Risk assessment of nuclear waste package planning demonstrated on activated core internals of a German BWR

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Session 2: Risk, safety and knowledge management of the
International Workshop on Application of Advanced Plant Information Systems for Nuclear Decommissioning and Life-cycle Management

Tuesday, 4 December 2018, 10:40 am

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Outline

- Introduction
- Survey of Statistical Tool Set Setup
- Results
- Conclusions

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Project description

Tasks

Uncertainty sources

QA of core internals material

INTRODUCTION

Dismantling of core internals

- Activation ~1E16 Bq Co-60 / ~1E17 Bq total 1 year after shutdown
- Contamination (β-/γ- + α-emitters if fuel damage happened)
- Under water cutting and conditioning with limited working area space
- Packaging requirements (waste acceptance criteria interim storage +final storage, ADR, container/cask licences)
- Approval of supervising authority (concept and steps)
- Documentation
- Schedule

Challenge of the supplier: Technical concept and risk analysis

Requirements

- Binding technical concept
- Dismantling concept
- Waste packaging concept
- Qualified process for verification and documentation (BGE)
- Schedule
- Fixed estimate of cask / container number and types
- Fixed estimate of disposal volume

Uncertainty sources

- Lacking verification / validation of radiological characterization
- Limited scope of radiological characterization (measurement/calculation) not suitable for package planning
- Ambiguous mass specification in technical documents (raw / as built)
- (Interpretation of regulations)

QA of core internals material

- Co-60 key nuclide for dose and WAC
- Identification of 3 QA groups:
  - Base material of large / security relevant components
    -> Strict QA, low Cobalt content
  - Material for welding and centring pins (fuel elements)
    -> Strict QA, sometimes very high Cobalt content
  - Standard material
    ->Normal QA, Cobalt content unknown

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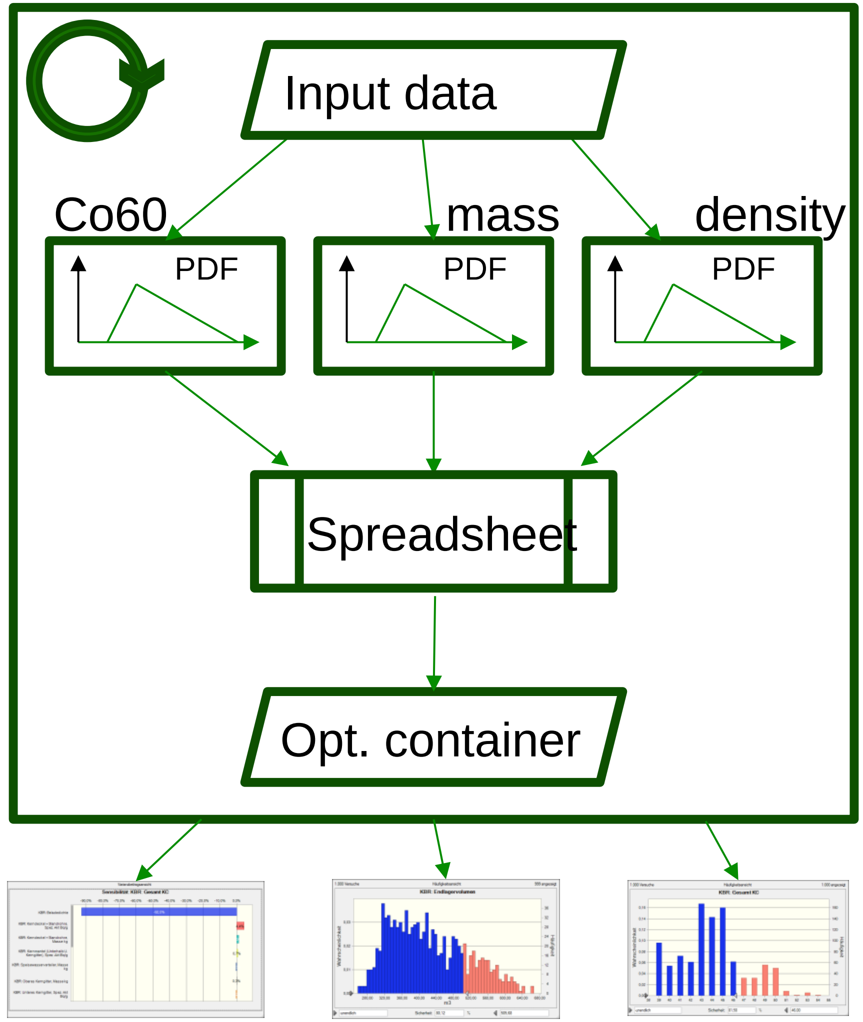
- Statistics
- Input data
- Boundary conditions
- Optimum activity loading

