Risiko- og pålitelighetsanalyser

Eksempler på anvendelsesområder med fokus på P&A og CO_2 lagring

Eric Ford, Seniorforsker

07.02.2023

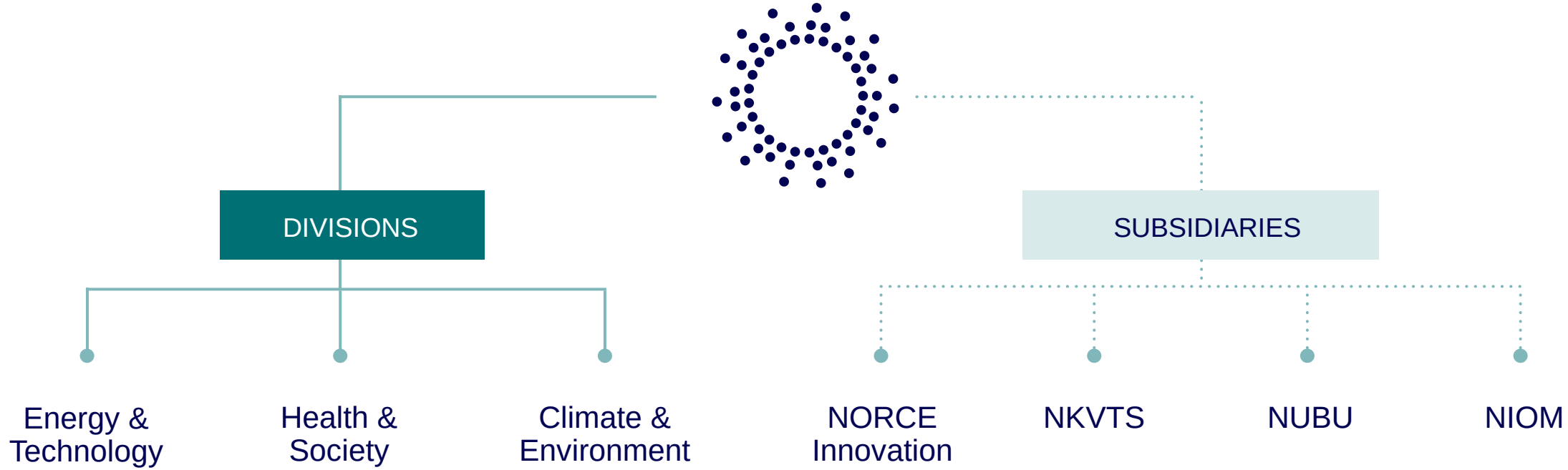
Agenda

- NORCE: Organization and research
- Past project experience
- Focus areas 2023
- Examples of applied risk research (P&A, CCS, ++)

NORCE

Organization and risk-related research

How we are organised



DIVISION → RESEARCH GROUP

Energy & Technology

Well Operations and Risk Management

Sigmund Stokka
Brønnoperasjoner og risikostyring Research Director Well Operations and Risk Management - Stavanger

Employees (14)

Amir Taheri Taheri
Researcher - Stavanger
amit@norceresearch.no
+47 51 87 51 61
+4745109952

David Gardner
Special Adviser Well Operations and Risk Management - Stavanger
daga@norceresearch.no
+47 51 87 91 82
+47 404 60 090

Eric Patrick Ford
Senior Researcher - Bergen
erfo@norceresearch.no
+47 51 87 56 17

Jon Tømmerås Selvik
Senior Researcher - Stavanger
jsel@norceresearch.no
+47 51 87 50 99

Katherine Beltrán Jiménez
Researcher - Stavanger
kajt@norceresearch.no
+47 51 87 52 92

Mohammad Mansouri
Senior Researcher - Stavanger
mman@norceresearch.no
+47 51 87 51 12

Øystein Arild
Special Adviser Well Operations and Risk Management - Stavanger
oyar@norceresearch.no

Erlend Randeberg
Senior Researcher - Stavanger
erra@norceresearch.no
+47 51 87 50 76
+47 936 22 917

Hans Joakim Skadsem
Senior Researcher - Stavanger
hask@norceresearch.no
+47 51 87 52 25

Hans Petter Lohne
Senior Researcher - Stavanger
halo@norceresearch.no
+47 51 87 50 61

Neda Olsen
Senior Researcher - Stavanger
neol@norceresearch.no
+47 51 87 52 99

Peter Breuhaus
Chief Scientist - Stavanger
pebr@norceresearch.no
+47 51 87 50 77
+47 920 19 068

Steinar Kragset
Senior Researcher - Stavanger
stkr@norceresearch.no
+47 51 87 54 30

PhD (2)

Risk and reliability research at NORCE

Division	Group	Field	Topics	Approx. researchers
Energy & Technology	Well operations & risk management	CCS	Storage integrity/Leakage simulation	4
		Exploration Drilling	Safe operating limits	
			Blowout analysis	
			Oil spill preparedness modelling	
		Energy vectors/sectors	Risk modelling/security of supply	
		Plug & Abandonment	Well barrier integrity/Leakage modelling and experiments	
		Geothermal drilling	Risk assessment of geothermal wells	
		Well construction	Cost uncertainty assessment	
		Value of information	Decision making	
	Earth observation	Avalanche and landslide hazard and risk	Monitoring/Analysis	3
	Computational Geosciences and Modelling	CCS	Fault-related leakage risk	3
	Sustainable Energy Research Labs	CCS	Well integrity/injectivity	2
	Modelling and Simulation	Hydrogen	Risk perception/acceptance	2
	Digital Systems	Offshore wind energy	Social acceptance/environmental effects/maintenance optimization	2
	Drilling and Well Modeling	Drilling Automation	Real-time drilling safeguards and monitoring	4
Health & Social Sciences	Climate, environment & sustainability	Avalanche and landslide hazard and risk	Societal risks	2
	Work place and innovation	Invisible hazards	Risk perception/acceptance/communication	4
Climate & Environment	Forecasting Engine	Climate risk	Seasonal forecasting/Disaster risk	2
	Gene technology, environment and society	Modern gene technology	Biosafety issues for gene-edited products	2
	Earth Systems	Ocean biogeochemistry	Risk assessments of marine ecosystems	2
3	**12**	**18**	**20**	**32**

