The Big Picture

KKL’s Periodic Safety Review

Andreas Ritter, Deputy Manager, RP&Chemistry

Kernkraftwerk Leibstadt AG
CH-5325 Leibstadt | Telefon +41(0)56 267 71 11 | www.kkl.ch

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Overview

1. Scope
2. Radiation Exposure
3. Source Term
4. Releases to the Environment
5. Waste Management
6. RP Instruments
7. Chemistry
8. RP Events
9. Emergency Preparedness
10. Conclusions

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Scope

The licensee has to perform a comprehensive safety review every 10 years.

The following aspects have to be described/assessed:

- Safety Concept
- Operational Management and Operating Performance
- Probabilistic Safety Analysis
- Deterministic Safety Analysis
- Organisation and Staff
- Overall Safety Status (public documents)

- Radiation Protection
- Chemistry
- Waste Management
- Environment
- Safety related equipment (RP instrumentation)
- Events

- Radiological safety analysis
- Emergency preparedness

- RP Training

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Radiation Protection: Scope

- RP Processes
- Radiologically Controlled Area
- Source Term Management
- RP Instruments
- Limitation and Minimization of Exposure
- Radioactive Releases
- Medical Services

• RCA Boundary	• Filters
• Shielding	• Locked High Rad Areas
• Barriers and Postings	• Protective Clothing

• Contamination Control	• Reactor Water Clean Up
• Zinc Injection	• Foreign Material Exclusion
• Hot Spots	• Corrosion Control

• Goals and Results	• RP Tools
• RP Planning	• Opportunities to improve

• Aerosols	• Tritium
• Iodine	• Carbon-14
• Noble Gases	• Liquid Releases

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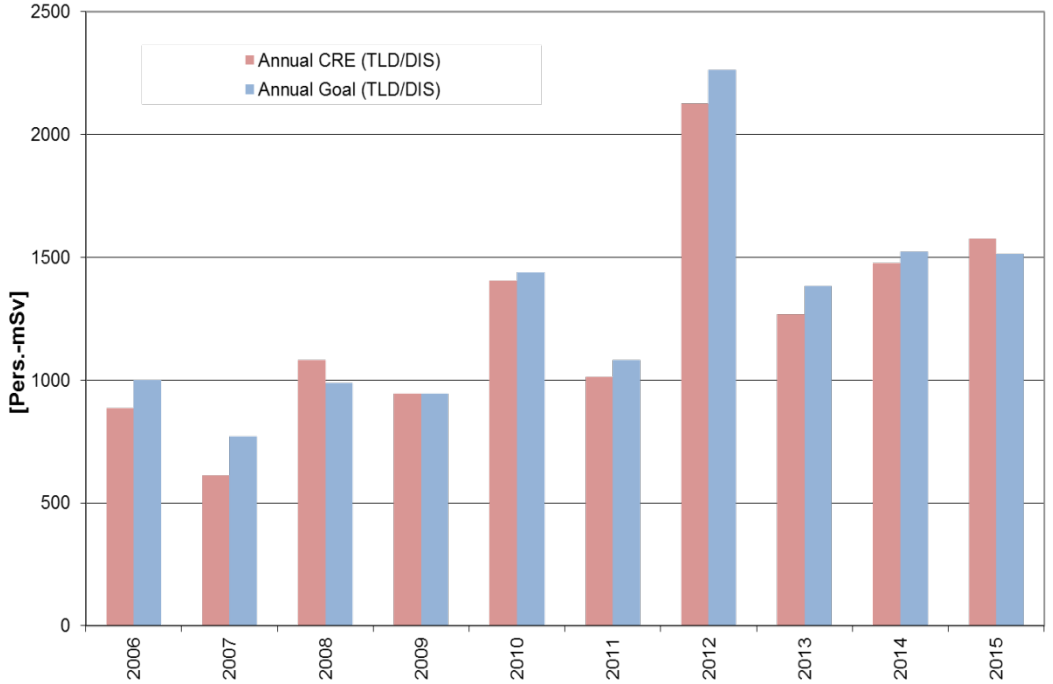
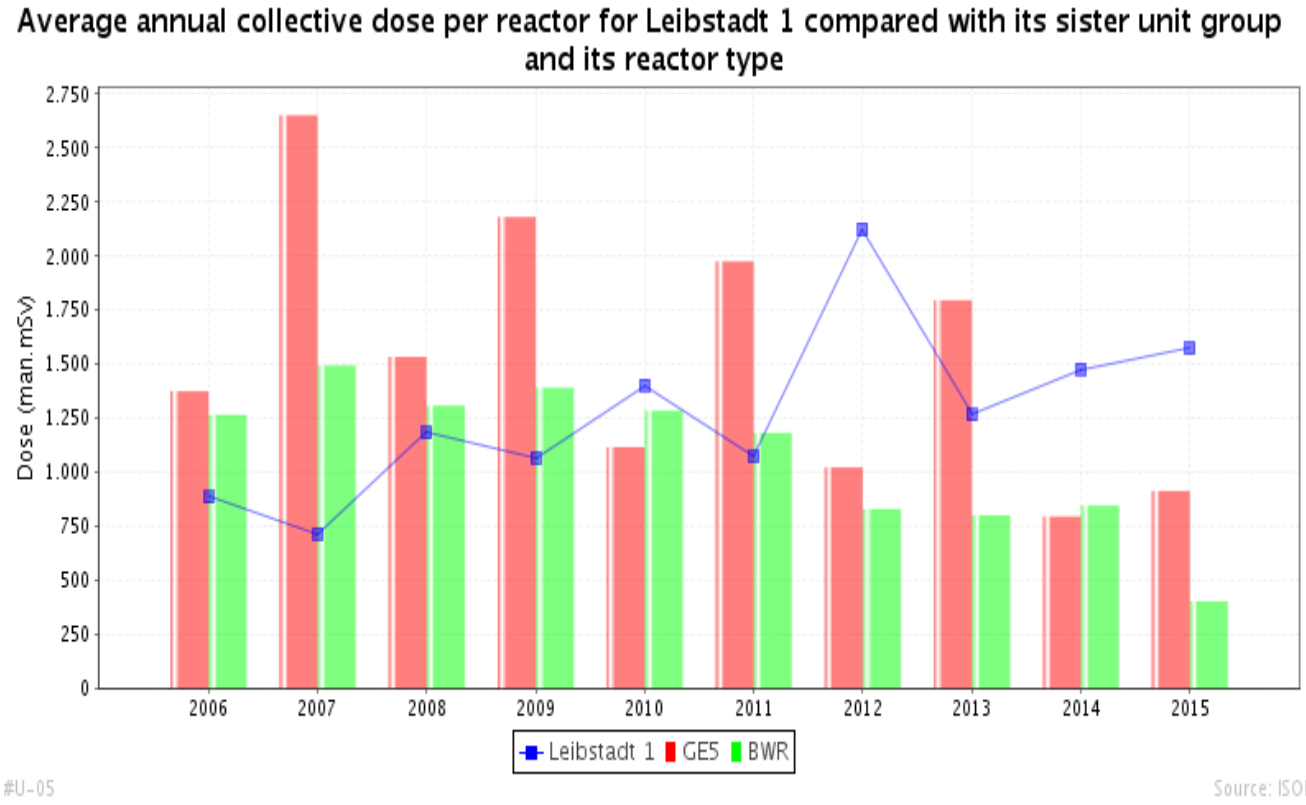
Collective Radiation Exposure





We are good at planning…..

….but we are falling behind the rest of the fleet!

