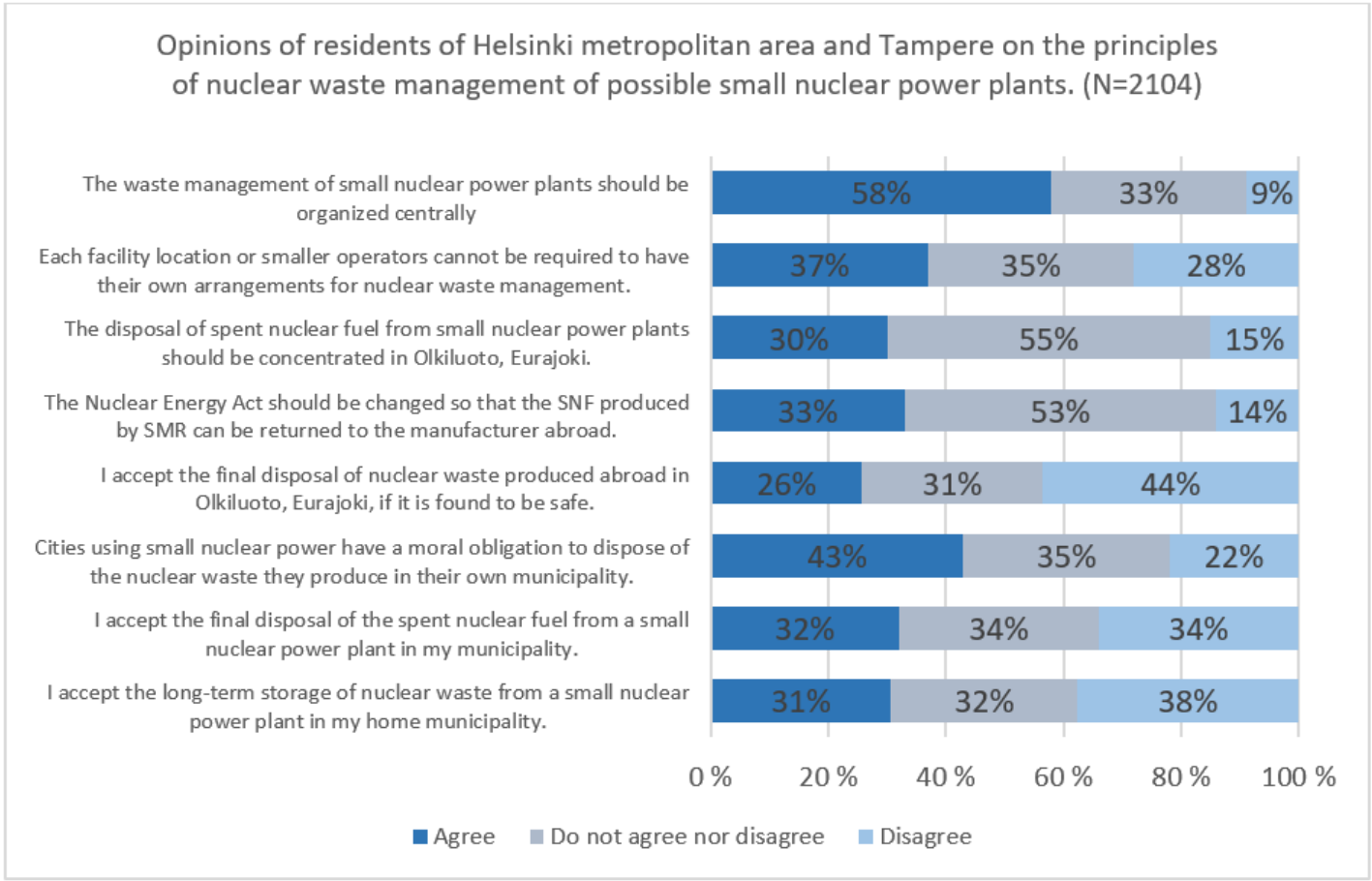


FIG. 2. Opinions of residents of the Helsinki metropolitan area and Tampere on the principles of nuclear waste management of possible small nuclear power plants (N=2104).