METHOD

Statistical tool set

- Stochastic risk analysis (Range Estimating Method) based on Monte Carlo Simulation (Crystal Ball)
- Triangular Distribution (PDF) for activity, mass, effect. Density
- Result is estimate range distribution rather than a single point estimate
- Formulas and input data in spreadsheet application



Input data, NPP Brunsbüttel as of 30.06.2015

Core internals KKB	Specific activity Co60	Mass	Co60 activity
Components	**Bq/g**	**kg**	**Bq**
Steam dryer	4,90E-01	3,00E+04	1,47E+07
Steam separator	4,10E+00	3,00E+04	1,23E+08
Shroud head + Tubing	1,54E+04	3,50E+04	5,38E+11
Feed water sparger	3,10E+01	2,00E+03	6,20E+07
Core shroud at active core	1,40E+07	2,87E+04	4,00E+14
Core shroud below the core plate	1,54E+04	1,43E+04	2,21E+11
Top guide	6,40E+08	5,00E+03	3,20E+15
Core plate	2,60E+06	6,00E+03	1,56E+13
Core flow measurement + Control rod guide tubes	3,80E+03	2,30E+04	8,74E+10
Recirculation pump (impeller)	2,00E+01	1,00E+04	2,00E+08
Total		**1,84E+05**	**3,62E+15**

Nuclide vector 1 year after shutdown

Fe55	Co60	Ni59	Ni63	Nb94	Mn54
53.08%	26.41%	0.21%	20.14%	0.03%	0.13%

Boundary conditions, regulations

Phases of core internals decommissioning	Operation Shutdown	Dismantling	Intermediate Storage	Transport to Repository	Final Disposal
Date [y]	2007	2018	2020	2040	2041
Duration [y]	-	2	20	1	-
Legislation	StrlSchV	StrlSchV	WAC[a)], StrlSchV	ADR, StrlSchV	WAC[b)], StrlSchV

[a)] **WAC LasmA,** [b)] **WAC KONRAD**

Cask / Container	Type	ABK	APG	WAC[a)]	ADR	WAC[b)]
KC II - VI	IP-2	I	3	3,40E+12	4,00E+11	6,10E+11
KC II	IP-2	II	-	1,70E+13	2,10E+12	1,20E+14
MOSAIK II	B(U)	II	-	3,40E+14		1,20E+14

[a)] **WAC LasmA,** [b)] **WAC KONRAD**

Optimum activity loading

- Definition of a decision variable: virtual cost (VC)
- Pricing of
  - Container / Casks of all types and shielding variants (range from 40.000 bis 144.000 VC)
  - Disposal volume (30.000 VC/m³)
- Optimization towards lowest virtual costs
- Range factors for sampling:

Range factor	Co60 activity	Component mass	Eff. packing density
Min. value factor	0.20	0.95	0.83
Max. value factor	10.00	1.05	1.17

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Loading (deterministic, stochastic)

