Addressing off-site criteria using Level 3 PSA

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Lloyd's Register Consulting

Working together for a safer world

Project funding and organisation

- Funding of the project is provided by:
  - Nordic PSA Group (NPSAG, www.npsag.org)
    - Stakeholders: Forsmark NPP, Ringhals NPP, Oskarshamn NPP, and Swedish Radiation Safety Authority
  - Nordic nuclear safety research (NKS, www.nks.org)
  - Finnish Research Programme on Nuclear Power Plant Safety (SAFIR, http://safir2014.vtt.fi)
    - Stakeholders: TVO, Fortum, Fennovoima, and STUK

Project funding and organisation (continued)

- Project working group consists of:
  - Lloyd's Register Consulting
  - RiskPilot
  - VTT
  - ÅF
  - Vattenfall

Organisation	Funded by
Lloyd's Register Consulting	
Risk Pilot	NPSAG & NKS
ÅF	
Vattenfall	NKS & Internal
VTT	SAFIR & NKS

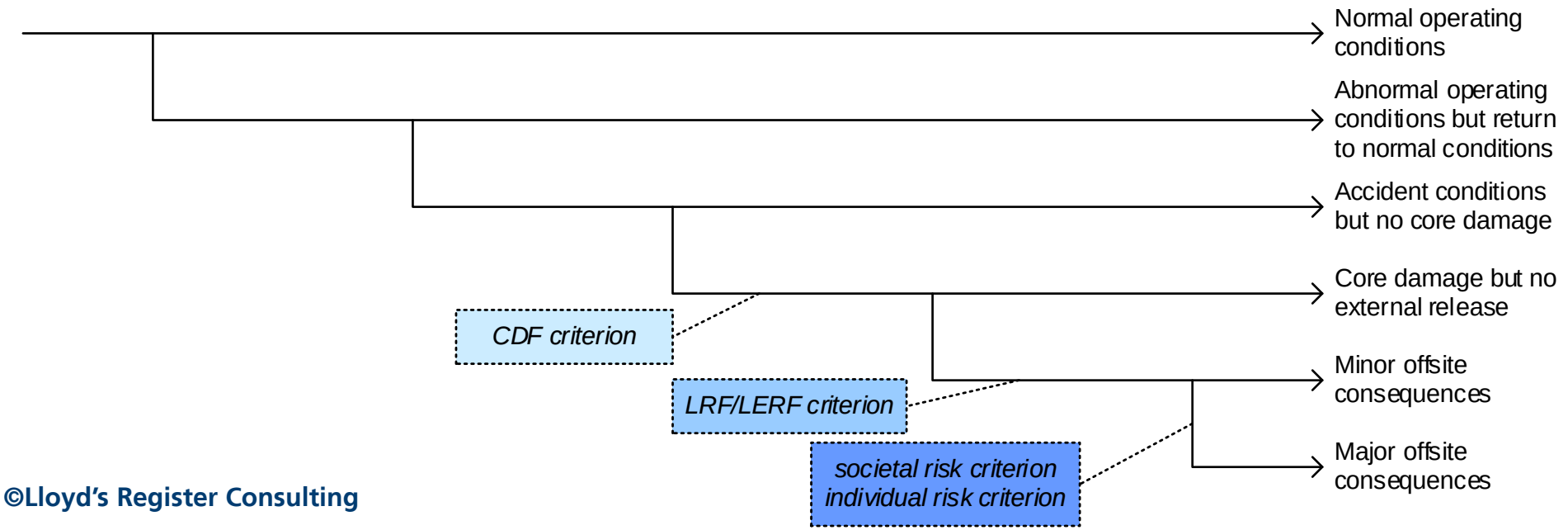
Agenda

- The “levels” of PSA
- Project background
- What is Level 3 PSA
- Why Level 3 PSA / Why not Level 3 PSA?
- Guidance document
- Concluding remarks

