



Nuclear Power Plant Gösgen

05/04/2019

@NPP Gösgen LTD & SST SwissSafeTech LTD; Full-Scope PSA Level 3 of NPP Gösgen



Needs for Review of Off-site Emergency Planning

- Chernobyl & Fukushima accident consequences
- Public sensibility and perception
- Authorities continuous demanding for the highest safety standards
- Utilities Social Responsibility



Needs for Review of Off-site Emergency Planning

March 06, 2012 09:30; 20 Minuten

Public sensibility and
perception



Full-Scope PSA Level 3 Of NPP Gösgen

Methods and Results



Kernkraftwerk Gösgen Däniken AG

SST+ **SwissSafeTech AG**

Däniken
April 05, 2019



Full-Scope PSA Level 3 Of NPP Gösgen

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Nuclear Power Plant Gösgen-Däniken LTD



- Built in 1979, Switzerland
- 1035 MW PWR
- **3 Loops**, KWU Design
- **Emergency Systems:** HPIS (4 pumps), 6 Accumulators, LPIS (4 pumps), EFWS (4 pumps), 4 Diesel Generators
- **Special Emergency Systems:** SEFW (2 pumps), SECC (2 pumps), 2 Diesel Generators
- **Containment:** Double (Steel & Concrete), UPES, CFVS

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KKG PSA Level 1 and Level 2



- All modes and all events integrated Level 1 - Level 2 PSA model.
- RISKMAN software is used for quantification.
- Covers all operational modes and all internal and external initiating events (including earthquakes and external floods) of any importance.
- Includes 156 initiating events for the at power model, from which 41 are seismic.
- 17 release categories, which are binned into “Super Release Categories” such as LER, LLR, and VENTF.



KKG PSA Level 3 – Model

Mapped site data

- Population
- Land use
- Agricultural data
- Meteorology

Plant data

- Layout & Geometry
- Accident Analysis
- Source terms

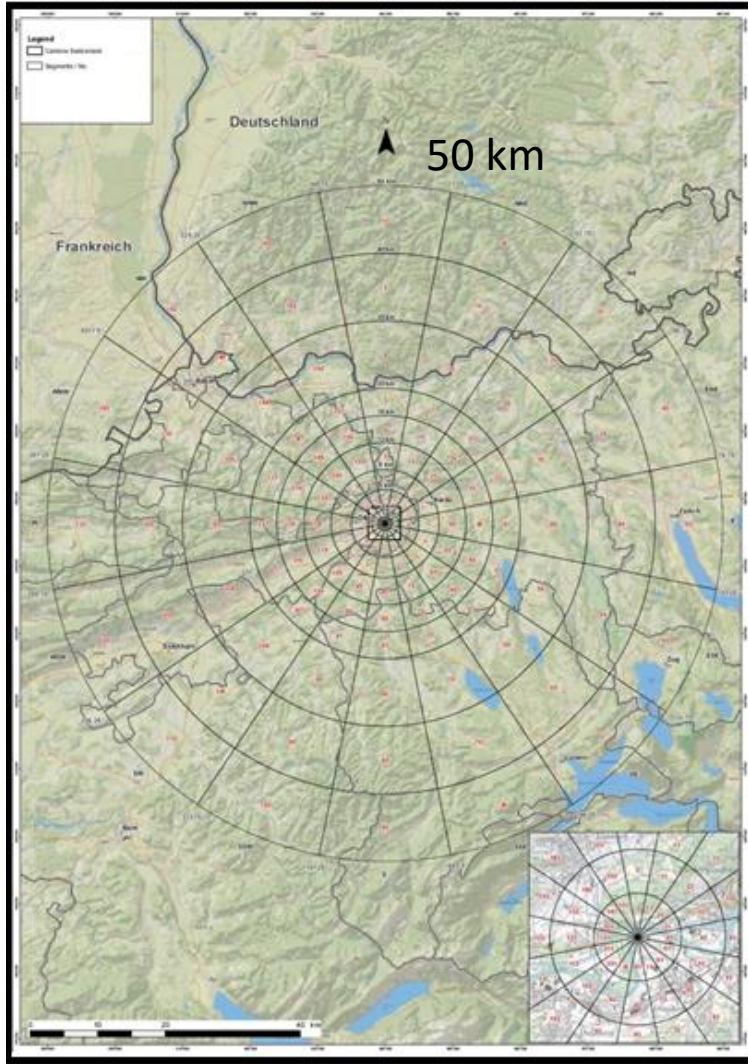
Swiss regulations

- Concept of nuclear emergency
- Emergency planning
- Countermeasures concept
- Contamination limits