Conclusions (1)

- The key research question posed in this article was how residents in the largest Finnish cities perceive the NWM options for SMRs.
- The results of the public opinion survey reveal a mixed picture on the question of NWM principles. On the one hand, **most respondents (58%) were in favor of a centralized solution.** On the other hand, especially women emphasize the moral obligation of the host municipality of an SMR to dispose of nuclear waste on its own territory (43% of all respondents agree, 49% of women).
- The debate is further complicated by the fact that only 32% of respondents would agree with SNF disposal in their own municipality and 34% supported the idea of returning nuclear waste to a foreign manufacturer.
- It is also noteworthy that the proportion of respondents who were unable or unwilling to give their opinion was at least 25% for all statements examined.

Conclusions (2)

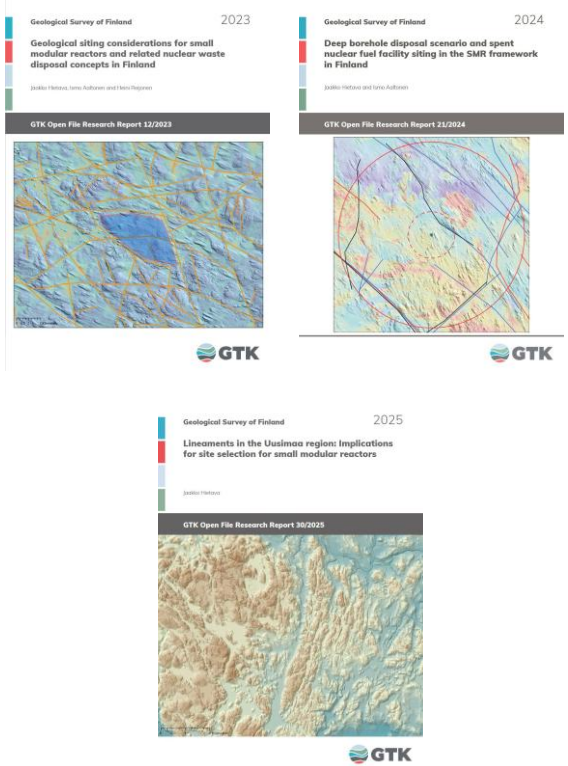
- This suggests that the majority among the general public still has only a vague idea of SMRs and, by implication, of the associated NWM options.
- Our findings lead us to assert that it is imperative to initiate public discussion on the ethical principles underpinning the NWM of the possible SMRs, notably on aspects related to distributive, procedural, and recognition justice [17].
- The key actors (potential licensees, authorities, politicians, and experts) should actively stimulate such debates on the ethical principles, and also be more explicit about the options regarding the methodologies and locations envisaged for NWM.

SMRSiMa Project, Geological survey of Finland, GTK

Jaakko Hietava, Geologist

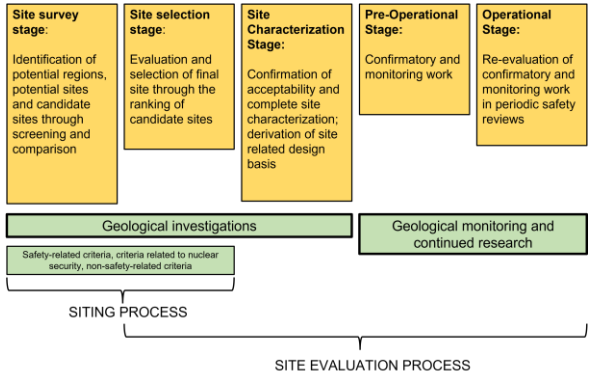
SMRSiMa project description for GTK

- **Geological site investigations are an integral part of nuclear safety**, and as such are required by current legislation and regulation in nuclear facilities
- Site investigation processes related to geology were reviewed and applied in the SMR context using current regulation perspectives and research on SMRs on nuclear facility siting
- GTK produced three research reports during the project:
  - **Geological siting considerations** for small modular reactors and related nuclear waste disposal concepts in Finland
  - **Deep borehole disposal** scenario and spent nuclear fuel facility siting in the SMR framework in Finland
  - **Lineaments in the Uusimaa region**: Implications for site selection for small modular reactors
- The goal of these reports is to provide information on the geological site investigation requirements in nuclear facility siting regarding reactor site selection and SMR related nuclear waste disposal in different scenarios