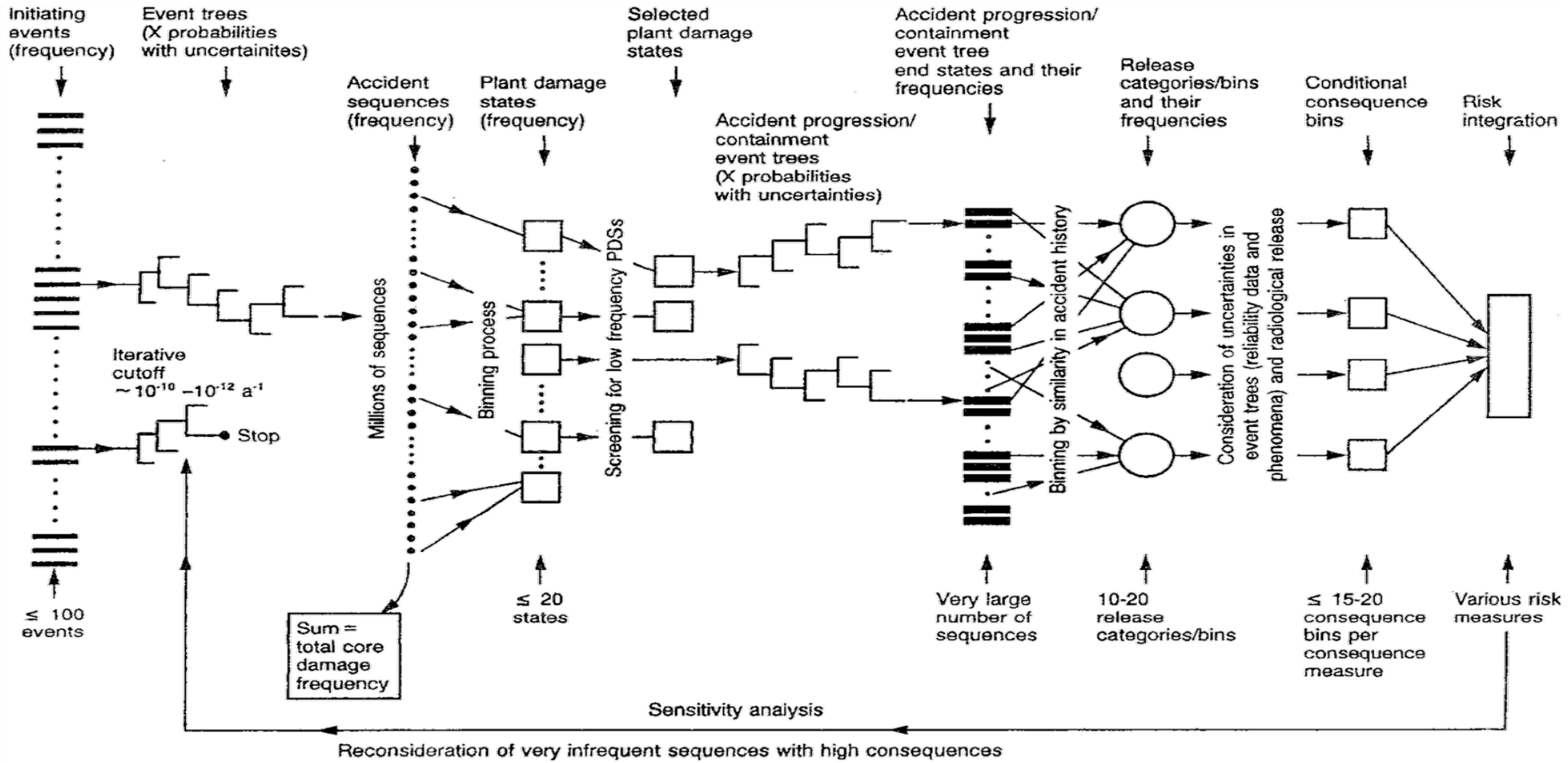
“Levels” of PSA

Defense-in-depth and PSA

Initiating event Level 1 PSA		Safety functions Level 1 PSA	Safety functions Level 2 PSA	Consequence Level 3 PSA	
DID level 1 Prevention of abnormal operation and failures	DID level 2 Control of abnormal operation and detection of failures	DID level 3 Control of accidents within the design basis	DID level 4 Severe accident management	DID level 5 Mitigation of the radiological consequences	Consequence