Risk & reliability-related publications: 2022

Title	Topics	Group
A Framework to Capture the Relationships in Drilling Data and the Propagation of Uncertainty	Drilling data, uncertainty	Drilling & Well Modeling
Advances in the subseasonal prediction of extreme events: Relevant case studies across the globe	Climate risk	Forecasting Engine
Benefit and risk assessment of fish in the Norwegian diet - Scientific Opinion of the Steering Committee of the Norwegian Scientific Committee for Food and Environment	Biochemistry, contamination	Health & Social Sciences
Exploring the complexity of hydrogen perception and acceptance among key stakeholders in Norway	Hydrogen, risk acceptance	Health & Social Sciences
Oil spill preparedness: Modelling challenges and implications for decision-making	Oil spill preparedness	Risk Management
Evaluation of guidance provided by international standards on metrics and timelines for run-life estimation of oil and gas equipment	Equipment reliability	Risk Management
Risk analysis of unmanned air vehicle and beyond visual line of sight flights : How does systems thinking add to the specific operations risk assessment method?	Operational risk management, aviation	Risk Management
On the new acceptance criteria in NORSOK D-010 for plug and abandonment of wells	Acceptance criteria, P&A	Risk Management
Wellbore stability assessment of an anisotropic shale formation in the North Sea	Well integrity	Risk Management

Experience: Projects/topics

NORCE
Risk Management

Eric Patrick Ford
Senior Researcher - Bergen
erfo@norceresearch.no
+47 51 87 56 17

Jon Tømmerås Selvik
Senior Researcher - Stavanger
jsel@norceresearch.no
+47 51 87 50 99

Hans Petter Lohne
Senior Researcher - Stavanger
halo@norceresearch.no
+47 51 87 50 61

Øystein Arild
Special Adviser Well Operations and Risk Management - Stavanger
oyar@norceresearch.no

Drilling & Well construction

Blowout risk

BLOWFLOW

Drilling risks

RiskVoyance

Oil spill preparedness

CoArc: A transatlantic innovation arena for sustainable development in the Arctic

Decision analysis

VOI software

Well construction cost

Risk€

Subsea wells

Equipment reliability

OREDA

Plug & Abandonment

Leakage risk / Well barrier integrity

P&A Innovation Program

PETROMAKS2-Stort program petroleum
Fluid Migration Modelling and Treatment
Alternativ tittel: Analyse og behandling av lekkasjeveier i ringrom utenfor foringsrør

CCS

Leakage risk / storage integrity

CO2 SPICER

REPP CO2

ENOS

Geothermal wells

Leakage risk / storage integrity

GeoWell

Energy sectors

Energy supply security

ELEXIA

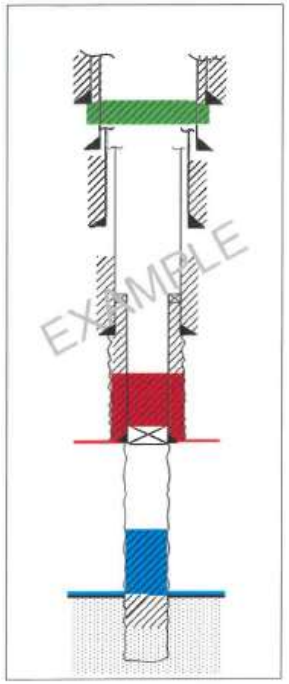
Focus areas 2023

- Areas of application:
  - Plug & Abandonment (P&A)
  - Carbon Capture & Storage (CCS)
  - Energy Grids
  - Offshore Wind
- Focus for risk assessments
  - Stochastic/Bayesian methods
  - Decision-making contexts
  - Comparing risk metrics
  - Communicating uncertainty meaningfully

Risk-based approach to Plugged & Abandoned Wells (P&A)

P&A Leakage Calculator: Quantifying quality of cemented well barriers

Plugging & Abandonment (P&A)



NORSOK D-010:2021

- Oil & gas wells are required to be plugged and abandoned (P&A) at end of their operative life cycle.

- ~3000 wells on Norwegian Continental Shelf (NCS) need to be P&A'ed in the future.

- Estimated cost (per Sintef) ~800 Billion NOK
- Required plug length (per NORSOK-D010) 100/50/30 m
- Reducing cost: New technology? Changing requirements?

Sintef-forsker: Ryddejobben etter oljealderen blir dyr

Sintef-forsker Harald Linga advarer mot en rådyr ryddejobb når oljealderen ebber ut de kommende tiårene.

Edvard Grieg-feltet i Nordsjøen. Foto: Håkon Mosvold Larsen / NTB

Av NTB

Publisert: 21. august 2021

https://e24.no/det-groenne-skiftet/i/ALRK3q/sintef-forsker-ryddejobben-etter-oljealderen-blir-dyr

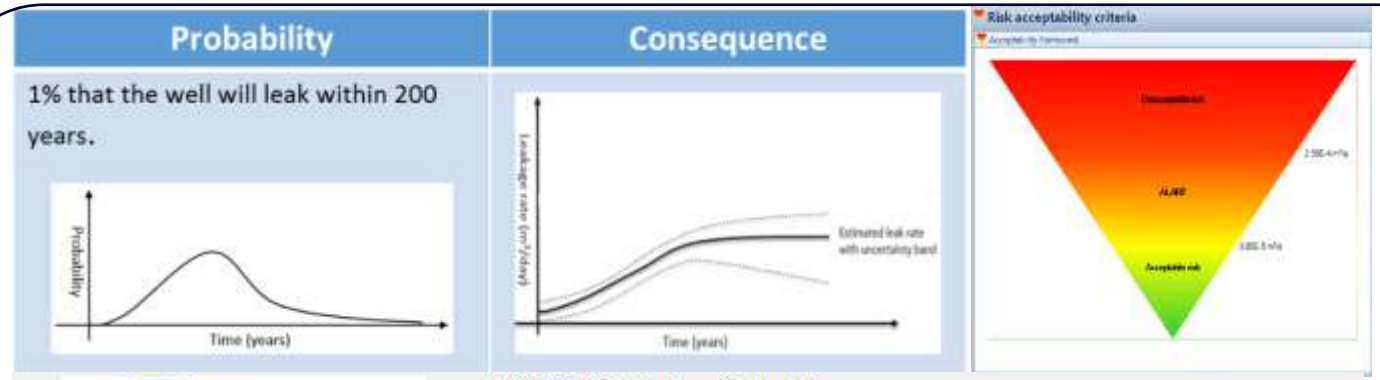
P&A Leakage Calculator: A Risk-based approach to P&A