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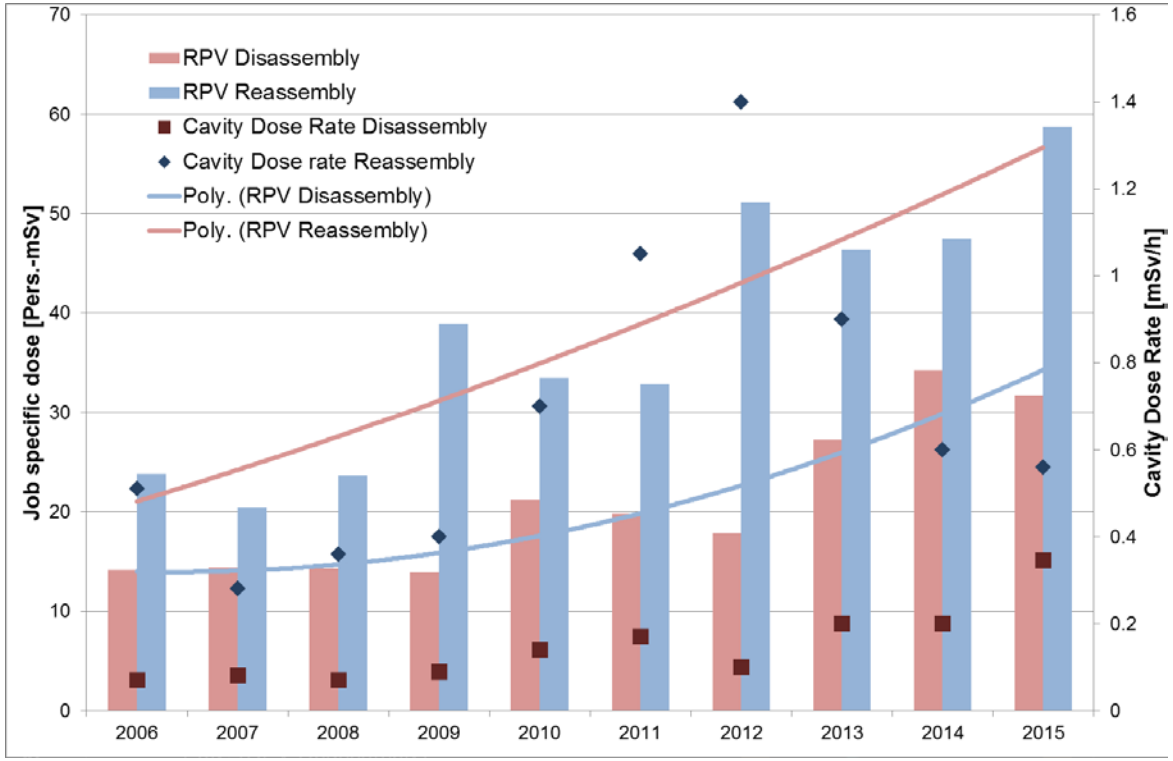
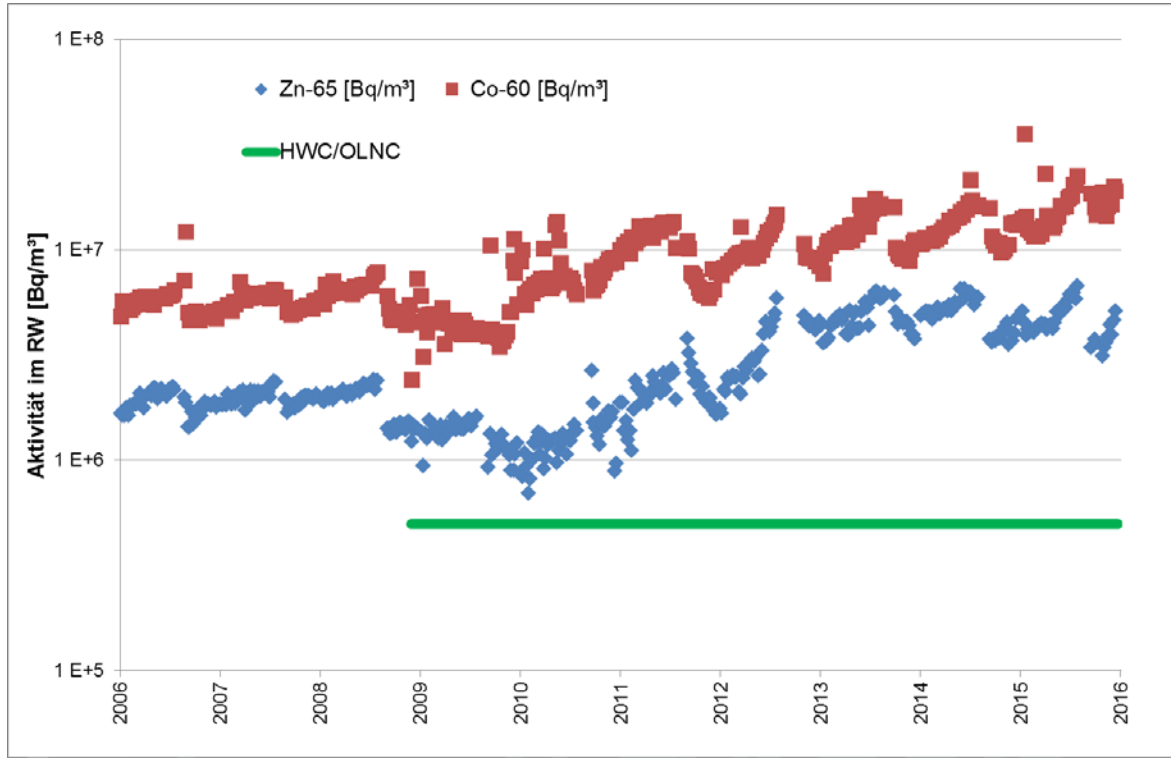
We have become a high source term plant



Cavity dose rate is increasing



Reactor Water Co-60-Concentration has increased by a Factor of 4

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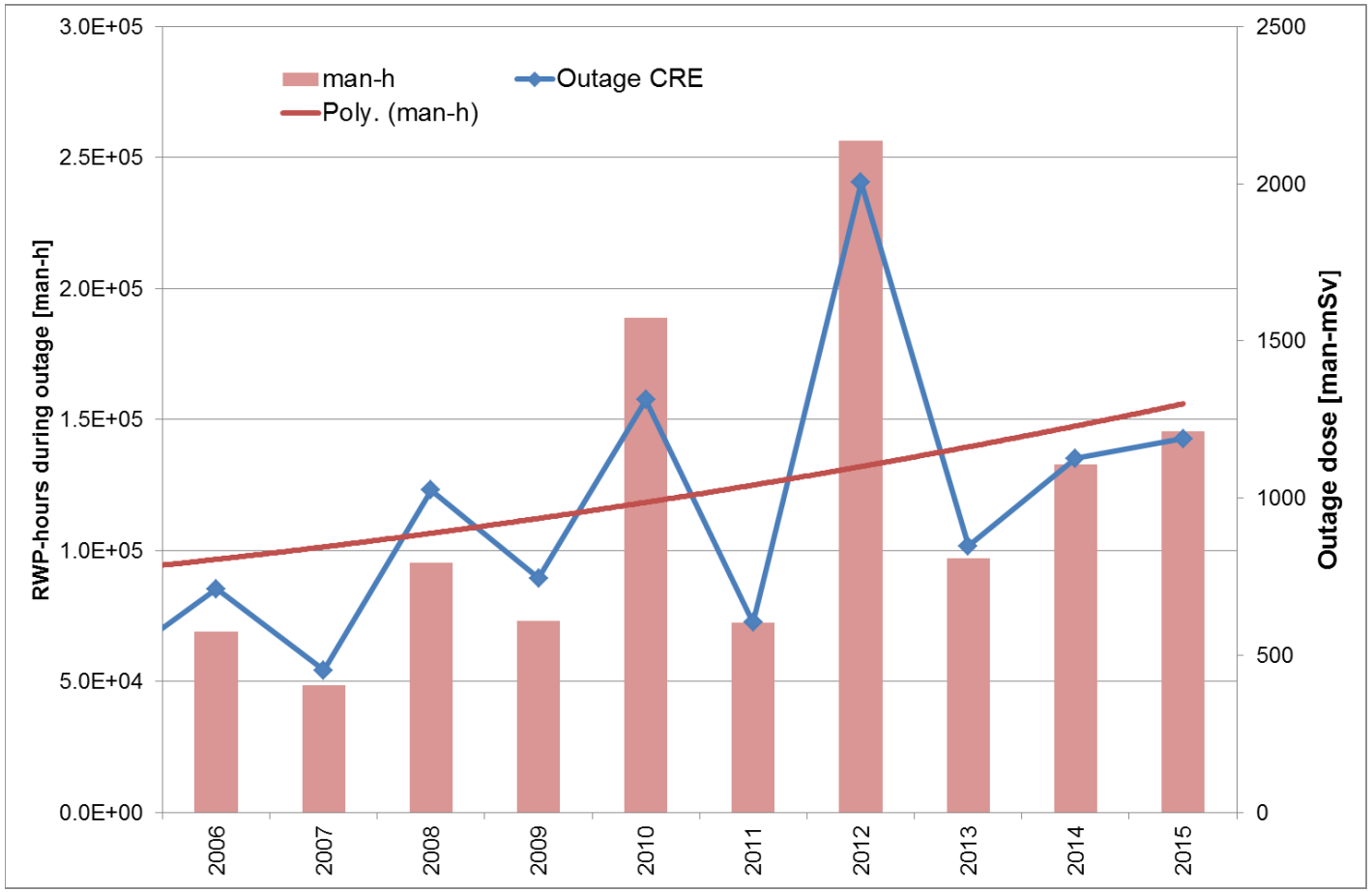
Workload is increasing