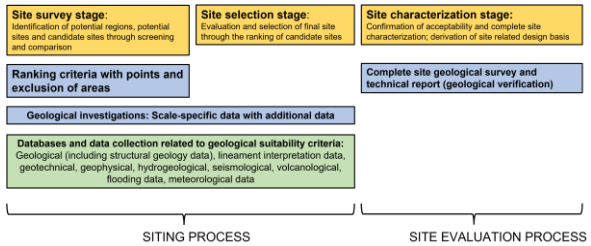


Geological investigations for nuclear facilities

- Geological site investigations in SMR production facilities can be done in several stages or **phases: Site survey, site selection and site characterization stages**
  - Geological monitoring during pre-operational and operational stages
- Different criteria related to safety and non-safety related criteria
- Geological investigations can be related but not limited to: geology, structural geology, geotechnical, hydrogeological, geophysical and seismic data collection
- Differences in underground construction and surface construction
- **The function of geological site investigations is to ensure the suitability and safety of the site for nuclear power generation purposes**
- SMR developers are responsible for site suitability, not all sites are geologically suitable due to various conditions with different lithologies
  - A staged siting process would ensure the viability and suitability of a nuclear facility site



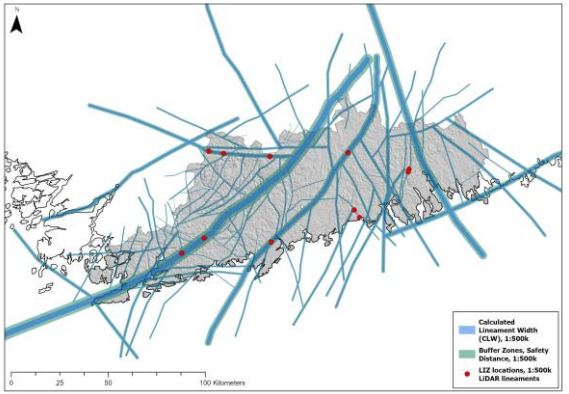
The siting process and site evaluation process for a nuclear power plan regarding geological investigations, modified from SSG-35, IAEA 2015.



Process flow chart for geological data collection in the siting process for a nuclear power plant, modified from SSG-35, IAEA 2015.

Project summary and conclusions

- IAEA report Safety Report Series No. 123 (2023) states that the scope of SSG-35 **is not limited to any particular reactor technology or type of nuclear installation**
  - Requirements for SMRs could be similar to conventional NPPs
- **SMR developers and vendors need to work with regulators and research organizations to scale geological investigations adequately in selected sites for selected purposes**
  - I.e., site area footprint for a 50 MW thermal reactor would be different than a 300 MW
- Nuclear waste management with interim disposal facilities and final disposal facilities must be included in the overall SMR theme from the start
  - Geological investigations for nuclear waste can be far more complex than reactor site selection due to safety case considerations and long-term requirements for the facility



Example of lineament interpretation and lineament width estimations related to site survey stage investigations with structural geology elements in the Uusimaa Region, modified from Hietava, 2025.

Block-in-block principle used in nuclear waste final disposal facility site selection, modified from Hietava, 2025.

Thank you and see you again soon 19.11.2025 in SMRSiMa seminar!

- Scan the QR-code for a registration link!

Project is planned to continue in SAFER2028 with a new name CHARMAS.

SMR waste characterisation, waste management, society and siting