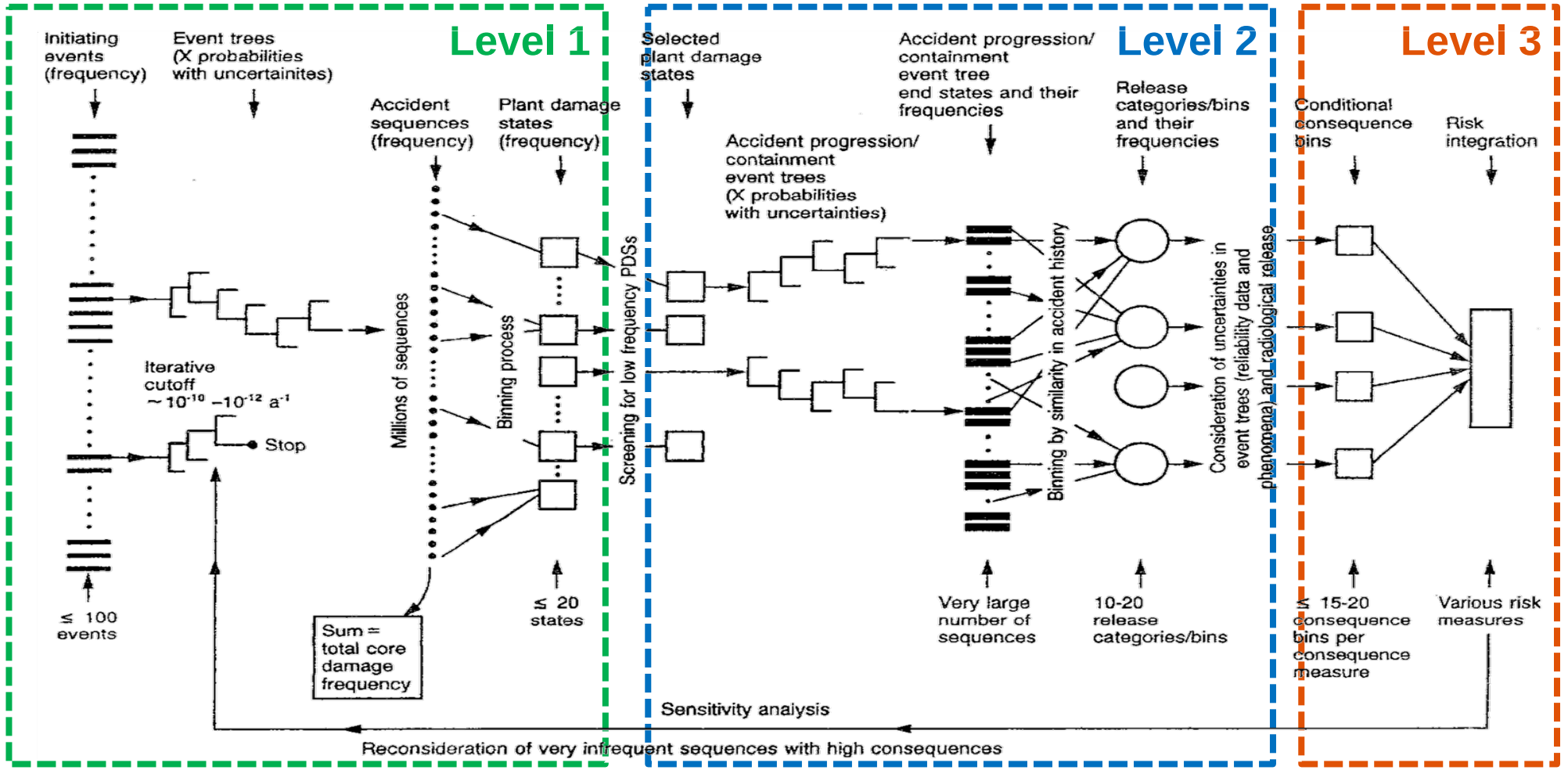


PSA overview



Ref. IAEA Safety Series N. 50-P-8

PSA overview – the "levels" of PSA



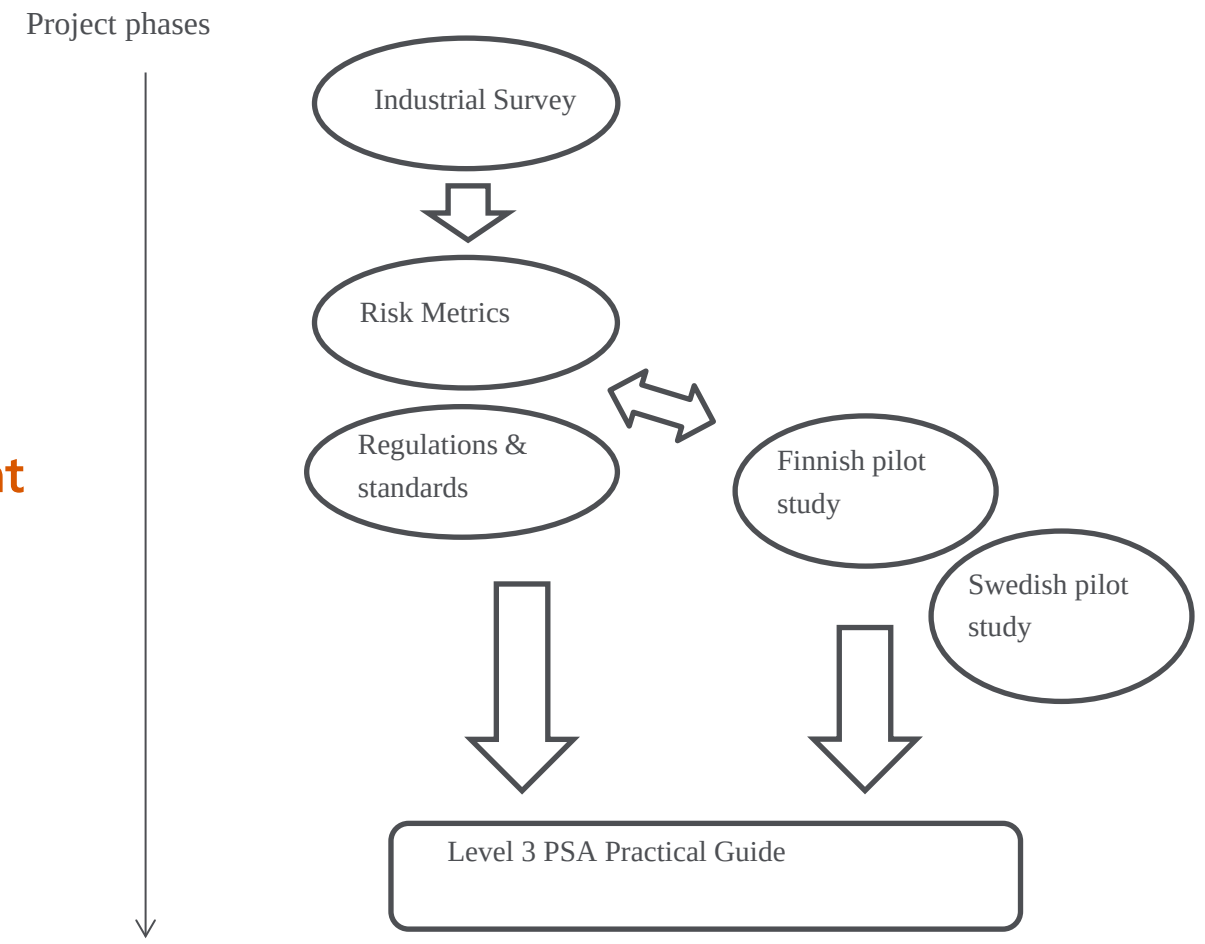
The Level 3 PSA project

Project background & objectives

- A need to explore the potential use Level 3 PSA has been identified in response to:
  - Fukushima disaster
  - International standard/guideline development
  - New builds in region
  - Development of new/updated regulation
- The project is defined as an enhanced scoping study with objective to explore questions such as:
  - What are the needs for Level 3 PSA?
  - For whom would a Level 3 PSA be beneficial?
  - What kind of results should then be used?
  - What is happening internationally with respect to Level 3 PSA guideline & standards?

Project organization

- The project is a 3 year R&D project
  - Industrial survey
  - Risk metrics study
  - Regulations guides and standards
  - Finnish and Swedish pilot studies
- The ultimate objective of the project is to develop a Nordic **guidance document** on how to perform a Level 3 PSA.