- Annual Refueling Outages: big workload every single year
- No relief through 18/24-month-cycles



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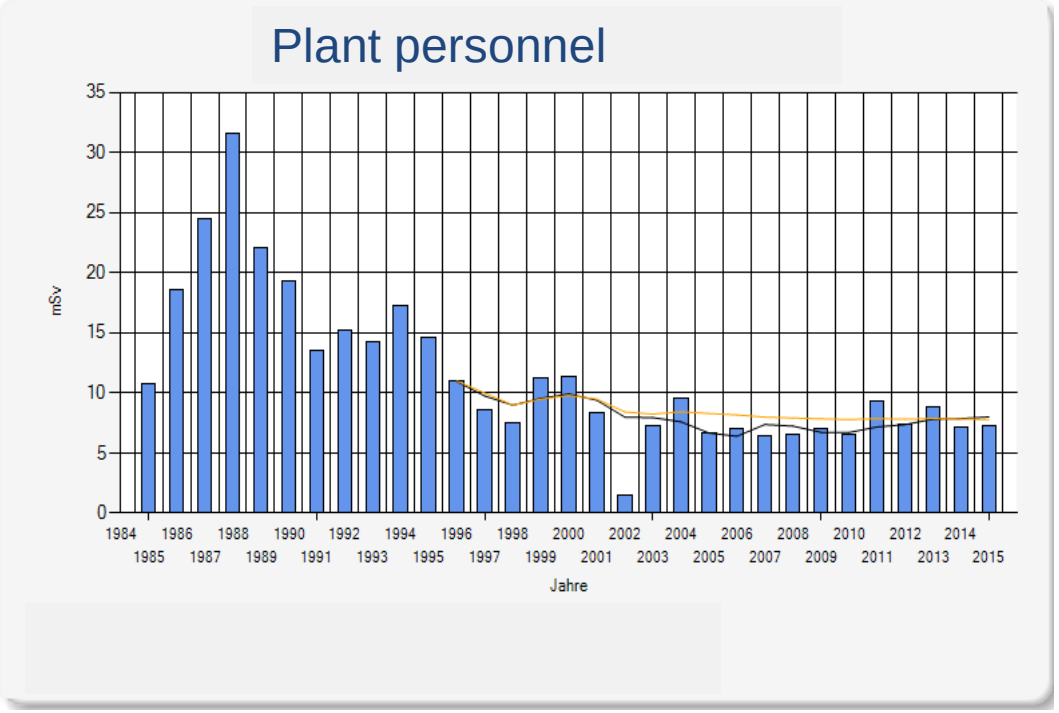
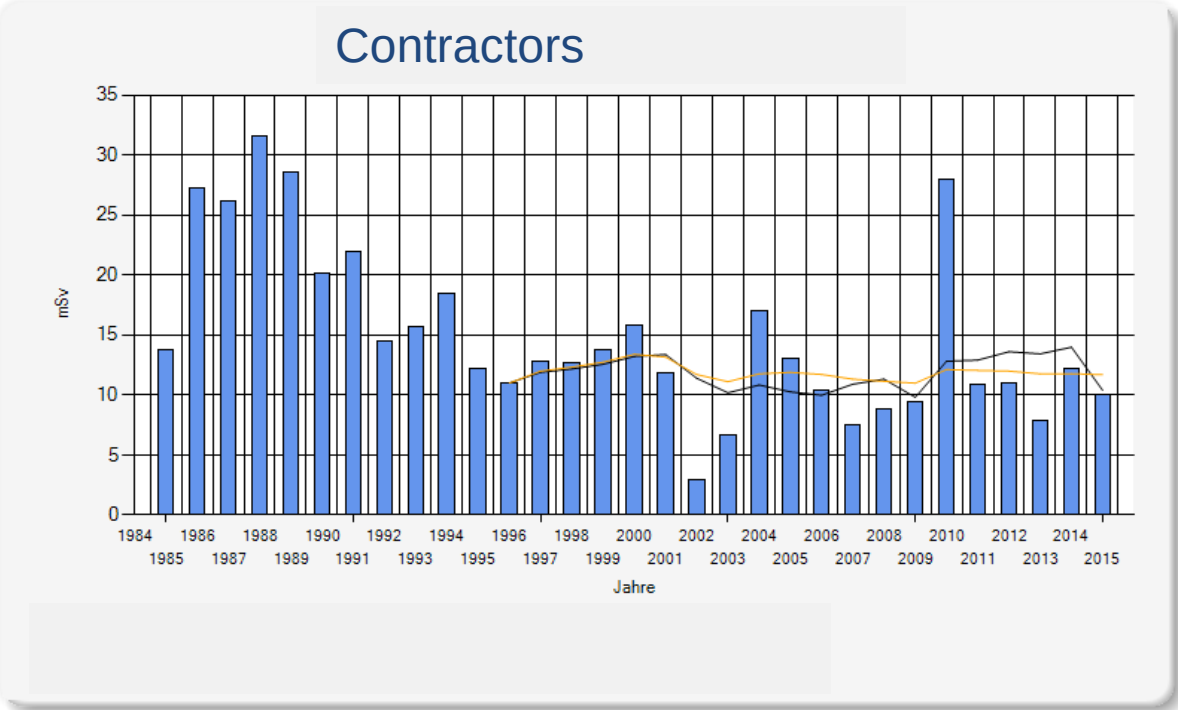
Maximum yearly individual dose