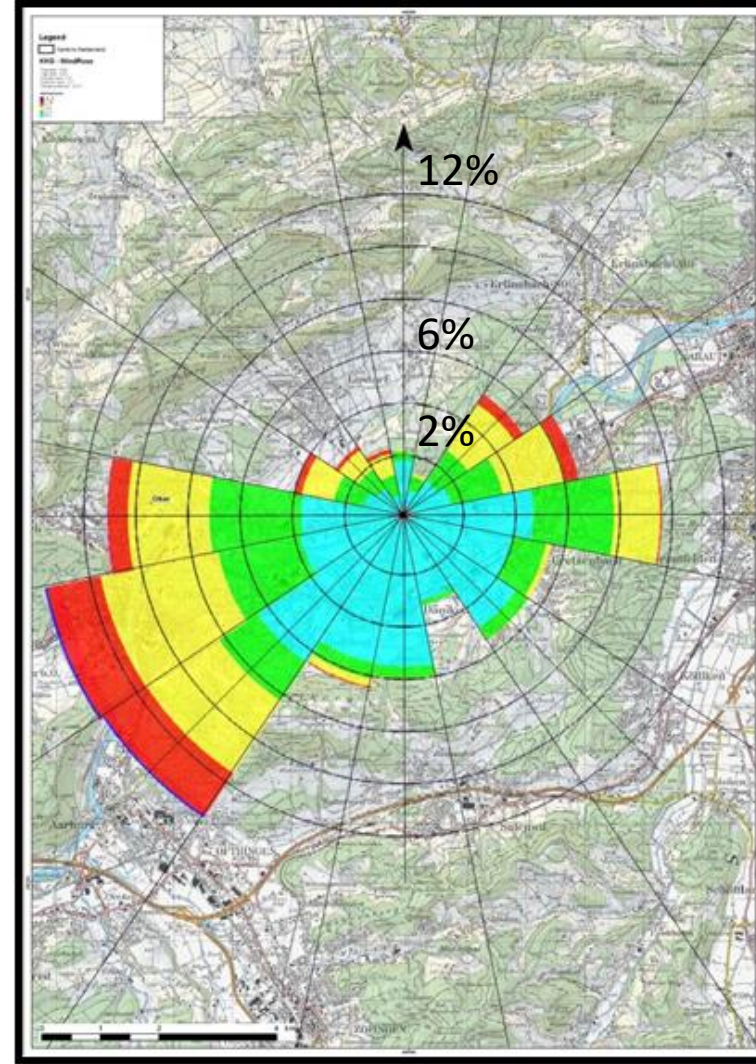


Spatial grids

- 16 compass sectors
- 10 downwind distances



Spatial Grids



Wind Rose

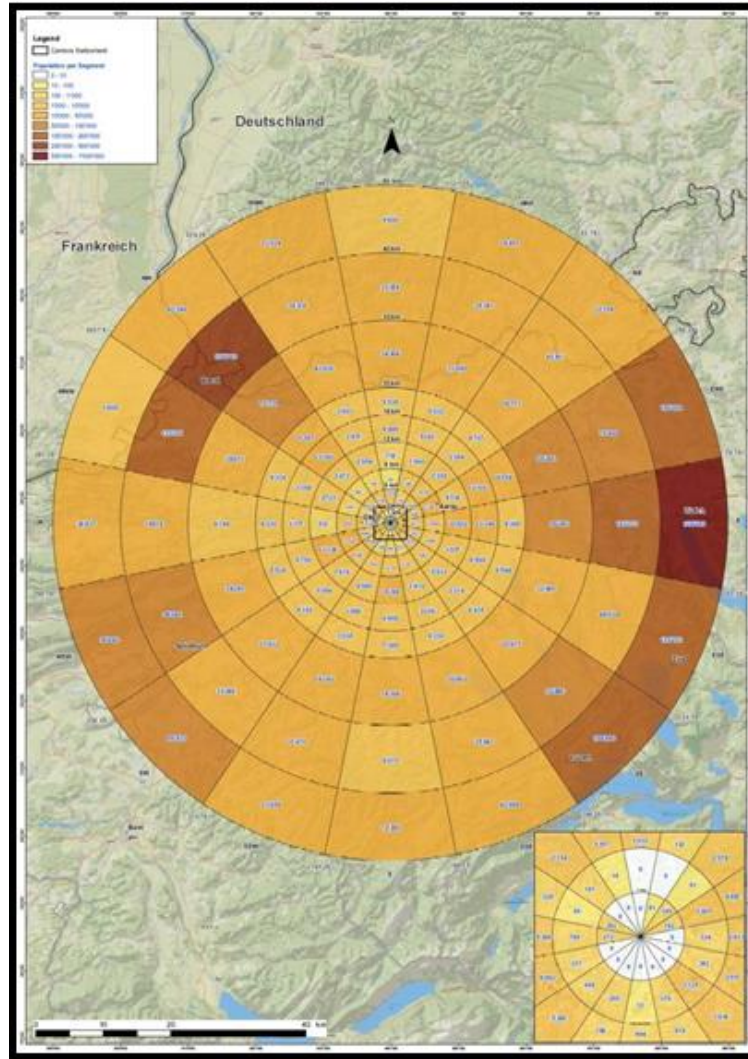
Meteorology Data

Hourly records
(8760 per year)

