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## Summary of the Zoning Workshop of the NORDIC-SMART project: Goals

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#### **Outline**

- Why the focus on SMR's?!
- Probabilistic seismic hazard analysis (PSHA)
- Quick inventory of the key model inputs:
  - Seismic sources, Seismic source characteristics: Gutenberg-Richter parameters, Ground motion prediction equation, GMPE
- Model logic-tree and uncertainties.
- Goals of the harmonization project.

#### Why the focus on SMR's?!

- SMR have reduced complexity (e.g. they are only for heat not electricity etc.).
- Risks are therefore also scaled down.
- To facilitate SMR projects, it would be advantageous if elements of siting and/or earthquake hazard estimation could be expedited.
- This is not entirely possible, but in some elements it cam be done.

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#### **Seismic hazard estimation**

- Seismic hazard models forecast future hazard, important for long-term safety planning. Main method is Probabilistic Seismic Hazard Analysis (PSHA).
- PSHA aggregates effects of all earthquake scenarios; attempts to capture all uncertainties (i.e. aleatory variability and epistemic uncertainty).
- Result is the yearly probability of exceedance of e.g. a certain acceleration (PGA). This is used in the probabilistic risk assessment (PRA) of the NPP.
- PSHA inputs are: (a) seismic sources (SSZ's), (b) their characteristics depth, activity rates, maximum magnitude, (c) propagation of ground motion from the source (i.e. GMPE);

#### Something is known from earlier work...



Reproduction of Fig. 4-39 from Technical Report 37 of the Nuclear Radiation and Nuclear Safety Authority of Finland (STUK): https://www.julkari.fi/bitstream/handle/10024/146833/stuk-tr37.pdf?sequence=1&isAllowed=y Burck et al. (2023).

## Seismic sources (SSZs)

- SSZs are seismogenic structures representing sites of future earthquakes in the model;
- Areal SSZs are proxies to accommodate unidentified seismogenic structures; not physical characteristics of the earth's crust, but calculation artifice.
- Usually assumed that SSZ's are homogenous source of earthquakes; equal probability of earthquakes to occur at any location within the SSA.

E.g. of areal seismic zones used in Finnish NPP models (https://link.springer.com/article/10.1007/s11069-022-05666-4)





## **Characterization of SSZs (1)**

• Gutenberg-Richter relationship:

 $log_{10}(\lambda_m) = a_{GR} - b_{GR} \cdot m$ 

- An m<sub>comp</sub>, related to detectability, and an M<sub>max</sub> to limits of energy release.
- <M<sub>min</sub> earthquakes are irrelevant for the risk; depends on the intended use of the hazard calculated. NPP's have M<sub>min</sub>=M<sub>w</sub>4..5, which means that one postulates that <4-5 cannot harm them.</p>





#### **Characterization of SSZs (2)**

- Is it an earthquake or something else... mining, icequake, explosion.
- What measure of magnitude? What is the M uncertainty?
- Completeness is from what year all EQs>M<sub>w</sub> are in the catalogue
- High level of epistemic uncertainty in each characterization step.





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## **Characterization of SSZs (3)**



## **Ground motion prediction**

- GMPEs have a median prediction for M<sub>min</sub> < M<sub>w</sub> < M<sub>max</sub>, distance 0<R<sub>rup</sub> < 300...500km.</li>
- A median prediction uncertainty, an epistemic uncertainty (or use multiple GMPE's).
- An estimate of the variability or σ. If modeling GM using M and R<sub>rup</sub> there is an unaccounted variability in observed GMs.



#### "Collectors" of the epistemic uncertainty



## **Results of different model options**



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#### **Project goals & structure**

- The main goal is to harmonize data items and methods in PSHA procedures in Nordic Countries; but NOT to equalize, since preserving epistemic uncertainty is crucial.
  - Task 1: Developing a harmonized seismic source zoning (SSZs) across northern Europe and creating a joint, homogenized, Nordic earthquake catalogue. (2024)
  - Task 2: Procedure harmonization for GR activity rate estimation of SSZs in the Nordic countries. (2024)
  - Task 3: Provide a set of harmonized hazard model inputs for GR parameters for SSZs in the Nordic countries. (2025)
  - Task 4: Integrated Nordic PSHA hazard model developed for the probabilities (frequencies of 10<sup>-4</sup>...10<sup>-7</sup>/year) relevant to nuclear facilities (2025).



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