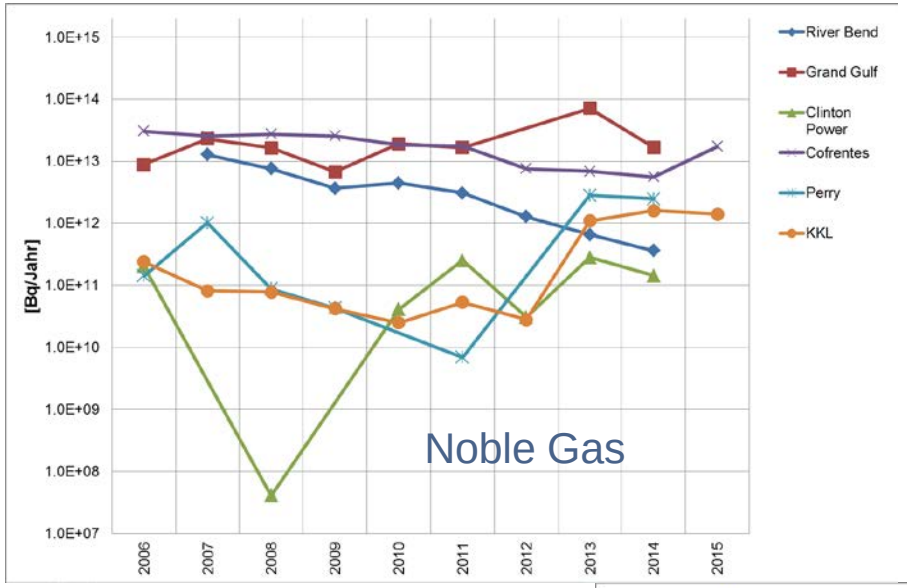
Plant personnel well below 10 mSv (1 rem)

Contractors around 10 mSv
2010: Diving accident
1994: Dose limit lowered 50 mSv -> 20 mSv

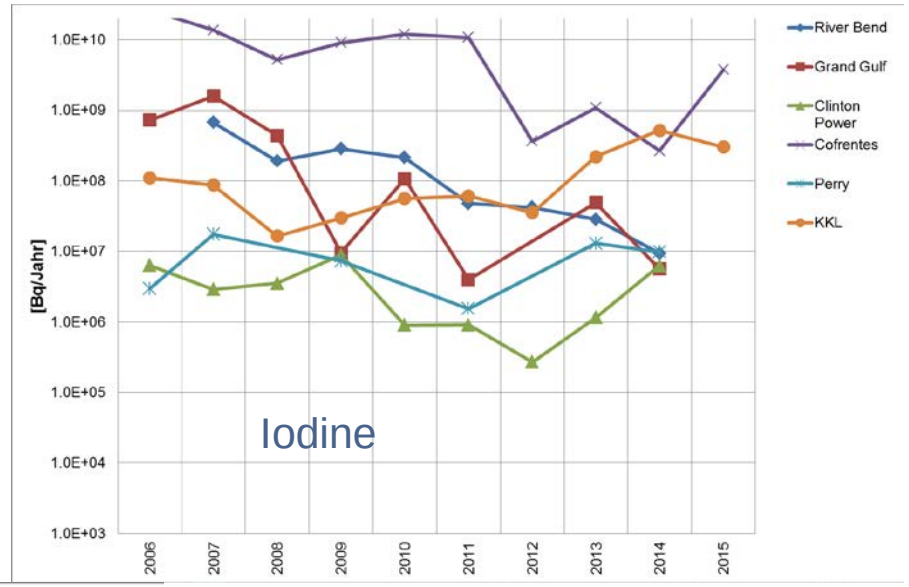
Major Changes in RP within last 10 Years

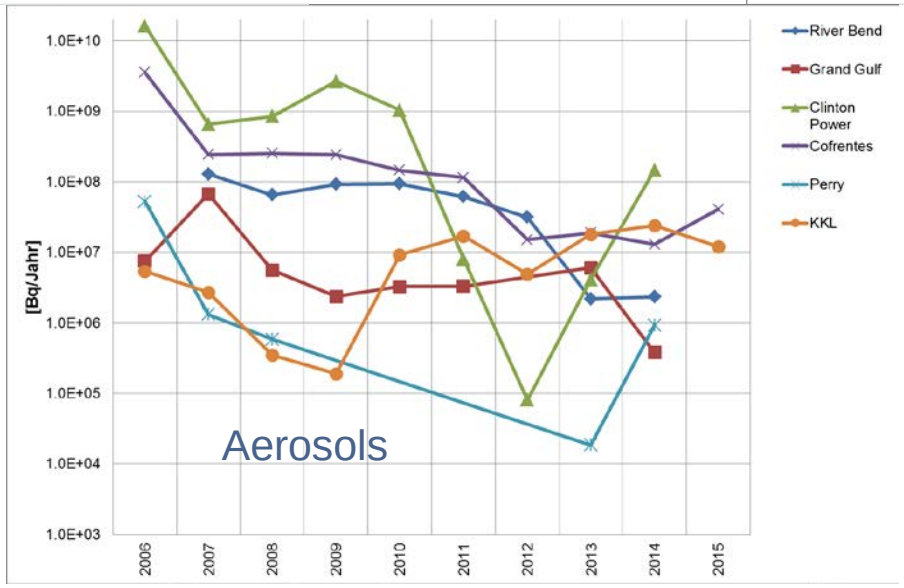
- Implementation of teledosimetry
- Implementation of teledosimetry for diving operations
- Installation of 47 cameras in steam affected areas -> waiving of operator walkdowns
- Implementation of Locked High Radiation Areas
- New procedure for work with irradiated fuel
- New procedure for work with X-ray testing-equipment
- New procedure for work inside stack
- New decision chart when failed fuel is detected
- Generic dose rate alarm for electronic dosimeters: 100 mSv/h (10 R/h)

Gaseous Releases



Failed Fuel in 2013/2014





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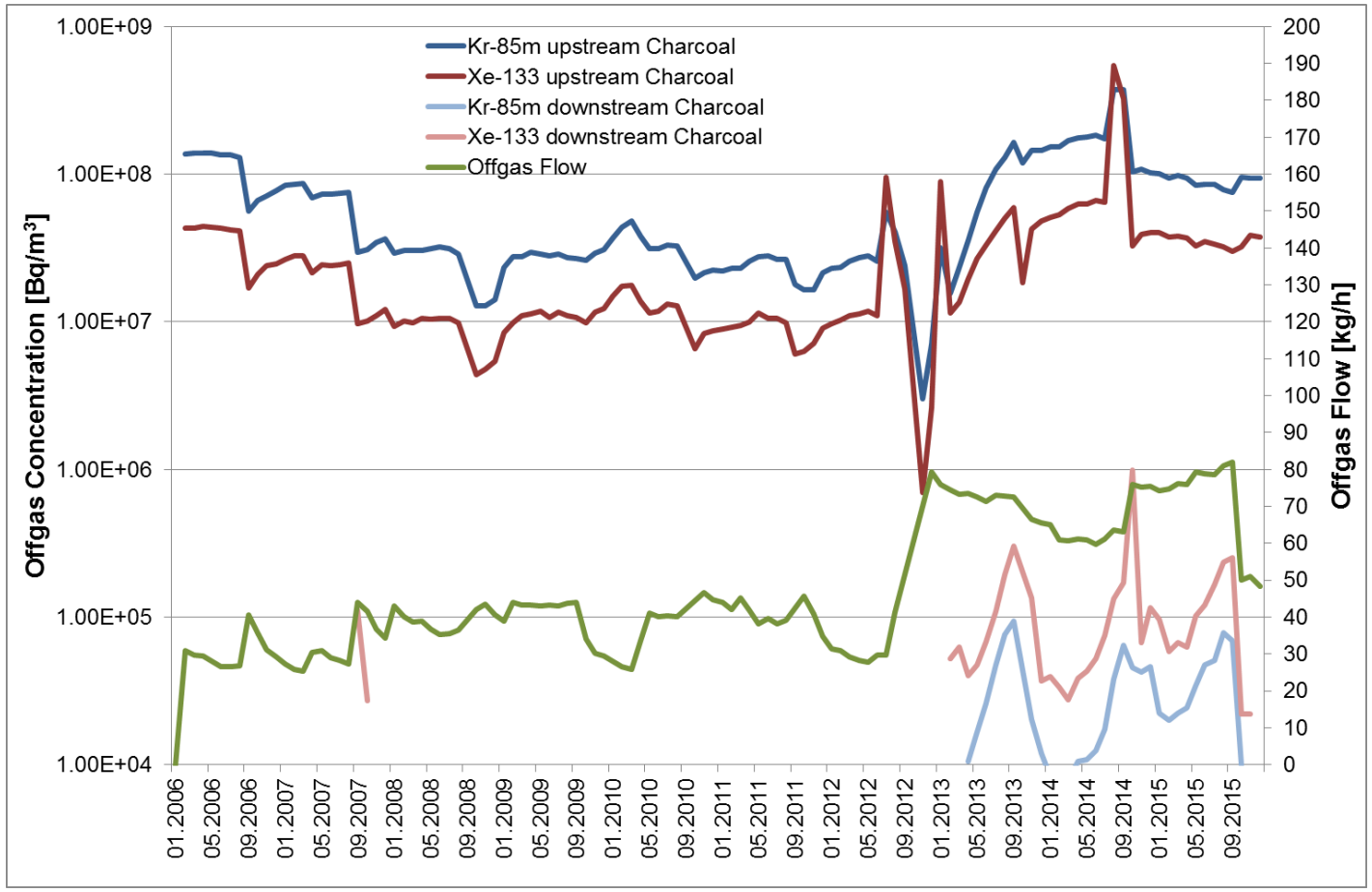
Condenser Air Inflow Leakage