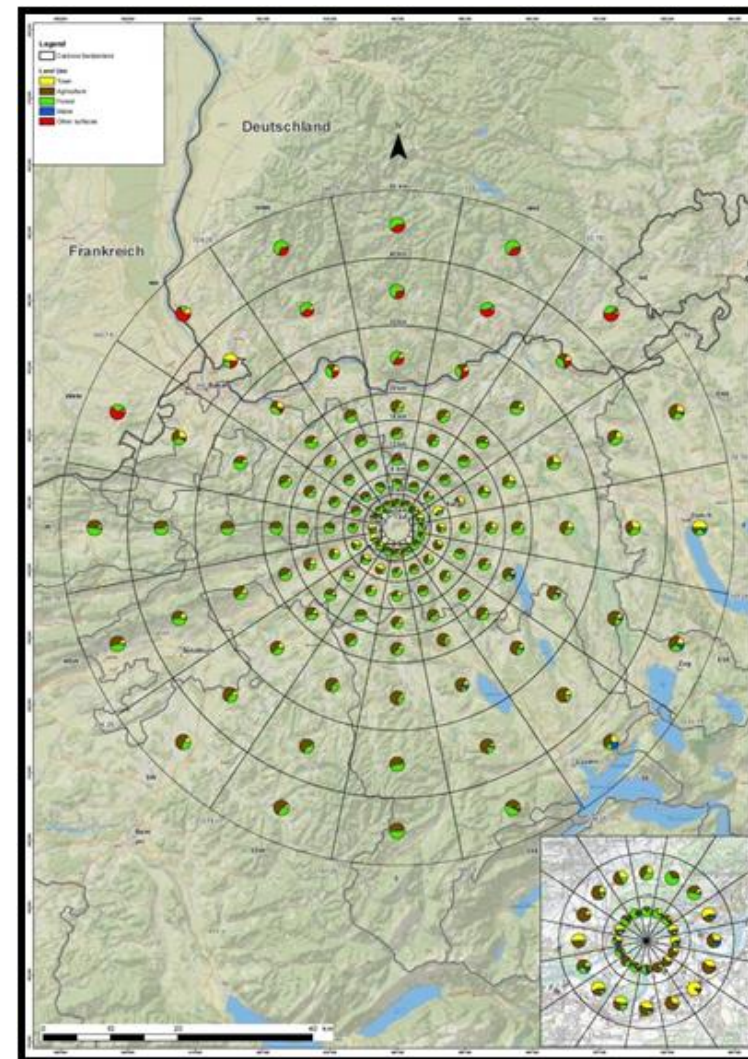
- Annual records (2011)
- 20 years period (1989 -2008)



- Population distribution
- Area weighted averaging



Population Distribution



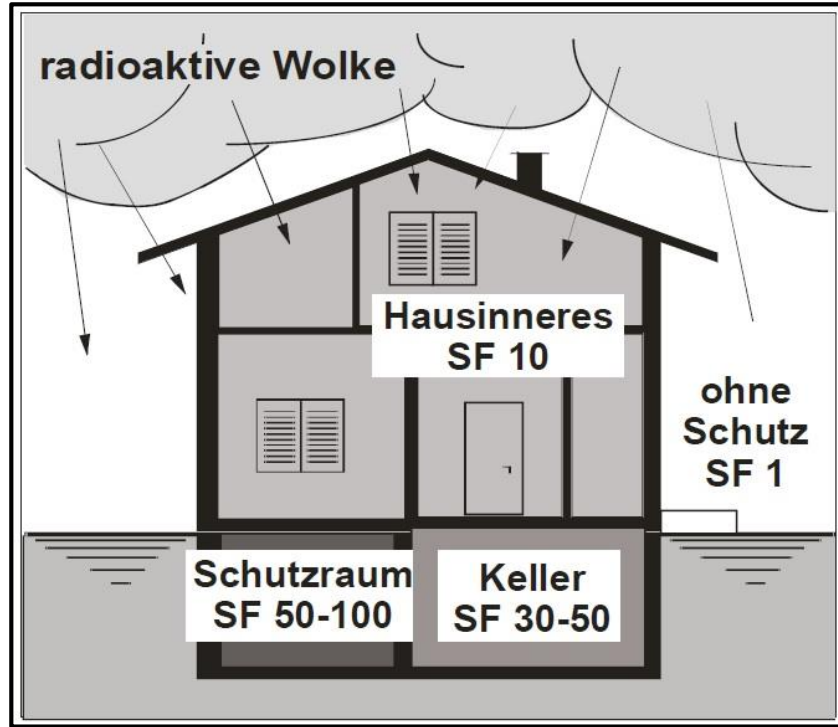
Land Use

- Land use
- Settlement area
 - Agricultural area
 - Forest area
 - Lake and rivers
 - Other (all area that cannot be classified in the above categories)