P&A Leakage Calculator

P&A Innovation Program

Well under consideration for PP&A → Propose permanent barrier design → Design quality assessment: Compliance with NORSOK D-010? / Acceptable risk? → Final barrier system (A)

Quality evaluation, expressed in terms of leakage risk



- Decision support for P&A design
- Cost/benefit of alternative P&A designs
- Establishing risk acceptability criteria
- «Risking» of well barriers
- Estimation of expected barrier lifetime
- Environmental impact of various seepage scenarios
- Conformity to prevailing standards/guidelines?
- Sensitivity of P&A design vs. Well integrity

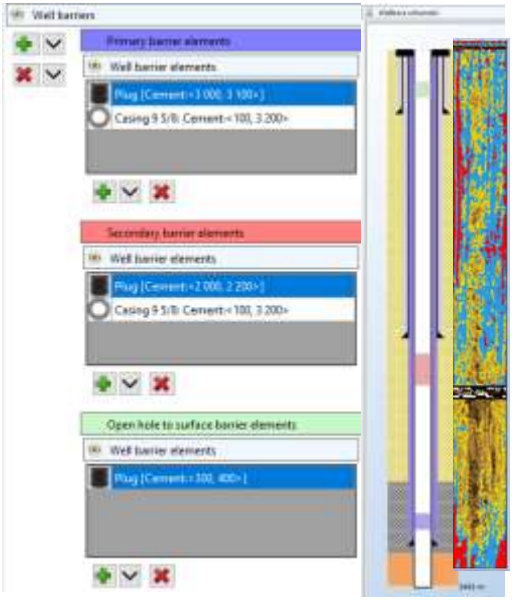
P&A Leakage Calculator - Overview

P&A Leakage Calculator

Stochastic/deterministic

INPUT DATA

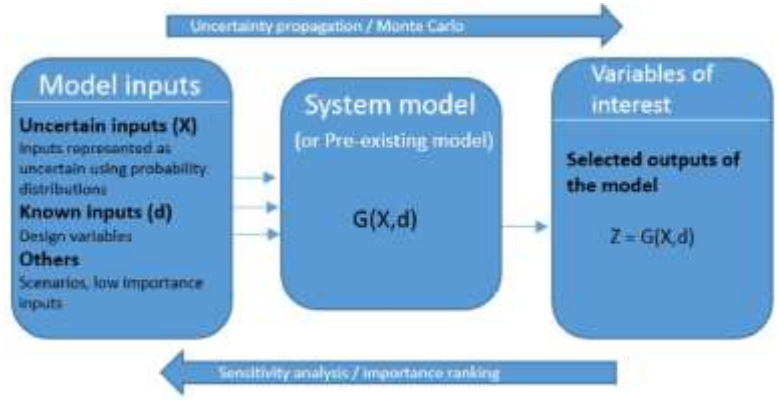
Well information
Geological information
Reservoir properties
Proposed well design
Proposed P&A design
Plug material mechanical properties
Well barrier envelopes
Failure mode properties
Lifetime data
Acceptability criteria



P&A Leakage Calculator
NORCE.Risk.LeakageCalculator
Version 1.6.2
NORCE
NORCE.Risk.LeakageCalculator

MODELS

PVT model
Material Balance model
Stress model
Failure Mode model
Microannuli models
Leakage Rate model
Time-To-Failure model
Monte Carlo Simulation framework



RESULTS

Total leakage rate over time
Total leakage rate per well barrier
Failure probability per barrier
Importance analysis per barrier/failure mode
Sensitivity analysis for plug length/location
Comparative analysis for alternative P&A designs

P&A Leakage Calculator: Input overview

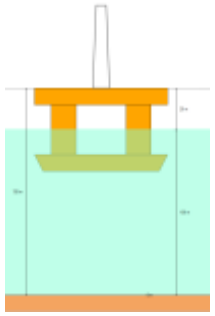
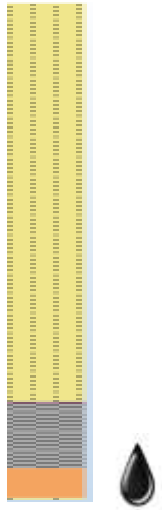
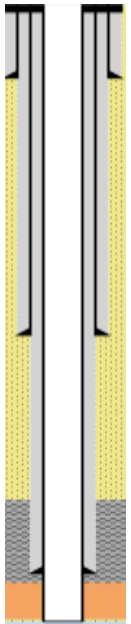
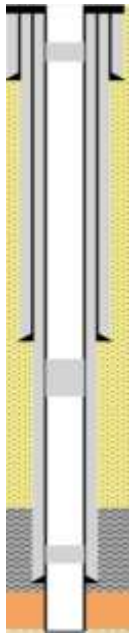
CATEGORY

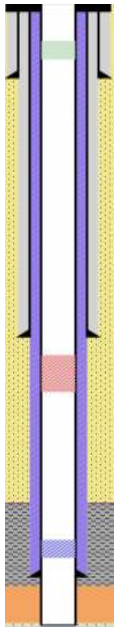
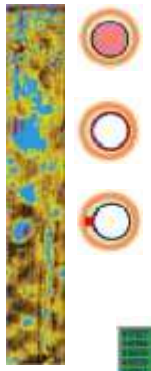
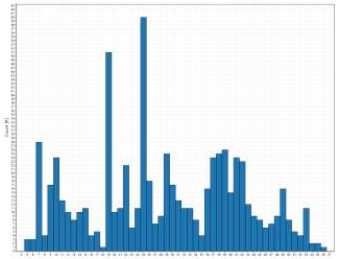
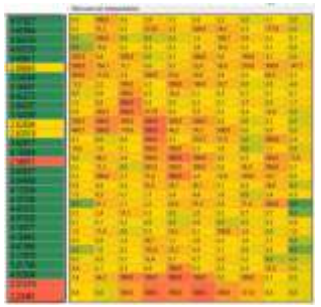
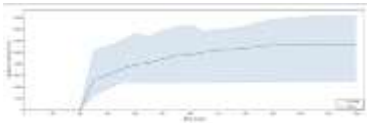
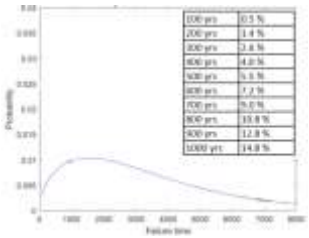
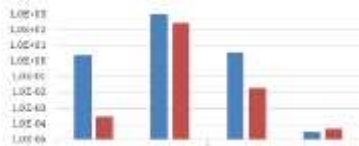
How is well designed?	What are the well barriers?	How can barriers fail?	Consequence?