- 2006 High Offgas Source Term
- No air inflow leakage to condenser -> low offgas flow -> long hold up time in charcoal filters -> Zero release

- 2013/2014 High Offgas Source Term and air inflow leakage -> Noble gas release

- 2015 High Offgas Source Term, no air inflow leakage -> no release



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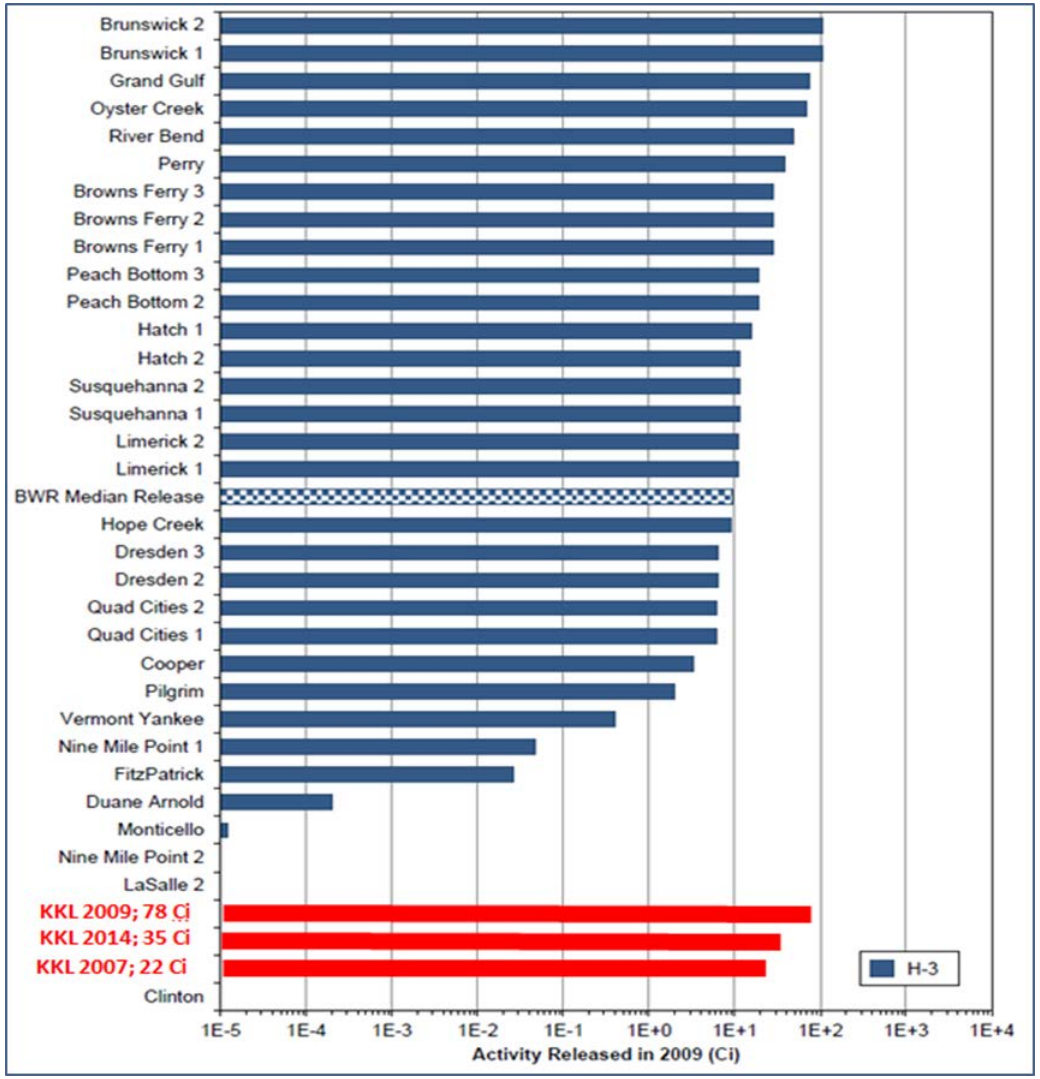
Liquid Tritium Release

- KKL's liquid Tritium release is compared to the fleet values 2009
- In 2009, KKL had defective control rod blades, releasing boric acid to the coolant: $^{10}B(n, 2\alpha)^{3}H$
- 2014 all defective control rod blades were removed: Tritium release on the way back to normal
- Some US-plants have very low releases



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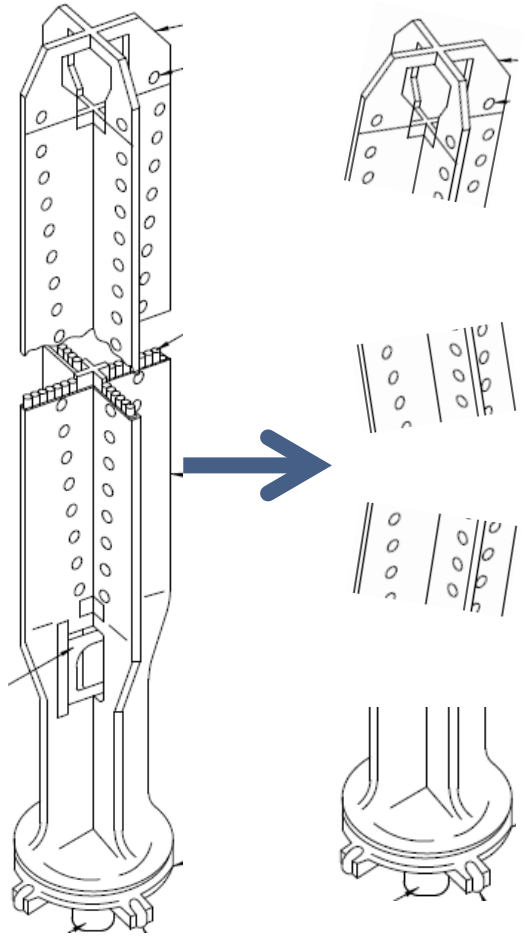
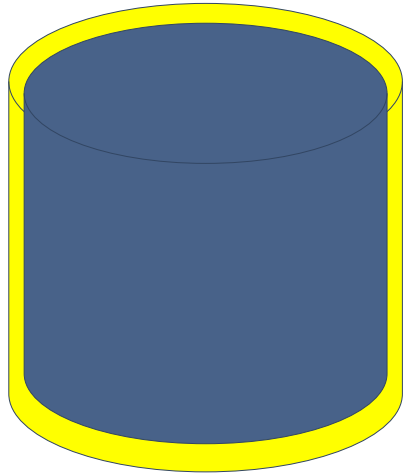
Core Scrap Disposal