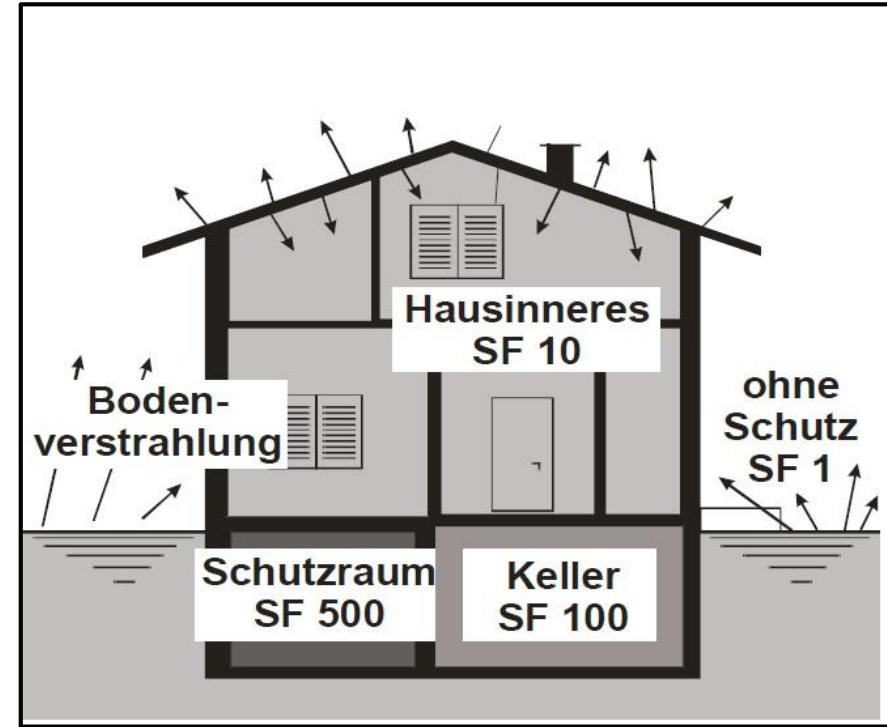


Swiss Countermeasures

Shield Protection Factors



Cloud passage phase



Ground shine phase

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KKG PSA Level 3 – Selection of Accident Scenarios



- 21 accident scenarios have been assessed to evaluate the new authority reference scenarios.
- Most cases belonged to large release categories (LER and LLR).
- All important release paths were taken into account.
- The most severe scenarios (7 out of 21) were selected for further PSA Level 3 analysis (4 base cases, with further 3 for sensitivity studies).



KKG PSA Level 3 – Selection of Accident Scenarios

Rel. Category	Initiating Events	Release Path
RCA1L	Massive Steam Generator Tube Rupture (50 x SGTR) Station Blackout+1SEFW Pump	Steam Generator Safety Relief Valve (SRV)
RCB1L	Military Aircraft Crash (MAC) and Total Station Blackout (Small break LOCA)	Containment & Reactor Building Failure
RCC1L	Total Station Blackout (TSBO) (Fast Scenario)	Under Pressure Exhaust System (UPES) Line Stuck Open
RCF2L	Total Station Blackout (TSBO) (Slow Scenario)	Containment Filtered Venting System (CFVS)



Interface Level 1 and Level 2 PSA to Level 3 PSA



- Release paths and release heights
- Alarm time
- Release time and duration
- Heat contents of plumes
- Radionuclide groups
- Core inventory
- Release fractions of radionuclide groups
- Plant layout
- Size of important building
- Release categories' frequencies