General info | Formations | Casings | Plugs | Plug materials | Barriers | Failure modes | Failure data | Results

INPUT DATA

Name Location Operator Offshore?	Depth Rock type Reservoir? (Fluid properties) (Pressure evolution)	Depths Dimensions Cemented segments	Depth Length Material	Permeability Mechanical properties Degradation	Type WBE's	Possible failures Crack size Microannuli model Log data	Screening: similarity to historical data	Leakage rate evolution MTTF Sensitivity Comparative analysis

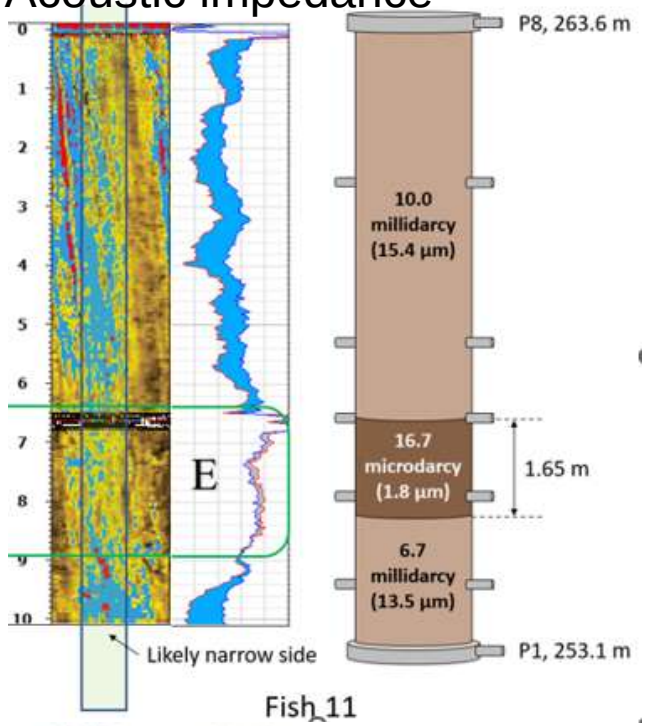





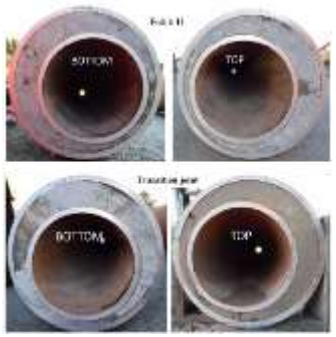








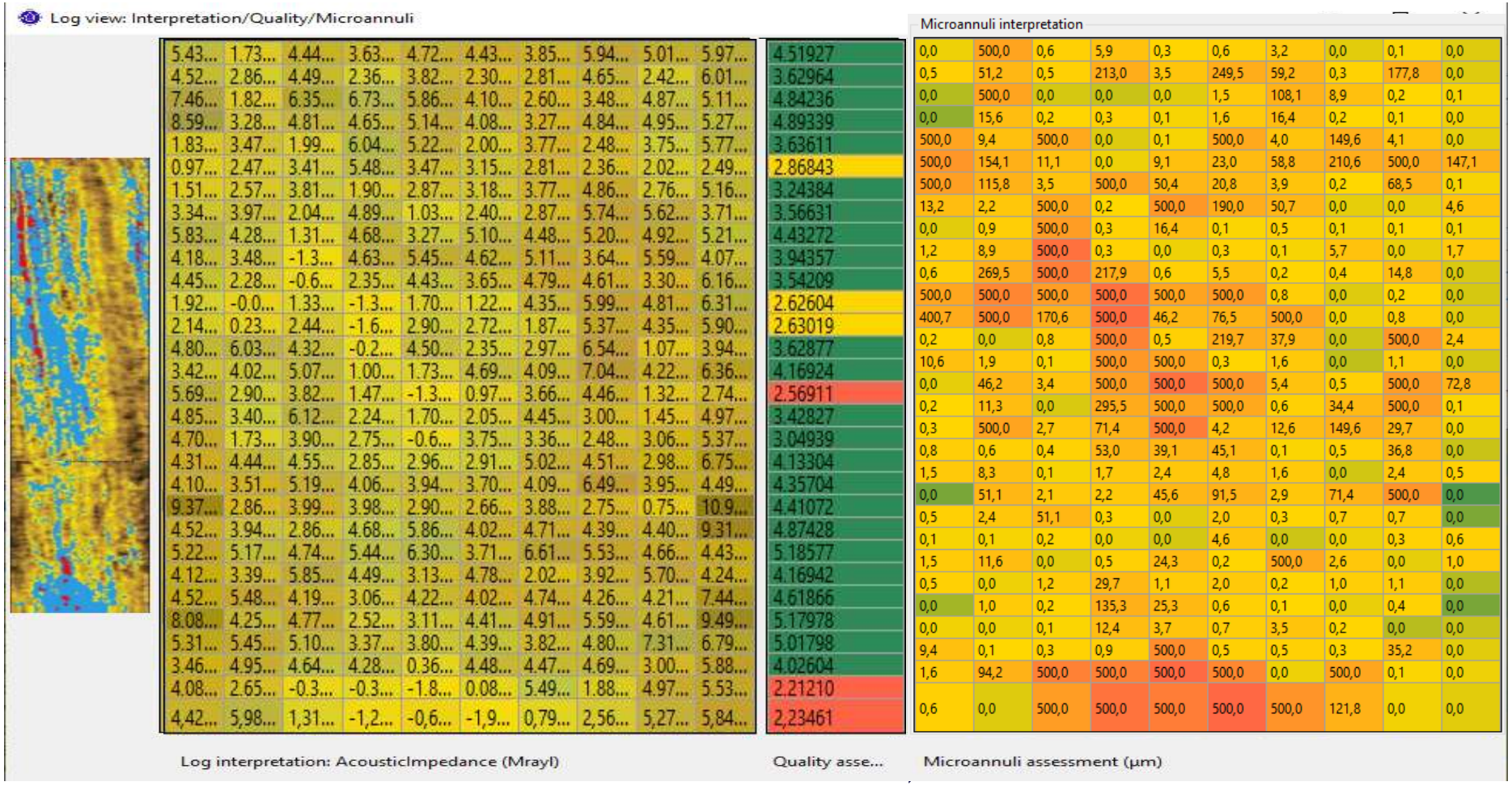
Challenge: Convert information to risk-related metrics