What is Level 3 PSA

Early part of the project focused around defining what is Level 3 PSA

- Level 3 PSA is a probabilistic offsite consequence assessment
  - Probabilities can be attributed to many different things
    - Weather
    - Source terms
    - Countermeasures
  - Important consequences/ considerations depend on stakeholder
- Level 3 PSA usually quantified by quantification of atmospheric spreading of a release source term
- Risk metrics study identified three primary categories of Level 3 PSA risk metrics:
  - Health effects
  - Environmental effects
  - Economic effects

Why/ why not Level 3 PSA

Why

- Direct assessment of health and safety risks, where Level 1 and 2 PSA criteria are surrogates
- Direct assessment of socio- economic risks
- Siting for new reactors
  - Compliment to traditional site evaluation
- Emergency planning
  - Countermeasures
  - Emergency Planning Zones (EPZ)

Why not

- Propagation of uncertainties
- Surrogate Level 1 and Level 2 PSA metrics likely to be more limiting
- Design improvements typically have indirect impact on Level 3 PSA, opposed to direct as in Level 1 and Level 2 PSA
- Level 3 PSA connected to site assessment/evaluation (siting for new reactors)
  - Operating sites already chosen

Results of case studies

Finnish pilot study

- Scope:
  - Atmospheric release from Fukushima accident w/o tsunami.
  - Weather conditions typical of Japan
- Conclusions
  - No early deaths
  - 16 expected cancers deaths
  - Evacuation has significant impact

Swedish pilot study

- Scope:
  - Atmospheric release below, near, and above Level 2 PSA regulatory limits.
  - UK EPR source terms.
  - Generic Nordic plant site
- Conclusions
  - Extremely low risk of early deaths, even with very pessimistic assumptions
  - “Manual analysis” provided significant insight into underlying methods

Need for Nordic guidance

- Little existing guidance on Level 3 PSA
  - IAEA Safety Series guide on Level 3 PSA (1996)
  - Large US studies (WASH-1400, NUREG-1150, SOARCA)
  - Countries that require Level 3 PSA are usually confidential
- Little Nordic experience prior to Level 3 PSA project
- Ongoing international work
  - IAEA – TECDOC draft developed through (1 Technical Meeting, 3 Consultant Meetings)
  - ANS/ASME – Level 3 PSA standard in nearing draft completion

Little current guidance, on-going international activities moving ahead slowly

Level 3 PSA guidance document

- Focus on Nordic Nuclear Safety
  - Guidance framed based on Level 2 PSA requirements as applied in Sweden and Finland
  - Nordic weather / topographical considerations
- Difference between this guidance and IAEA, ANS/ASME
  - Application specific considerations
  - Specific lessons from pilot projects
- Draft guidance document out for stakeholder comment
  - Chapter 1 - introductory discussion on the purpose and need for Guidance
  - Chapter 2 - outlook on the regulatory framework, guides and standards
  - Chapter 3 - challenges, limitations and benefits with performing Level 3 PSA.
  - Chapter 4 - describes the main elements for a Level 3 PSA.
  - Chapter 5 – conclusions (to be completed after January seminar)

Closing remarks

- Level 3 PSA is a probabilistic offsite consequence assessment
- Project insights
  - Varied interests and opinions on Level 3 PSA
  - Modest amount of international work ongoing
  - Need for Nordic guidance
- Finnish pilot project and Swedish pilot project provide two unique perspectives in the development of the guidance document
- Final project seminar 28 January 2016
  - Presentation of pilot studies
  - Guidance document to be presented
  - Conclusions to be included in final guidance

Where do we go from here…

- 1-day project seminar January 28th, 2016
- Guidance document completion
- Completion of international activities
- Review of US NRC study
- Development of new regulations in Sweden
  - Possibly include Level 3 PSA
- Interfacing hot-issues
  - Multi-unit PSA
  - External events
- **Continued collaboration between PSA & Radiological experts!**

1-day project seminar January 28 2016!!