PSA Level 3 RUN03 MAC

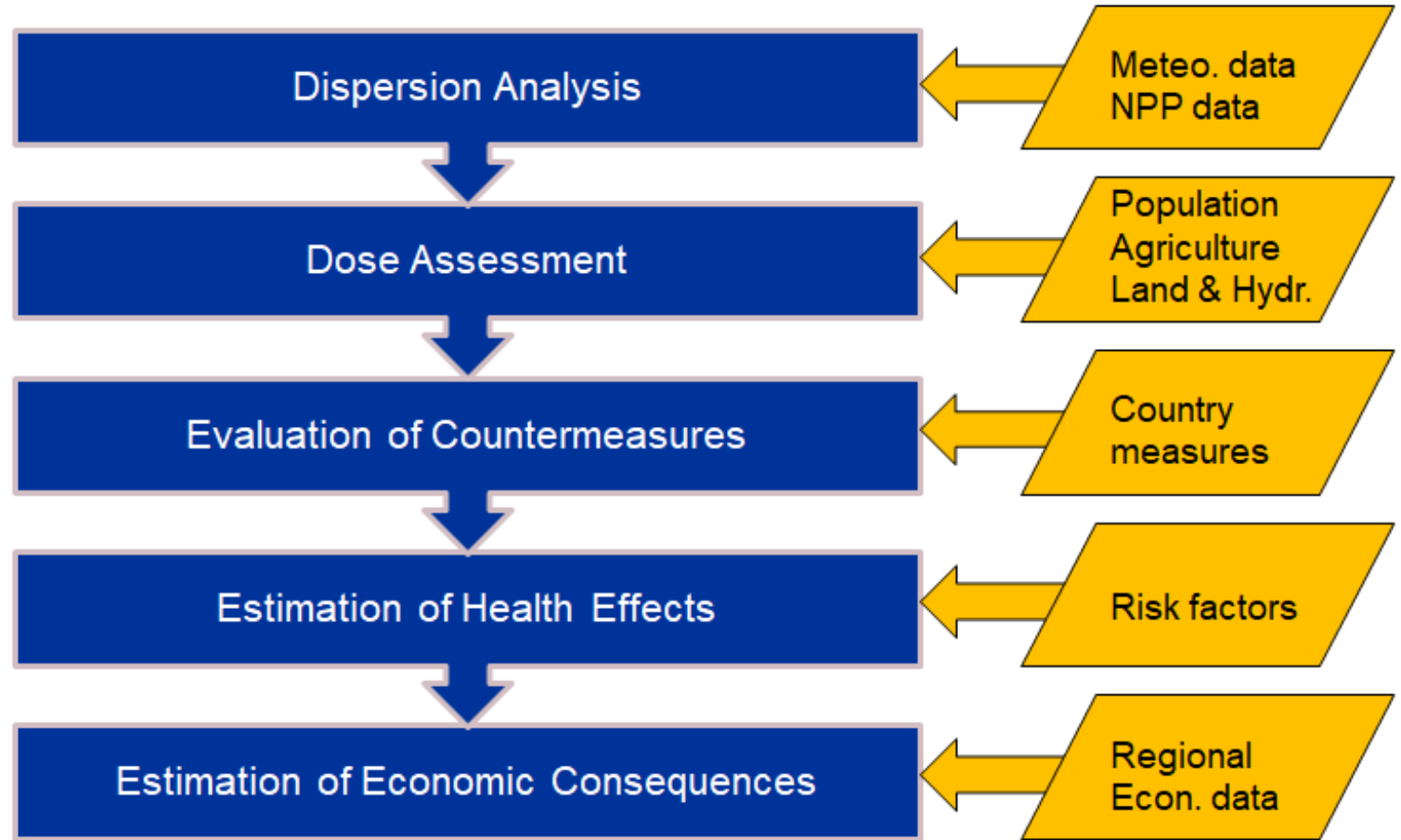




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Basic Elements of PSA L3

Basic Elements of PSA L3



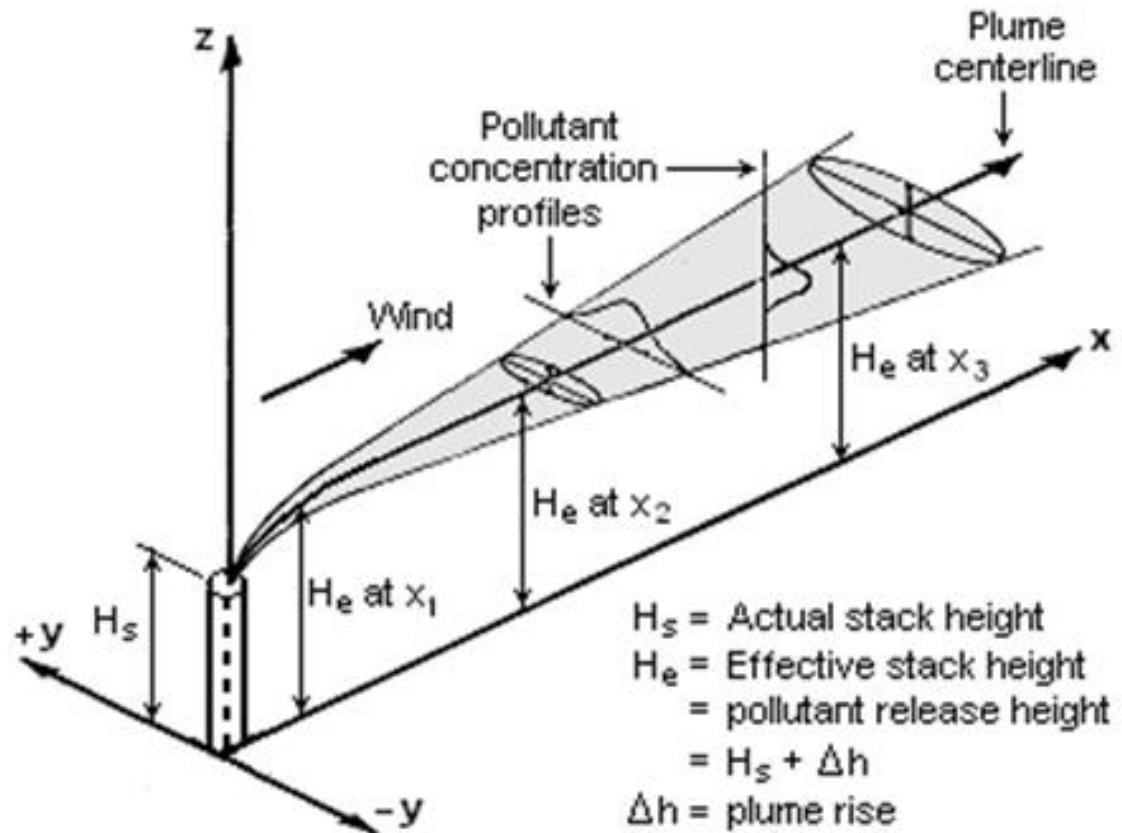


Plume Model: Gaussian Dispersion Equation

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$$\chi(x, y, z) = \frac{Q}{u} \cdot \frac{f(y^2, \sigma_y^2)}{\sigma_y \sqrt{2\pi}} \cdot \frac{g_1(z, H, \sigma_z^2) + g_2(z, H, \sigma_z^2) + g_3(z, H, \sigma_z^2)}{\sigma_z \sqrt{2\pi}}$$