P&A Leakage Calculator

Cement-bond log:
Acoustic impedance







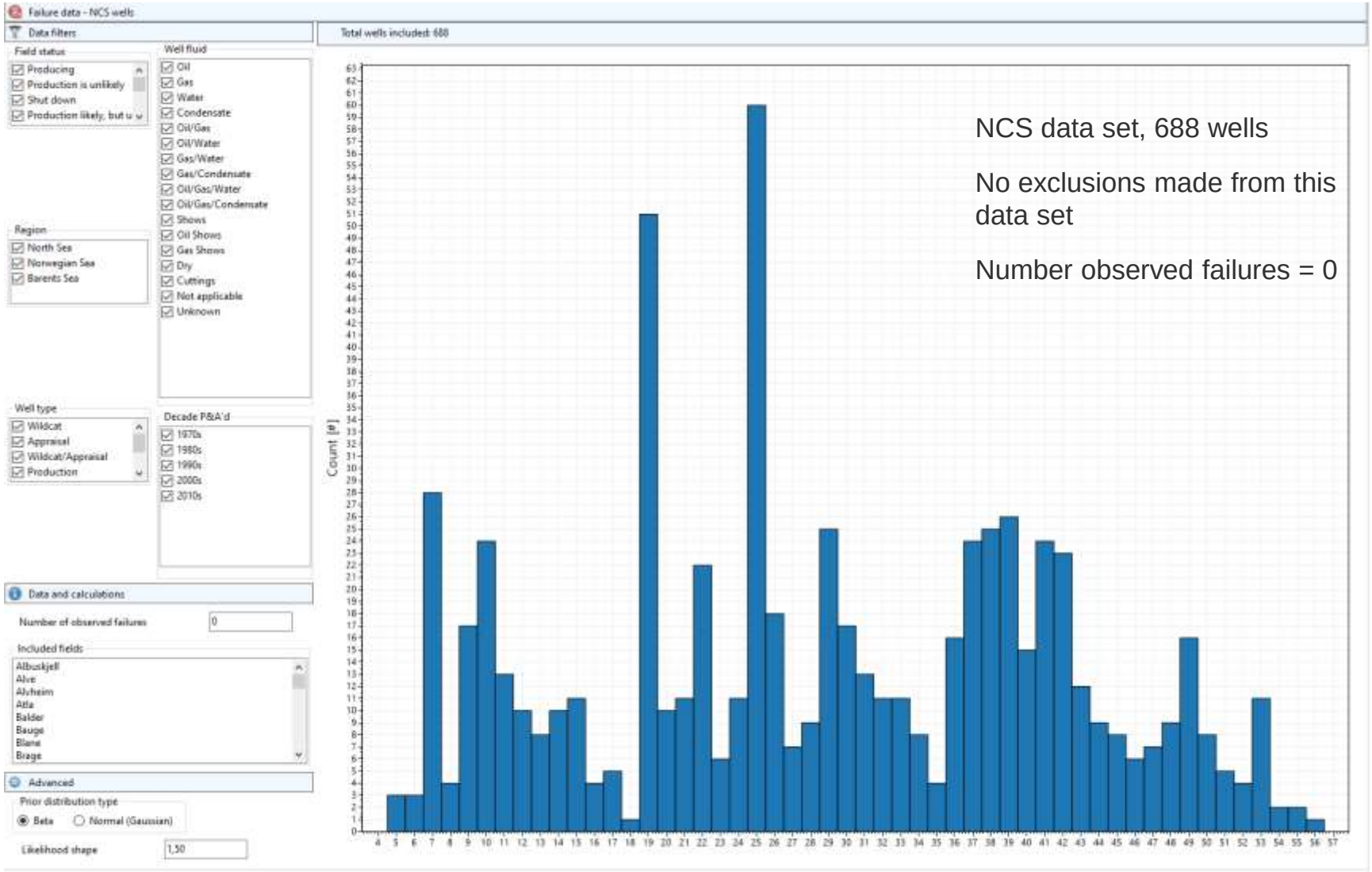
Model representation

Barrier quality

Microannuli
(risk-related metric)

Skadsem, H. J. 2021. «Study of Annular Permeability and Ultrasonic Log of a Sandwich Section Retrieved from a North Sea Production Well.» *Submitted to SPE Drilling & Completion* 1-21.

Challenge: Evaluation of «barrier performance» – NCS well data



OLJEDIREKTORATET

FAKTASIDER
OLJEDIREKTORATET

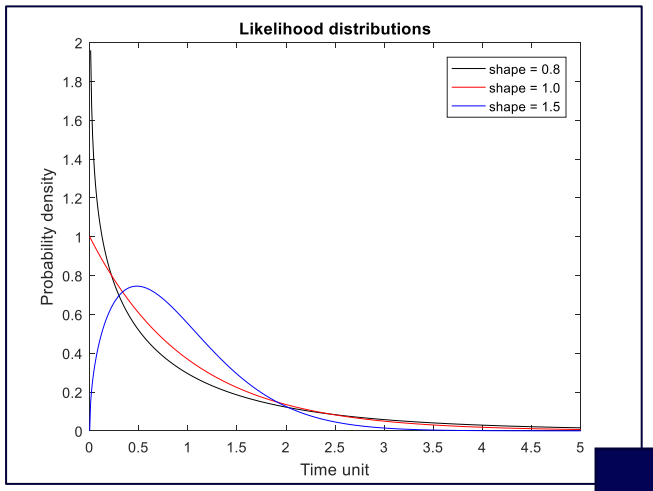
Data collected from the publicly available webpages of the Norwegian Petroleum Directorate

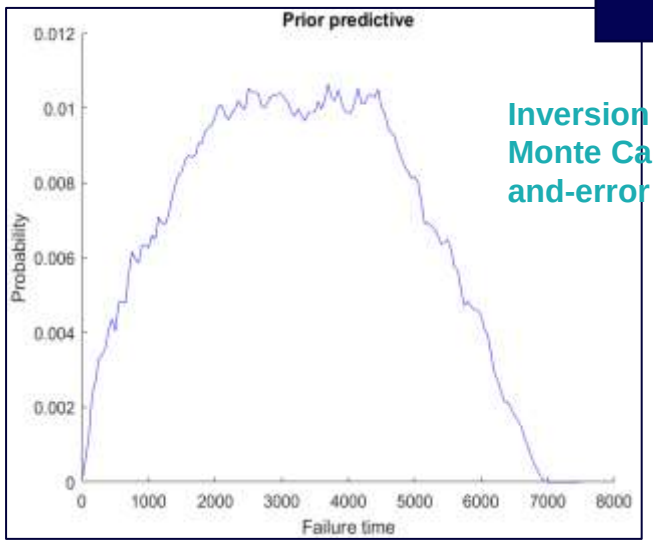
Framework: Bayesian approach

- Combines relevant data, in this case survival data, and a physical model for how failure occurs
- Need to make an assumption on the probability distribution that explains time-to-failure; in this case we have selected a Weibull distribution
- In a Bayesian setup, the physical model is assigned as «prior information», while the survival data are «data»
- Parameter updates are conducted by using Bayes formula