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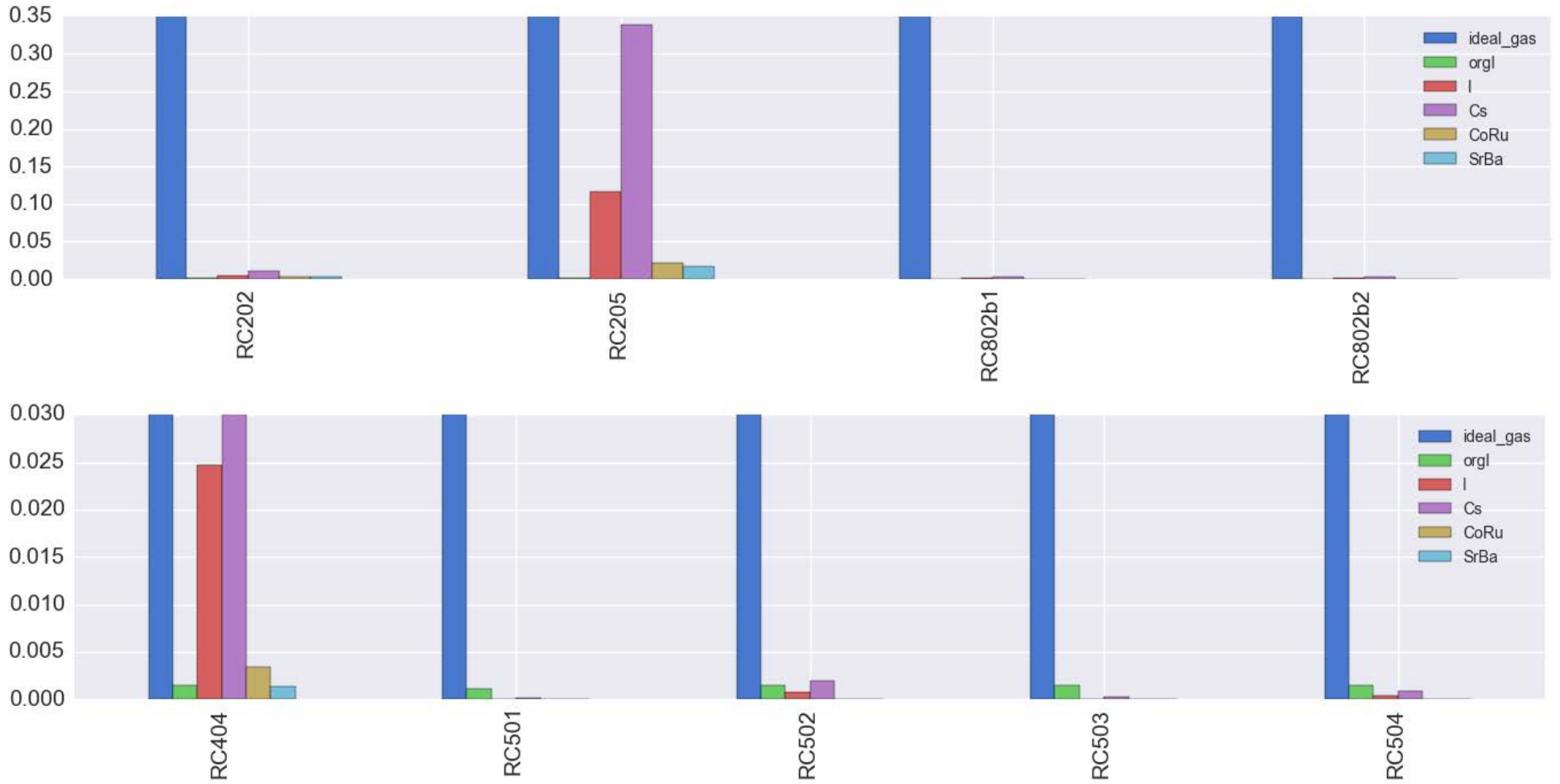
Swedish pilot – scope of analysis

Cs Release Fraction/ Release Timing	<0.04%	≈0.04%	>0.04%	>>0.04%
Early (release starts < 10 hr post-CD)	No relevant case found	No relevant case found	RC 802b (Small, 9.17E-4)††	RC 202 (3.99E-3) RC 205 (1.16E-1)
Late (release starts > 10 hr post-CD)	RC 501 (5.72E-5) RC 503 (1.08E-4)	RC 504 (4.08E-4)	RC 502 (7.72E-4)	RC 404† (2.47E-2)

†: Release starts at 7.8 hr, however, since the release is of long duration it is judged adequately represented as a late release.
††: The maximum of the CsI and CsOH MAAP isotopic group release fractions is listed.