Gaussian Dispersion

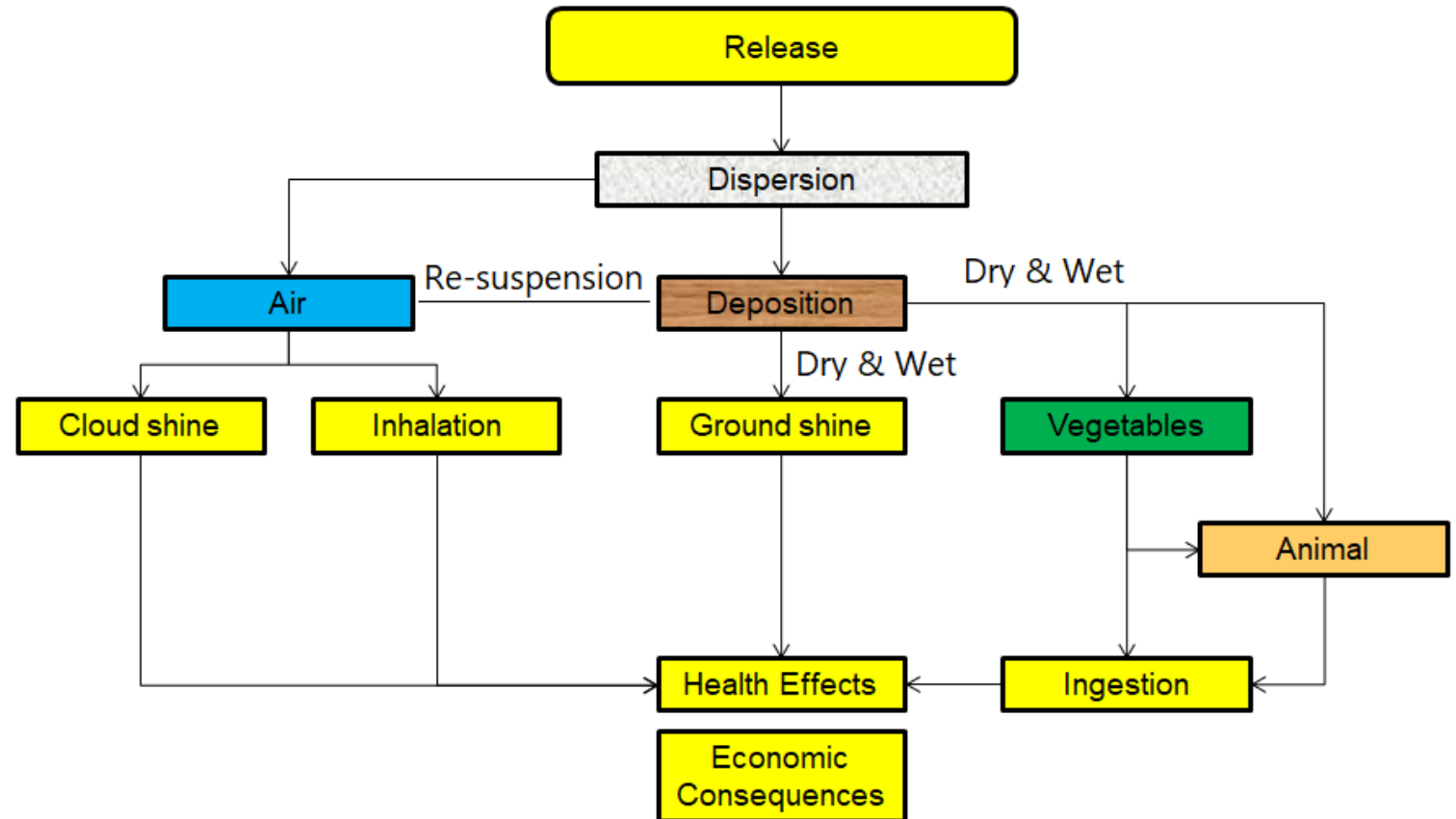




Atmospheric Exposure Pathways

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Atmospheric Exposure
Pathways



Full-Scope PSA Level 3 Of NPP Gösgen

Full scope PSA Level 1, Level
2, and Level 3 - coupled
results



Full scope PSA Level 1, Level 2, and Level 3 - coupled results