Item	Mass [kg]	Co-60 [Bq]
CR Blades	13’000	6E+15
Pins&Rollers	3	6E+14
Fuel Channel	2 Pieces	4E+10
LPRM/ Drytubes	950	1E+15
Jetpump-Beam	8	5E+10
TriNuc-Filter	4	





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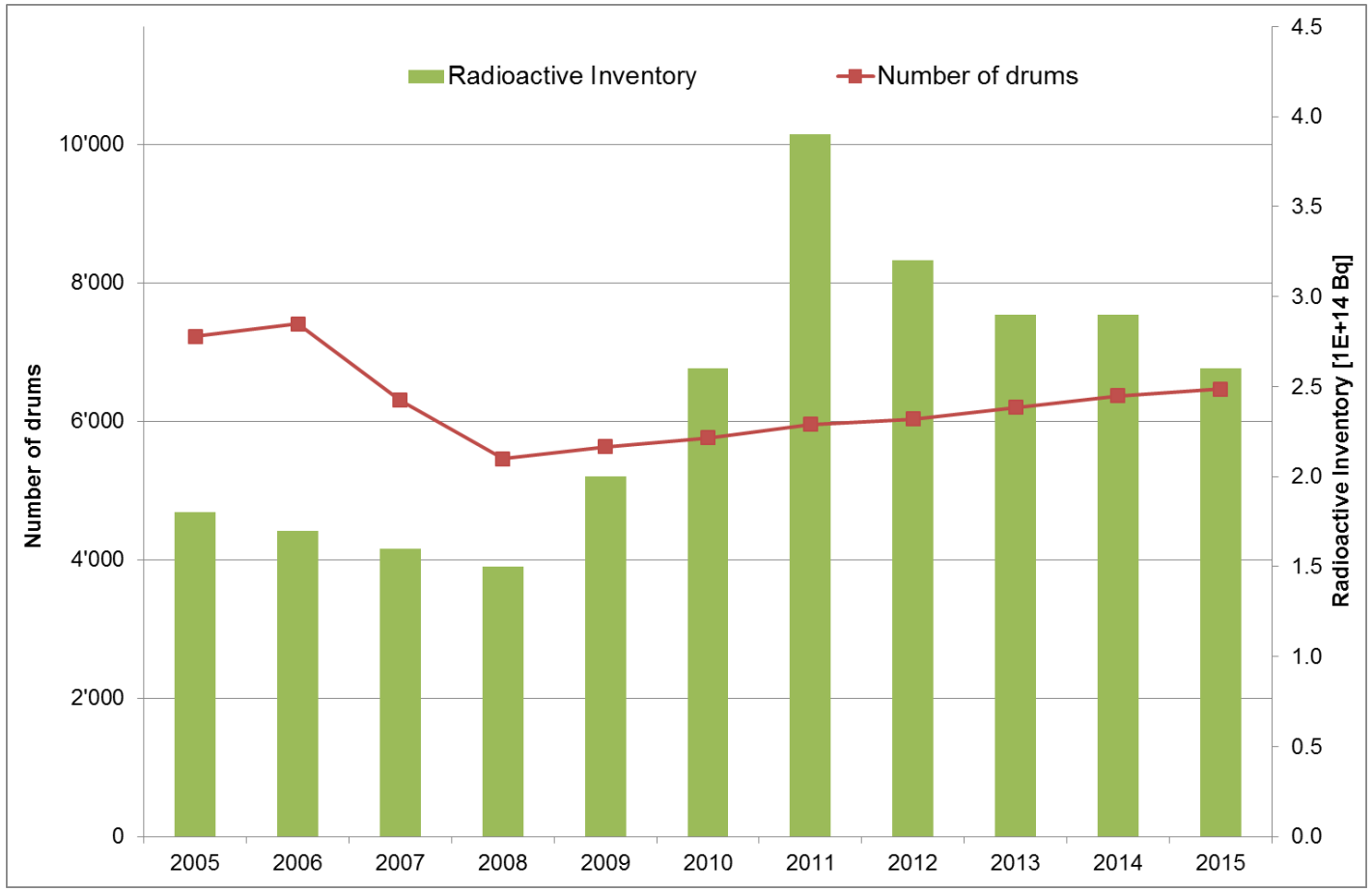
Waste Management: Site Interim Storage

- 2007/2008: waste was moved to the central repository
- 2011: «spent» Control Rod Blades were cut, compacted and stored into the interim storage
- 2008-2015: solidified, spent resin is stored (approx. 140 drums/year)
- 2012-2015: radioactive decay of control rods exceeds radioactive build up of spent resin



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Waste Management: New Site Interim Storage for contaminated Components

- Building is designed for «decay storage»
- Goal: Free release of radioactive contaminated components after 40 years

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Shipping of radioactive Material

Year	Waste	Fuel	Tools	Misc.	Total
2006	2	8	12	43	65
2007	37	2	6	69	114
2008	4	8	8	93	113
2009	3	9	12	46	70
2010	5	1	10	44	60
2011	4	4	14	56	78
2012	6	10	14	47	77
2013	3	7	8	37	55
2014	4	5	9	27	45
2015	4	5	11	42	62

- 40 % of shipping cross-border
- 10 loaded fuel casks with 673 spent fuel bundels were shipped off-site
- 72 sea-land-containers with 3672 drums of radioactive waste where shipped to the incinerator

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Handheld/portable RP Instruments

PSR 2005: too many different types!