Source term releases

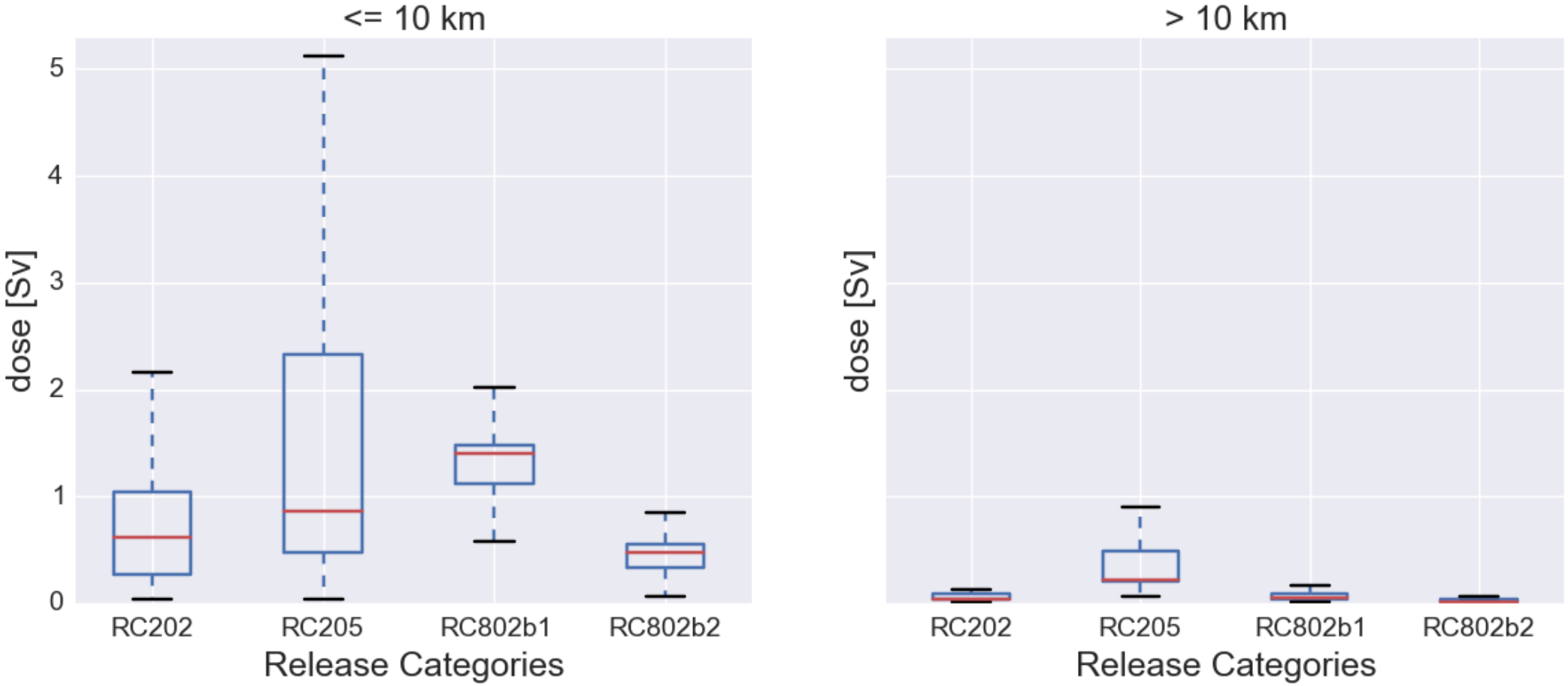


Swedish pilot – scope of analysis

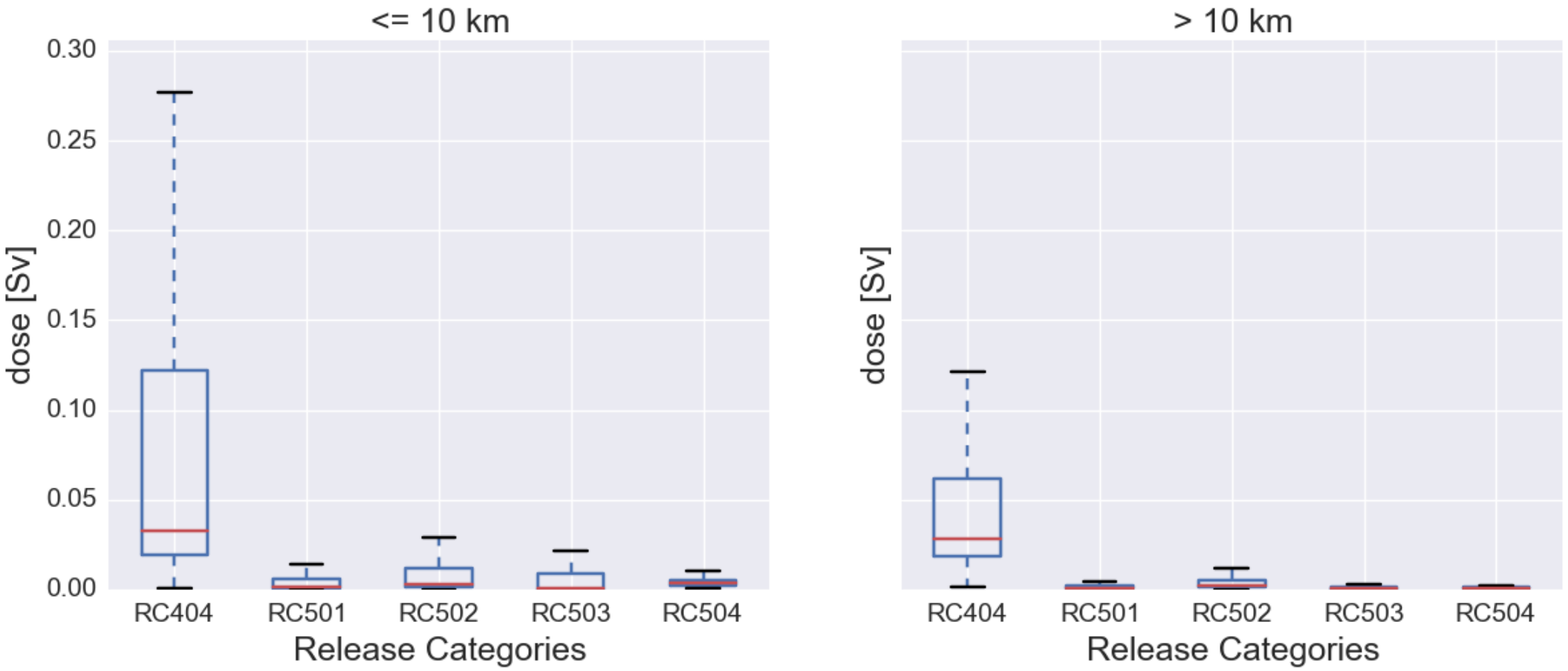
	Metrics	Health				Environment	Economic
Analysis Characteristics	Risk Measure/ Assumption	Maximum individual dose at 1 km (early effects)	Risk of (early) death to max-imum exposed individual	Collective Dose (late effects)	Number of Latent Cancers (late effects)	Size of land area with significant Cs contami-nation	Estimate of value of lost land due to Cs contamination
Analysis Area	Up to 50 km	X	X	X	X	X	X
	Up to 100 km	-	-	X	X	X	X
Countermeasures	5 km eva-cuation zone	X	X	-	-	-	-
Cs‡ ground con-tamination thres-hold	1000† kBq/m^2	-	-	-	-	X	X
	100† kBq/m^2	-	-	-	-	X	X

†: Cs ground contamination thresholds may need some iteration once radioactivity contour maps have been produced.
‡: Combined activity of ^{134}Cs and ^{137}Cs.

Maximum total individual dose @ 2 days (early releases)



Maximum total individual dose @ 2 days (late releases)



Contamination and population distribution
RC 205