The main outcomes of PSA Level 3 are **integrated risk results**.

An integrated risk result is **a frequency with which a consequence of a particular magnitude will be exceeded**. A consequence could be:

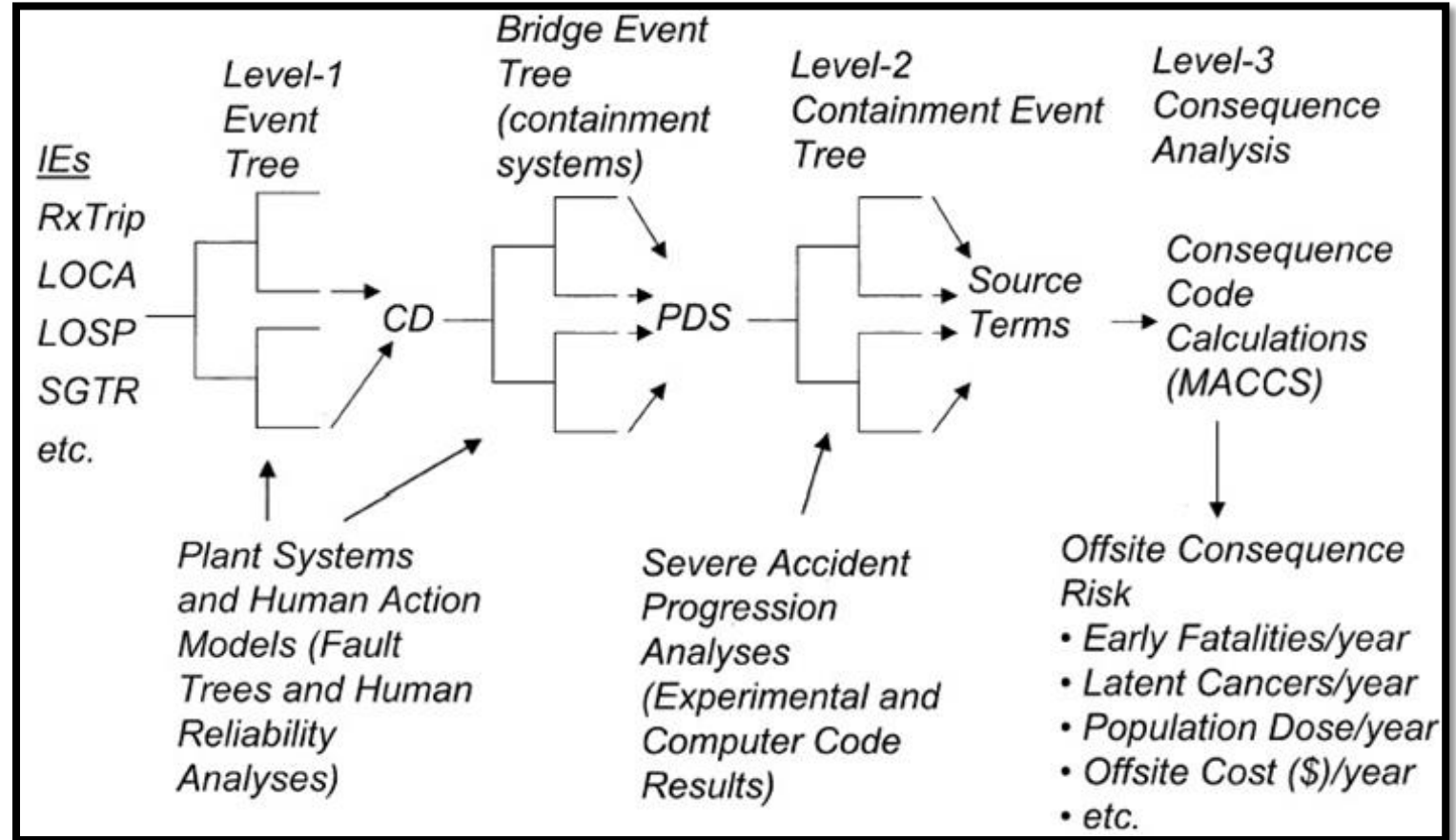
- Health (Early and Latent) consequences
- Economic consequences
- Contamination level