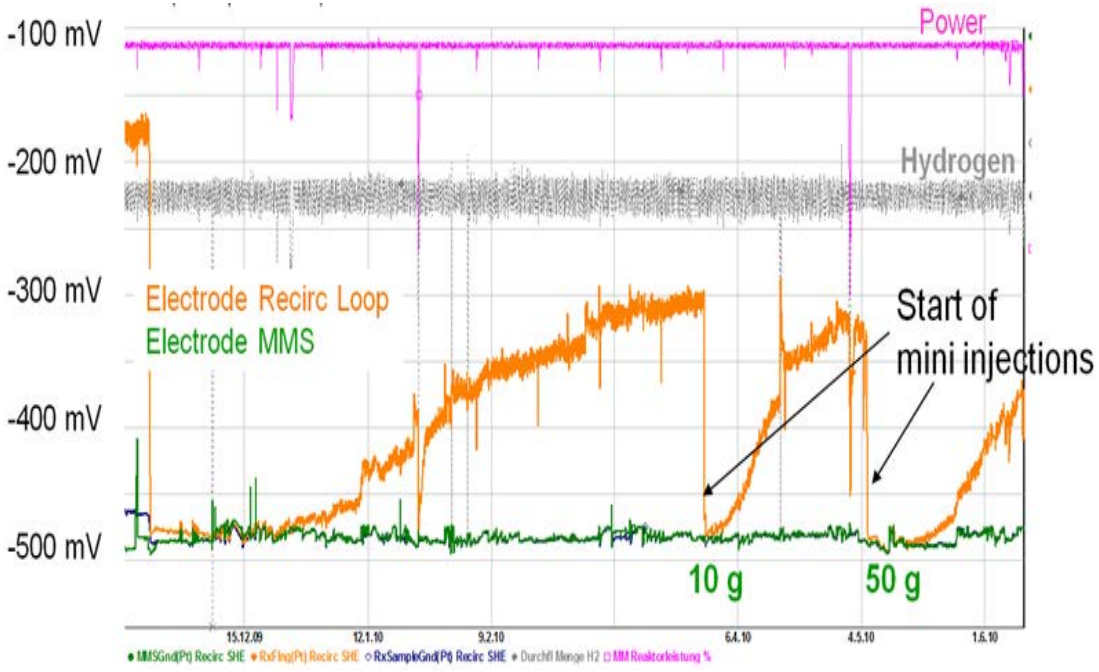
PSR 2015

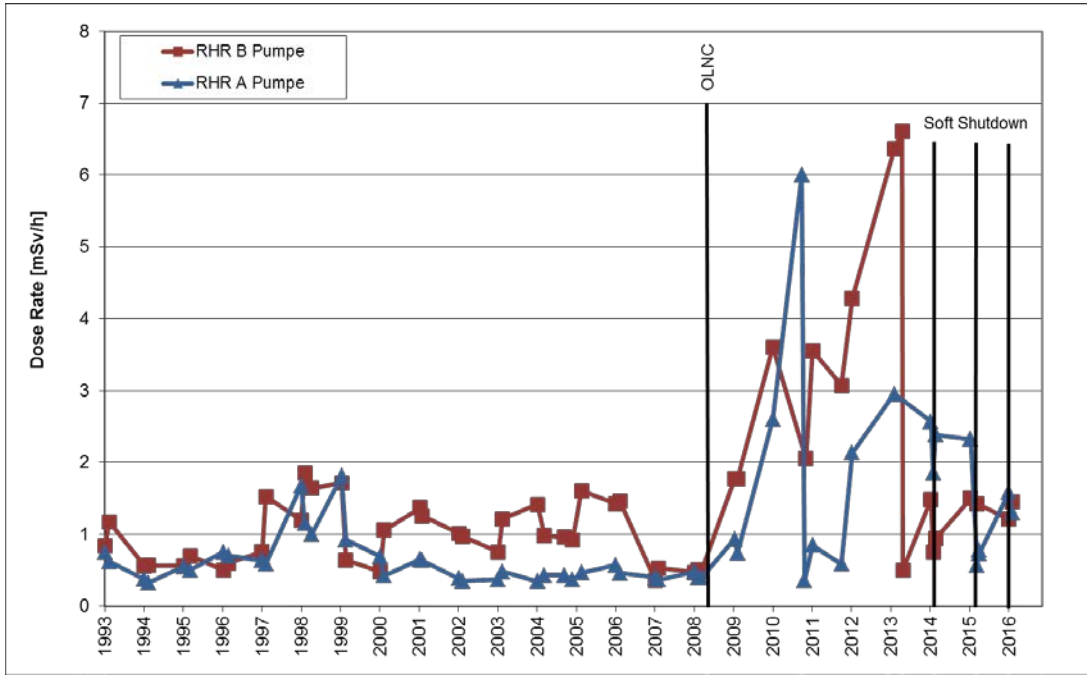
Major Changes in RP Instrumentation within the last 10 Years

- Emergence of Teledosimetry
- TLD Replacement by DIS (Direct Ion Storage)
- Replacement of 12 PCM’s
- Replacement of Containment Airborne Monitor
- Replacement of Stack Sampling Line
- Emergency Power Supply for certain Process Radiation Monitors added
- Relocation of Emergency stack monitors, to include filtered Containment venting emissions
- Installation of local Area Radiation Monitors in Locked High Rad Areas

Chemistry: Implementation of Online Noble Chemical Addition (OLNC)

- KKL first plant worldwide to move from Normal Water Chemistry to OLNC
- Increasing ECP is countered by frequent Platinum-Reapplications (every two months)
- Increasing trend of dose rates and Hot Spots, mitigated by Soft Shutdown





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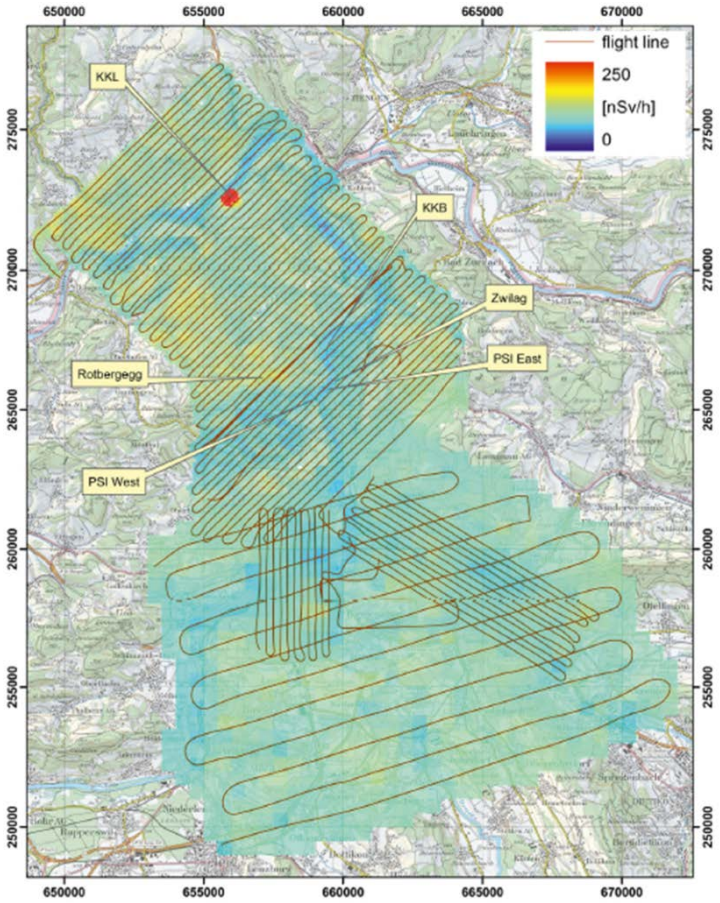
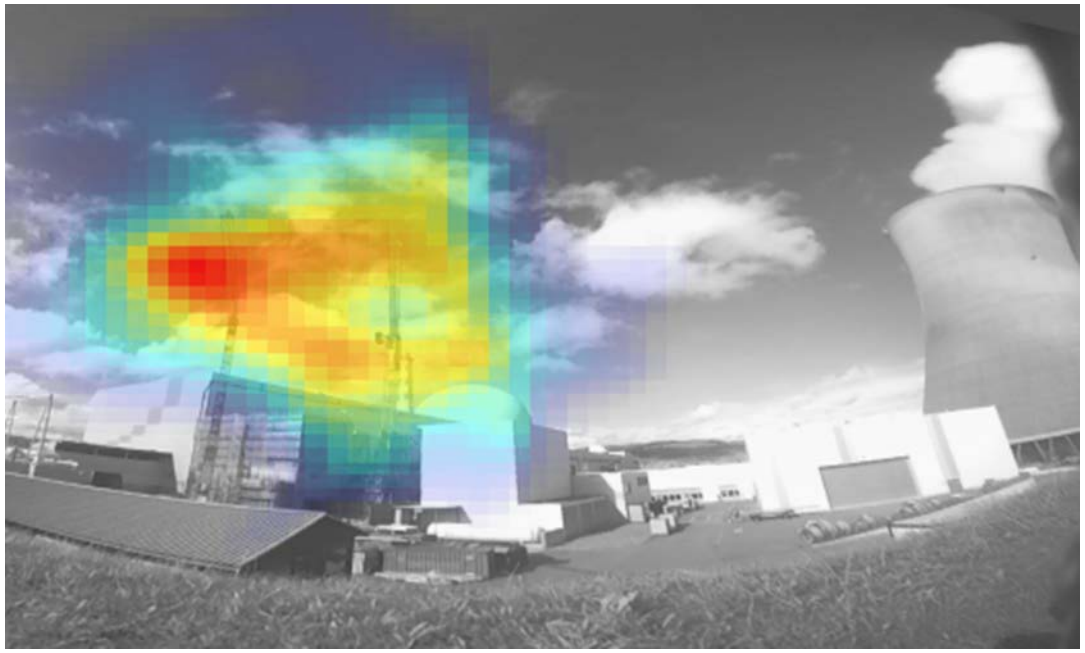
Environment: γ-Scan by Helicopter