Sensitivity

Risk assessment

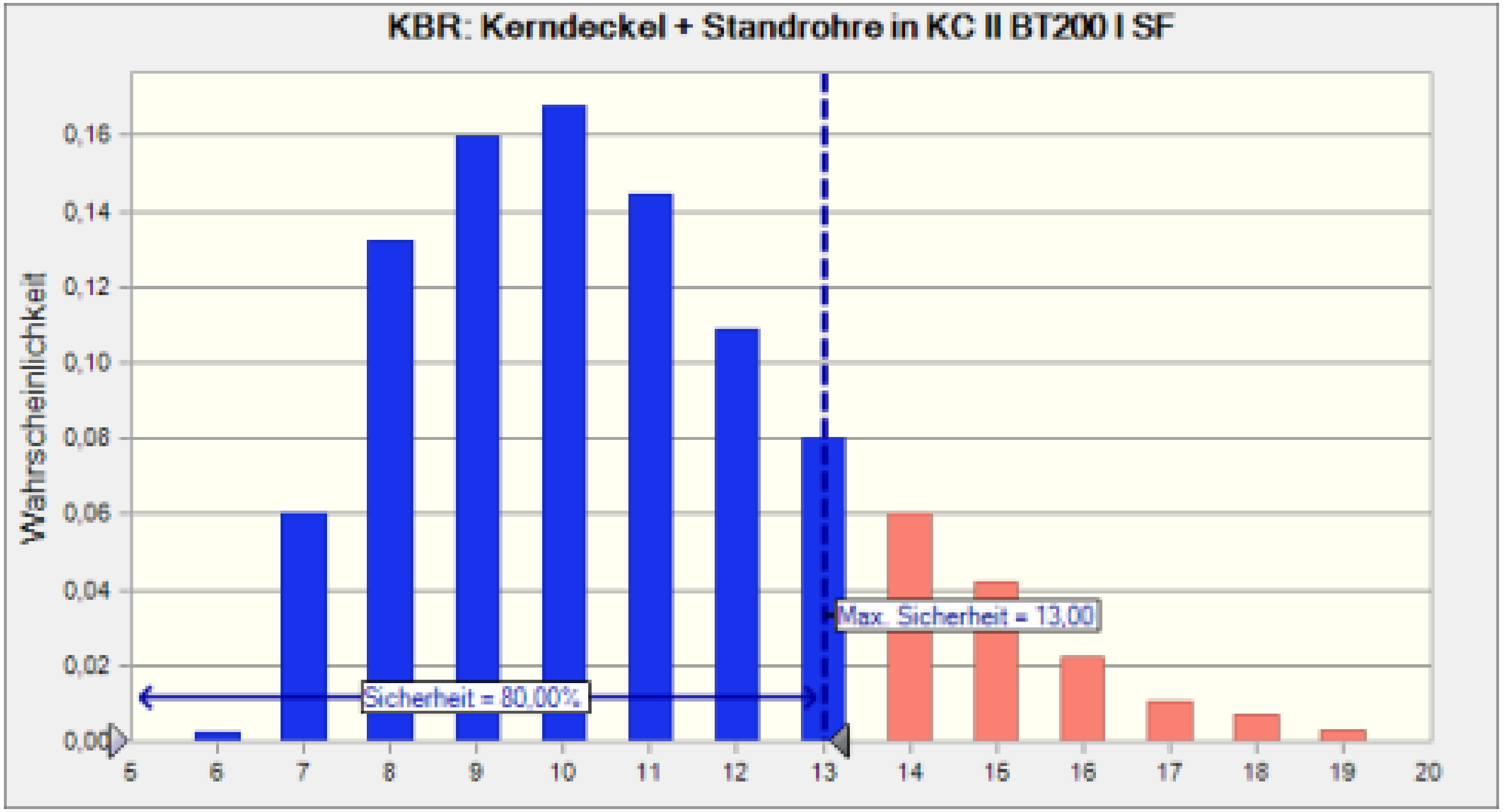
RESULTS

Deterministic result for average activity

Core internals KBB	Cask / Container	Final #	Net volume	Co-60
Component				Bq / package
Steam dryer	KC II BT200 I SF	9	41,58	1,63E+06
Steam separator	KC II BT200 I SF	9	41,58	1,37E+07
Shroud head + Tubing	KC II BT200 I SF	10	46,2	5,38E+10
Feed water sparger	KC II BT200 I SF	1	4,62	6,20E+07
Core shroud at active core	Mosaik II S U 050 mm	44	58,08	9,30E+12
Core shroud below the core plate	KC II BT200 I SF	4	18,48	5,51E+10
Top guide	Mosaik II S U 095 mm	30	39,6	1,19E+14
Core plate	Mosaik II S U 025 mm	8	10,56	1,73E+12
Core flow measurement + Control rod guide tubes	KC II BT200 I SF	7	32,34	1,25E+10
Recirculation pump (impeller)	KC II BT200 I SF	3	13,86	6,67E+07
# KC		**43**		
# Mosaik		**79**		
Disposal volume (m3)		**302,94**		