Bayesian methodology

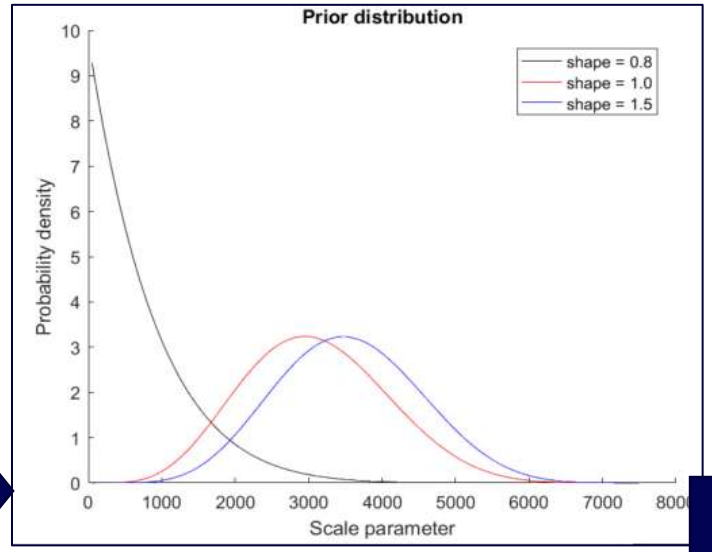
Shape of failure rate (increasing,constant, decreasing)



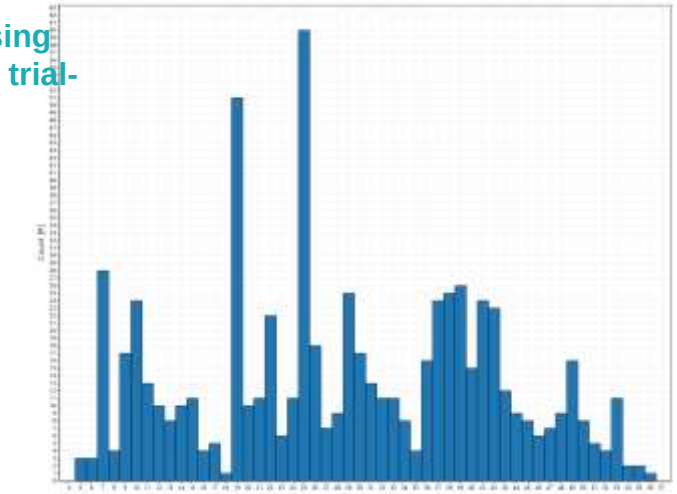


Physical model for microannuli

Prior distribution



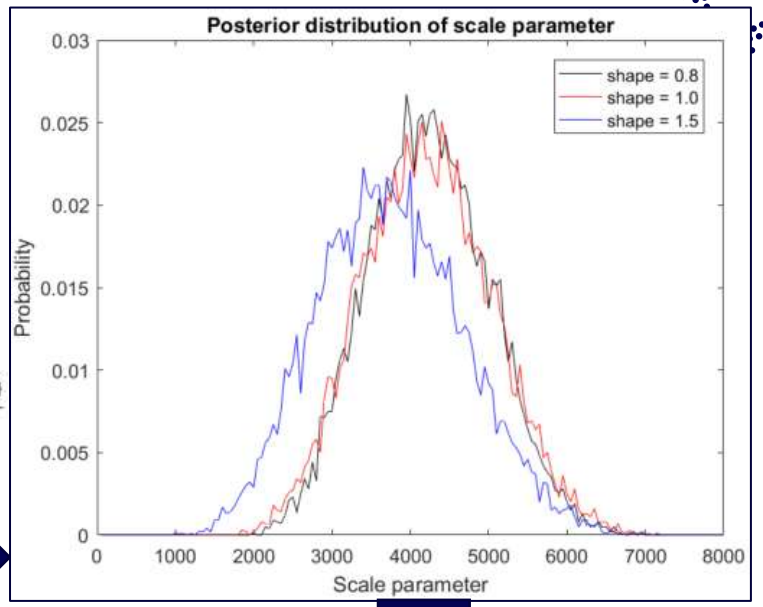
Inversion using Monte Carlo trial-and-error