Credit: Paul Scherrer Institute, Aeroradiometric Measurements in the Framework of the Swiss Exercises ARM14 and FTX14



- No artifical nuclides were found from KKL's emissions
- Cs-137 deposits still from the Chernobyl Accident (1986)
- ^{16}N-radiation over turbine building detectable from helicopter

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System Health Reports

RP Systems

- Area Radiation Monitors
- Process Radiation Monitors
- Leak Detection System
- Containment Air Concentration Monitors
- Containment Accident Monitor
- Post Accident Sampling System

Content

- Design Basis, Safety Functions, Classification
- Testing
- Modifications
- Operational Experience
- Corrective Maintenance
- Preventive Maintenance
- Limiting Conditions of Operation
- Documentation Status
- Ageing

Typical assessment:

«The system was able to fulfill its designed safety and operational functions. Availablity was high and necessary maintenance was carried out in a timely manner. Lack of spare parts will trigger modifications in the future.»

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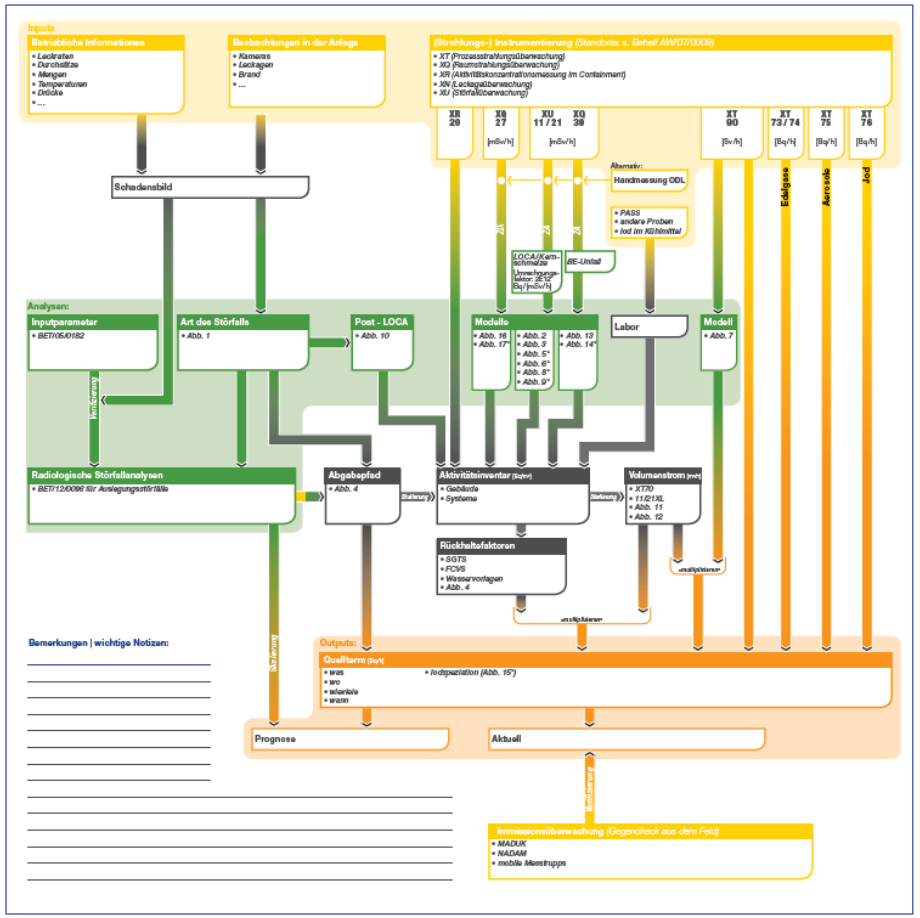
RP Events

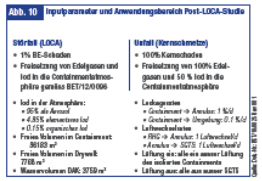
- 11x «Spread of Contamination»
- 3x «Failed Fuel»
- 3x «Unidentified Hot Spot»
- 1x «Loss of Control during X-Ray»
- 3x «Unplanned exposure»
- 2x «Intake of radioactive material»
- 2x «PCM malfunction»
- 1x «Contamination of a non-radioactive system»
- 1x «Dose rate too high outside RCA»
- 2x «Shipping of rad. material without proper paperwork»
- ….

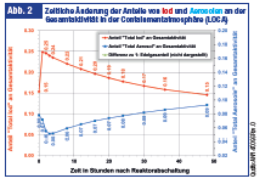
Radiological Design Basis Accidents

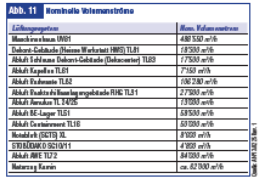
2006 Dose to public [mSv]	2016 Dose to public [mSv]	2016 Dose to public [mSv]
Closure of all MSIV (0,039)	Closure of all MSIV (0,002)	Offgas Charcoal Fire (0,3)
Main Steam Line Break (0,53)	Main Steam Line Break (0,18)	Airplane Crash on Waste Storage (5,9)
Instrument Line Break (0,002)	Instrument Line Break (0,002)	Lightning (0,003)
Loss of Coolant Accident (1,32)	Loss of Coolant Accident (19)	RPV Overfilling (56)
Fuel Handling Accident (0,16)	Fuel Handling Accident (0,7)	
Feedwater Line Break (0,012)	Feedwater Line Break (3)	
Offgas System Line Break (1,05)	Offgas System Line Break (0,05)	
Steam Air Ejector Line Break (0,13)	Steam Air Ejector Line Break (0,02)	
Radwaste Tank Failure (1,03)	Radwaste Tank Failure (0,03)	
Radwaste Evaporator Failure (0,003)	Radwaste Evaporator Failure (0,008)	
Earthquake (3)	Earthquake SSE (2,3)	
Fuel in Transfer System (3)	Fuel in Transfer System (??)	
Leak in Reactor Water Clean Up (1,32)	Leak in Reactor Water Clean Up (0,12)	

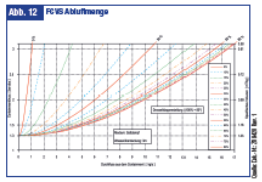
Emergency Preparedness: Decision chart to assess radioactive releases to the environment

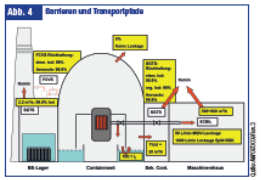


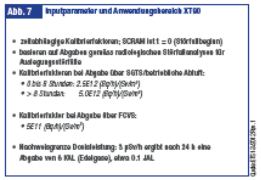












- Based on observable facts
- Sheet of paper only, no manual, no computer, no electric power needed
- Easy to use, basic mathematical skills sufficient
- User groups: RP and Operations staff
- Gaseous effluents prediction [Bq/h] (Ci/h)
- Off-site dose calculation by National Emergency Center

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Conclusions

- Workload 330 man-days over a period of 2 years to complete the Periodic Safety Review; 905 pages of text
- Quality of RP planning is high
- CRE trend needs action plan
- Source term needs closer look
- Lack of fuel failures is crucial
- Activities in high and variable radiation fields require particular oversight
- RP instruments performance as required
- Outdated RP instruments need replacement

- Regulator’s statement: «RP performance is consistent to the law»

Questions?

Andreas Ritter

Deputy Manager,
RP&Chemistry