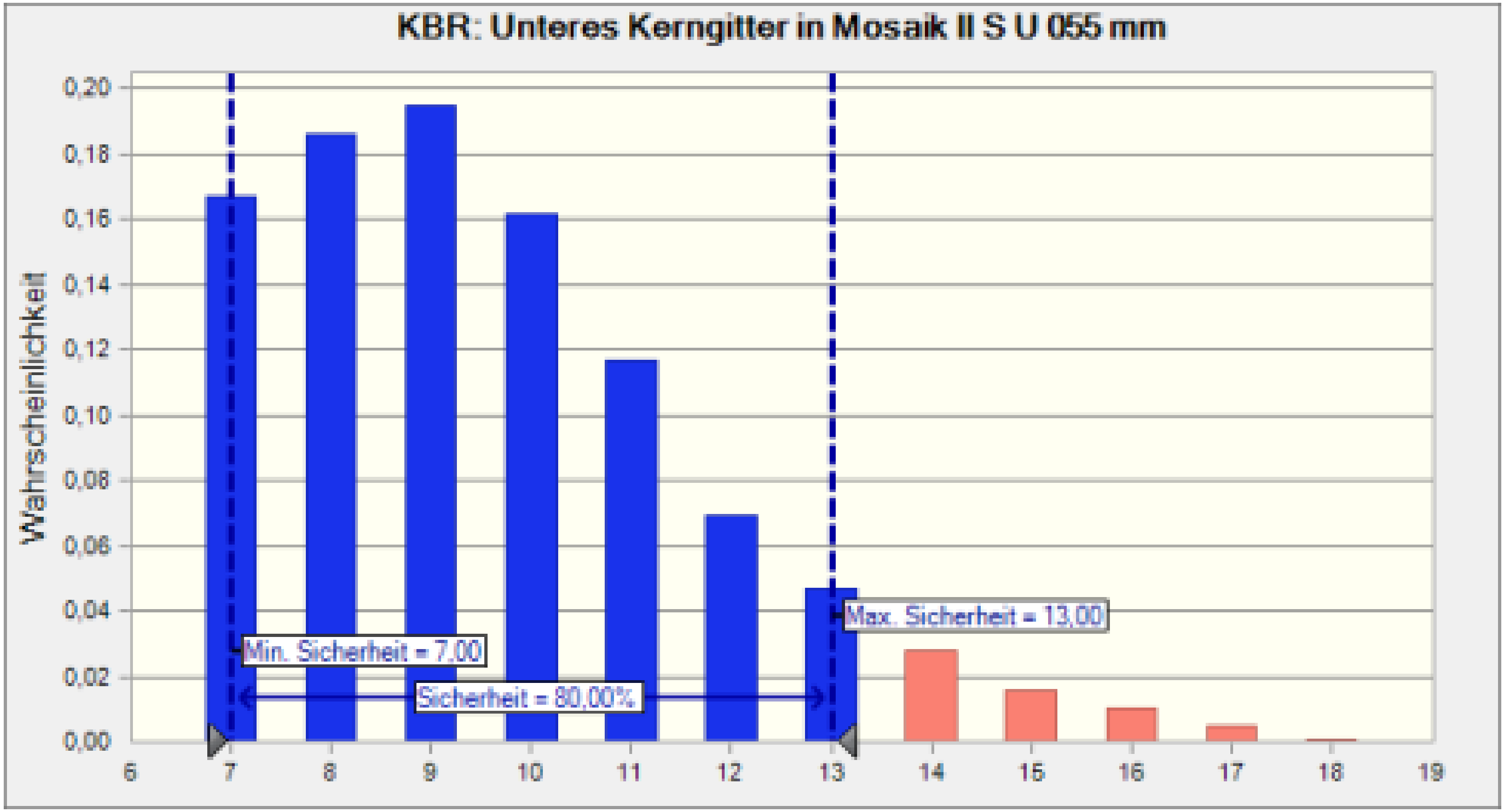
Virtual cost of 19.3 Mio. VC

Statistical distribution: Shroud head + Tubing



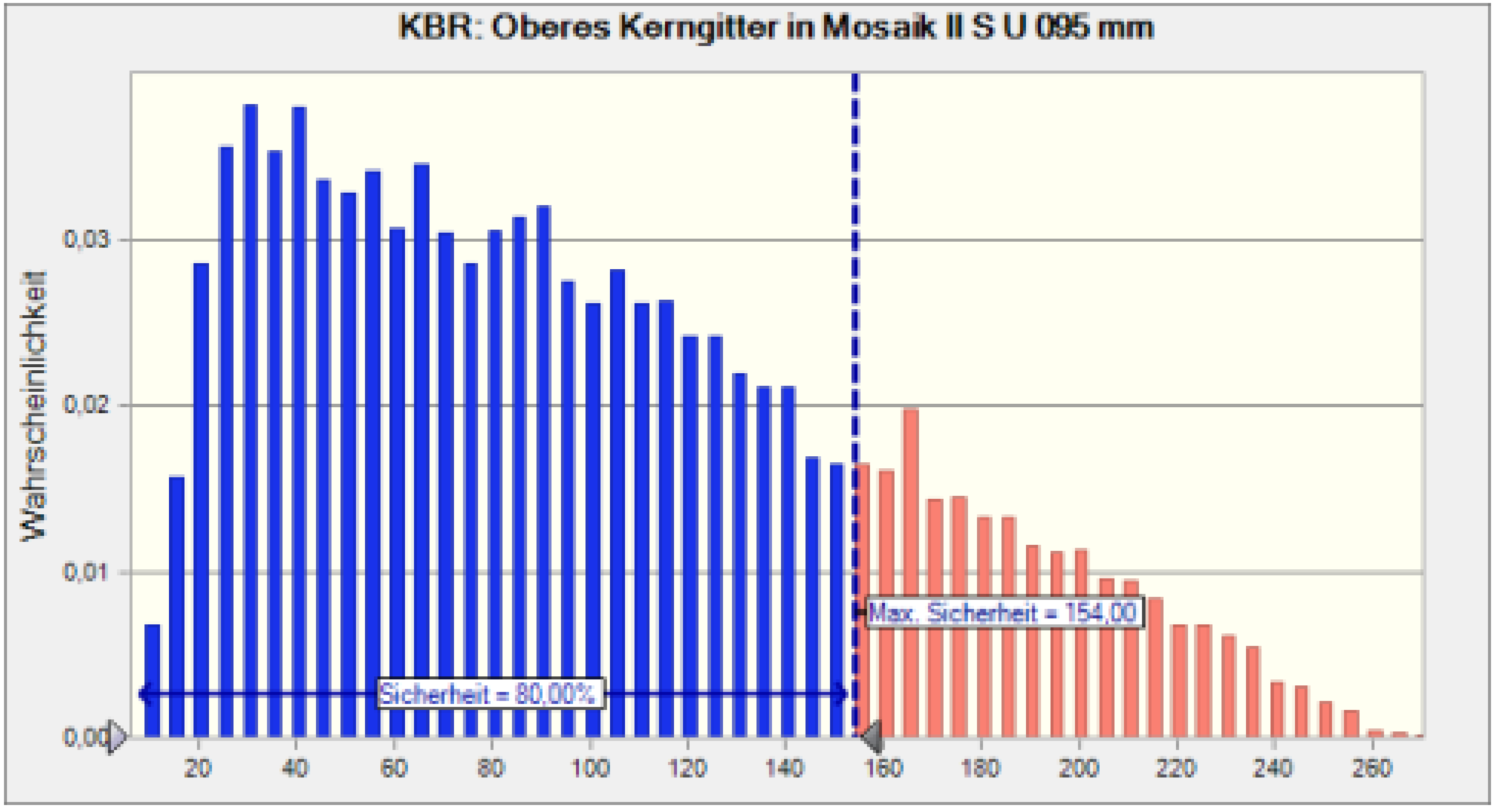
Base case: 10 KC II BT 200

Statistical distribution: Core plate