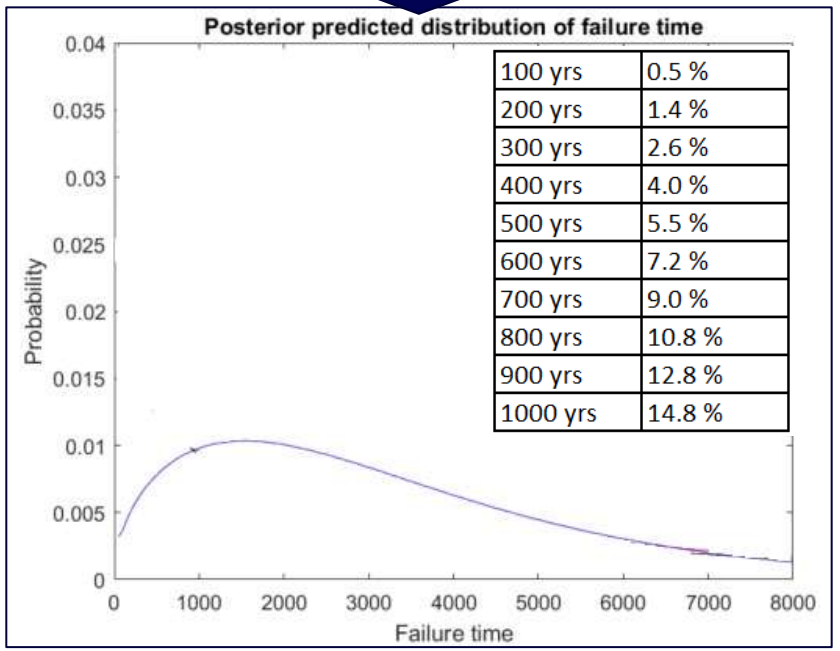


Lifetime distribution for P&A'ed wells on the NCS

$$P(A|B) = \frac{P(B|A)P(A)}{P(B)}$$

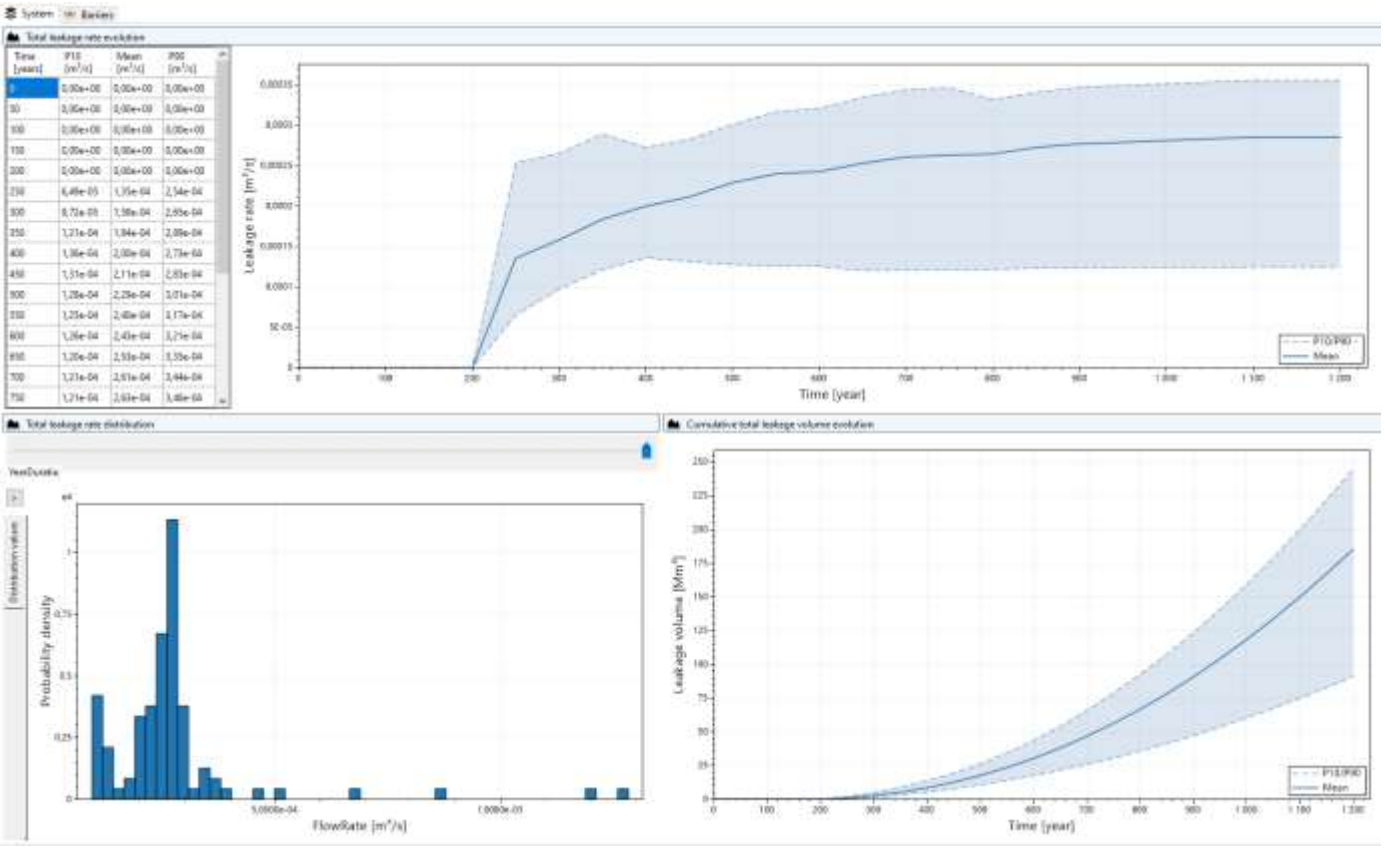
Bayes formula

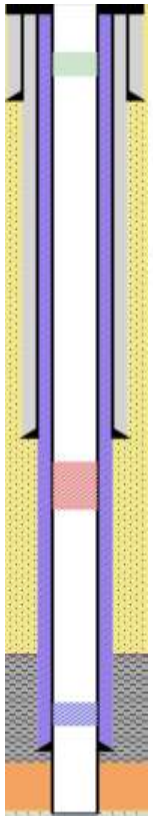


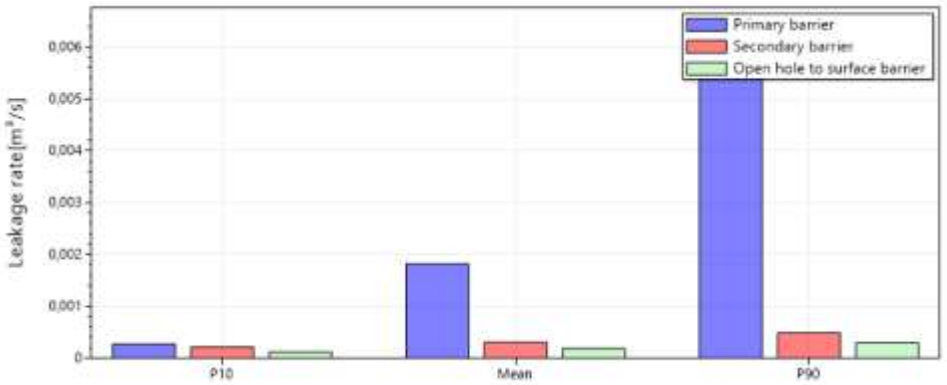


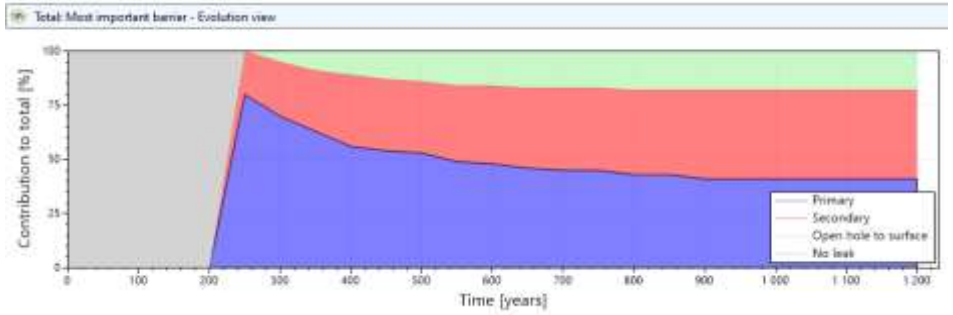
100 yrs	0.5 %
200 yrs	1.4 %
300 yrs	2.6 %
400 yrs	4.0 %
500 yrs	5.5 %
600 yrs	7.2 %
700 yrs	9.0 %
800 yrs	10.8 %
900 yrs	12.8 %
1000 yrs	14.8 %