The integrated risk result are presented in form of a risk curve (in terms of Complementary Cumulative Distribution Functions, CCDF).

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Integrated PSA Level 1, 2, & 3

Full scope PSA Level 1, Level 2, and Level 3 - coupled results



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Integrated Risk Results



Integrated Risk Results

- Release Categories and Release Frequency, from PSA Level 2
- Complementary Cumulative Distribution Function from PSA Level 3
- Conditional probability vs Frequency of Exceedance

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Health Effects



Probabilistic Safety Assessment Level 3

Health Effects

- Deterministic effects (early effects)
During emergency period
- Stochastic effects (Latent effects)
Post-emergency period

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Countermeasures



Probabilistic Safety Assessment Level 3

Countermeasures

- Short term
 - Sheltering the affected population
 - Provision of stable iodine tablets
 - Evacuation
 - Human decontamination
- Long term
 - Relocation
 - Food bans
 - Land decontamination

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Economic Consequences



Probabilistic Safety Assessment Level 3

Economic Consequences

- Evacuation, Relocation
 - Population
 - Industries
- Human & Land decontamination
- Food ban



KKG PSA Level 3 – Results

Maximum Early Fatality Distance

Rel. Category	Initiating Event	Release Path	No Counter measures	Countermeasures
RCA1L	Massive SGTR	SRV	5 km	250 m
RCB1L	MAC	RB failure	2 km	100 m
RCC1L	TSBO (Fast)	UPES	0 km	0 m
RCF2L	TSBO (Slow)	CFV	0 km	0 m



Point Estimate Quantification of Average Individual Risk

Case	Early fatality [1/a]	Late cancer [1/a]	Total [1/a]	Seismic Contribution [%]
No Offsite Emergency Measures	1.92E-15	3.91E-09	3.91E-09	95.25
Emergency Measures Including a Successful Evacuation	0.00E+00	3.11E-09	3.11E-09	95.06



Release Category Contribution to Swiss Accident Fatalities

Case	Year 2010	
Swiss (Industries + Traffic)	1.73E-02	
PSA Release Categories	Evacuation	No Evacuation
RCA1L	0.00E+00	2.63E-04
RCB1L	0.00E+00	1.08E-04
RCC1L	0.00E+00	0.00E+00
RCF2L	0.00E+00	0.00E+00



Release Category Contribution to Swiss Cancer Fatalities

Case	Statistical data from year 2010	
Swiss	1.17E-01	
PSA Release Categories	Evacuation	No Evacuation
RCA1L	8.12E-03	9.13E-03
RCB1L	4.86E-03	6.31E-03
RCC1L	1.63E-05	1.76E-05
RCF2L	7.39E-07	9.78E-07

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Conclusions



- Early fatalities are not expected when the release path is the CFVS. Therefore the CFVS is an extremely efficient barrier to reduce the public exposure.
- A proper implementation of the “Swiss Emergency Planning” prevents Early Fatalities during emergency period (cloud passage).
- Sheltering strategy (Swiss cellars and use of Shelter) combined with the KI intake very efficiently reduce public exposure for the LER when the containment integrity is compromised (MAC case) or containment is bypassed (massive SGTR case).
- Small values for the maximum distance of Early Fatality Risk results are confirmed by the Fukushima accident. There have not been any reported casualties due to radiation exposure within the first year after the accident.
- Possible contribution to the Swiss cancer rate of fatalities, which looks to be constant according to Swiss Statistical data (2007, and 2010), is some orders of magnitude smaller.



Thank you for your attention

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