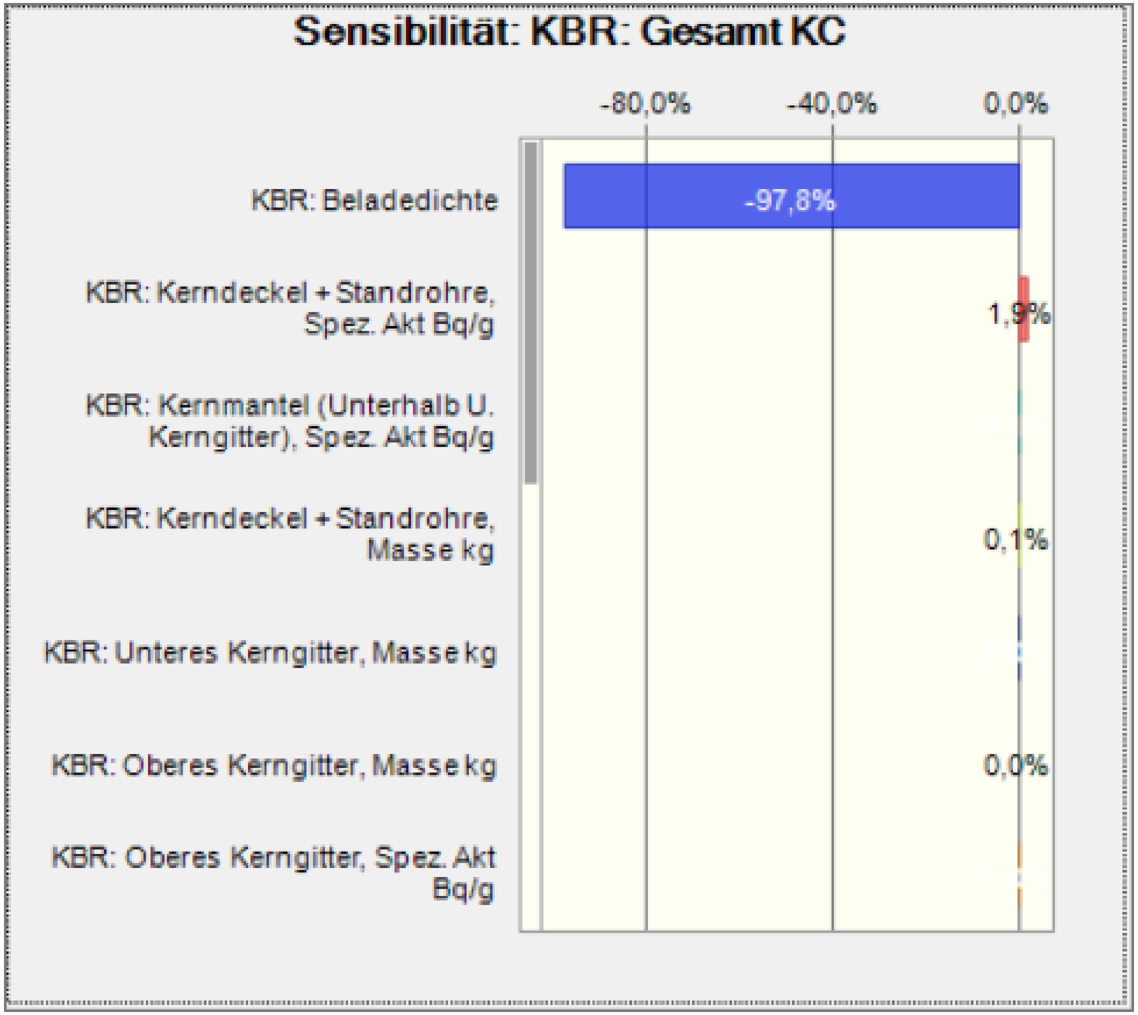
Base case: 9 MOSAIK II S U 55 mm

Statistical distribution: Top Guide

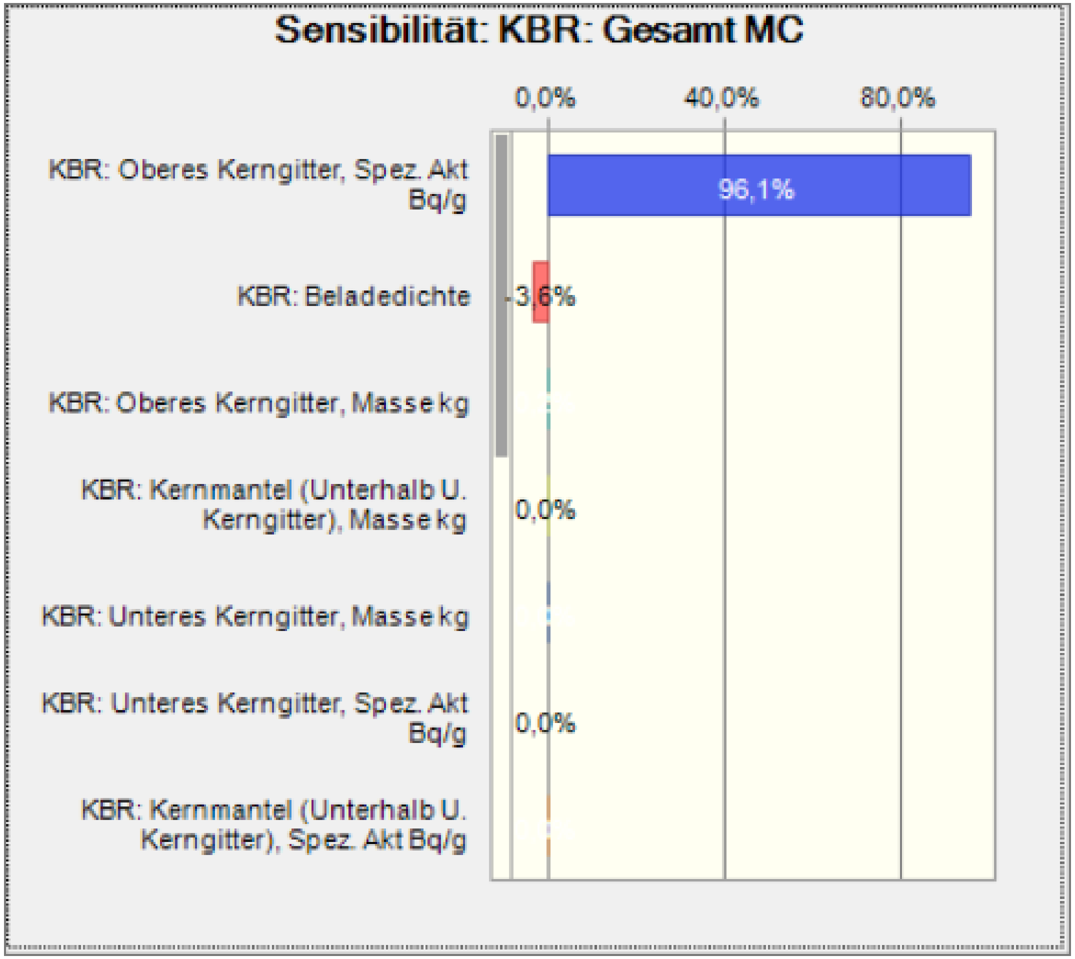


Base case: 27 MOSAIK II S U 95 mm

Sensitivity KONRAD Container



Sensitivity MOSAIK casks



Risk levels

Percentile:	Forecast	Stat. Accuracy
	Virtual Costs	
0%	12.362.400	
10%	19.248.600	2,54%
20%	22.236.400	2,72%
30%	24.764.200	2,64%
40%	27.579.800	3,73%
50%	30.183.400	2,33%
60%	33.058.000	2,59%
70%	36.468.600	2,99%
80%	40.910.800	2,42%
90%	46.131.200	2,88%
100%	66.451.800	

With equal probability of cost over- or underrun (50% risk level)
The contingency is about 11 Mio. VK

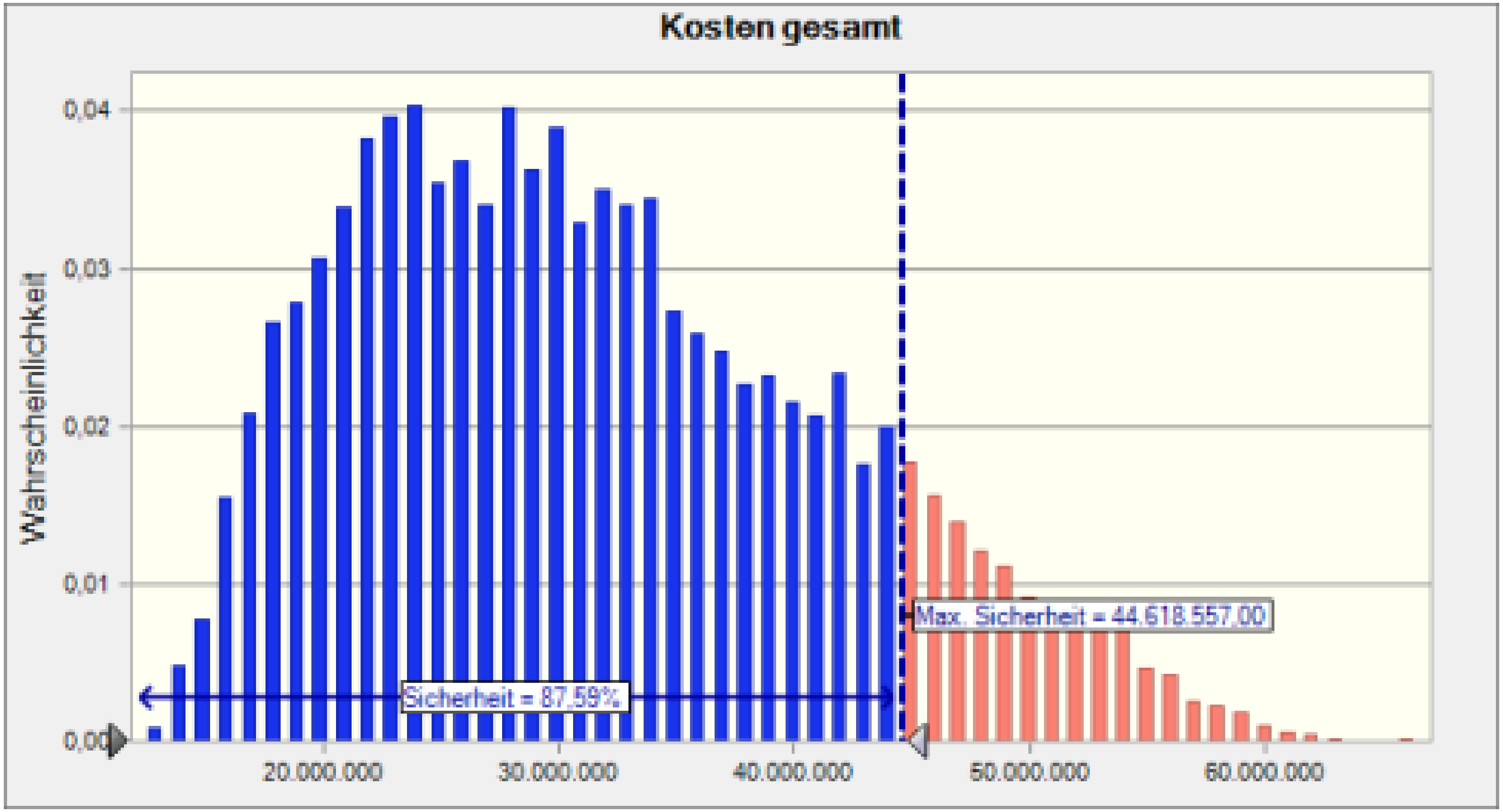
CONCLUSIONS

Conclusions

- Statistical assessment of core internals waste packaging with relevant input data for German NPP in view of risk and optimal loading
- Optimization towards lowest virtual costs
- Risk levels for contingency planning
- Risk analysis may help plant owner and supplier in finding a fair risk sharing
- Risk evaluation useful during project planning and execution
- Sensitivity identifies main impact quantities
  - KONRAD Container: packing densitiy
  - MOSAIK Behälter: activitiy of top guide
  - Risk reduction by means of suitable measures
- Items of the schedule can be part of the risk assessment
  - Caution with items on the critical path

Questions?

Statistical distribution: Total virtual cost



Statistical distribution: Disposal volume