Leakage rate results

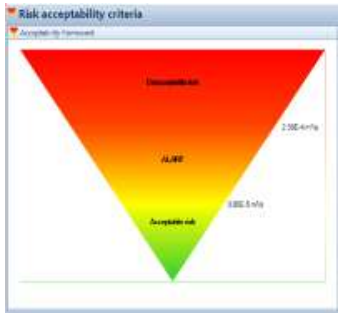






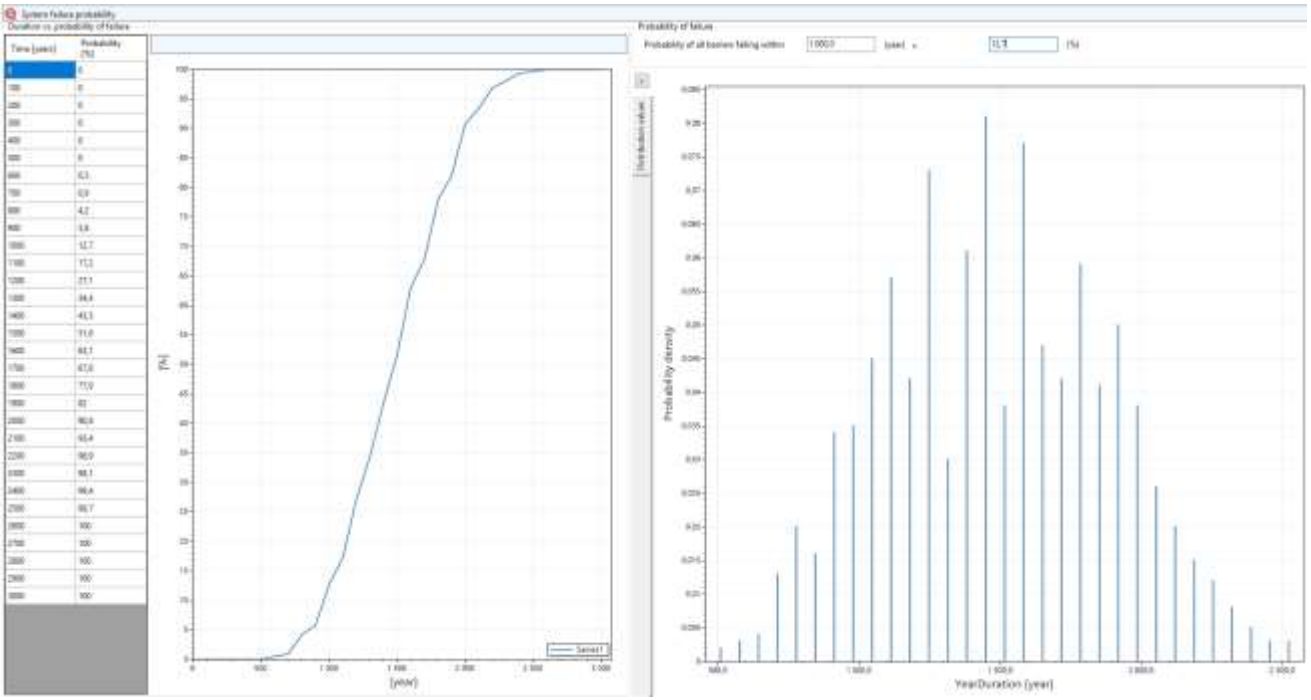


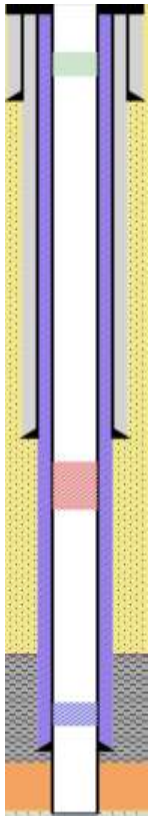
- System or barrier level leakage rate over time
- Estimated released volumes
- Importance and relative comparison of barriers

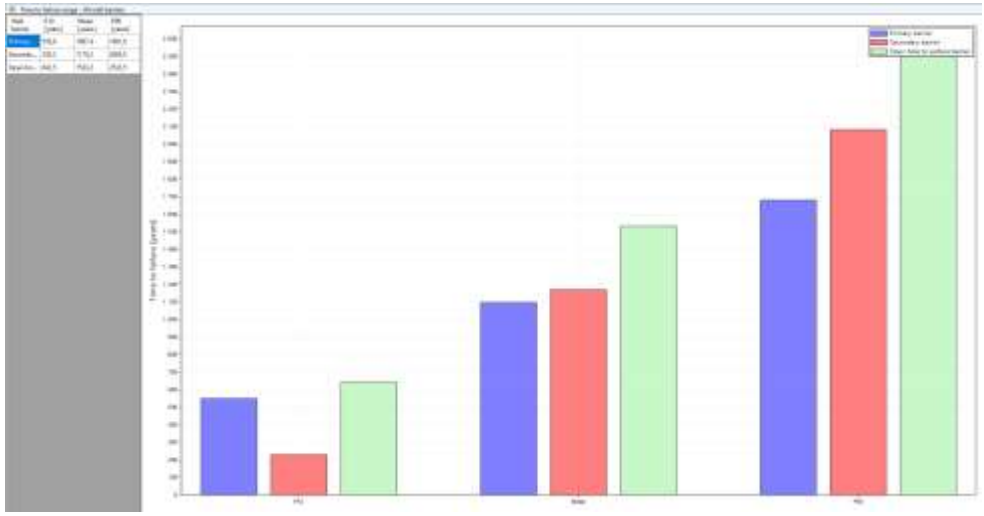


Is risk acceptable?
How can risk be reduced ALARP?

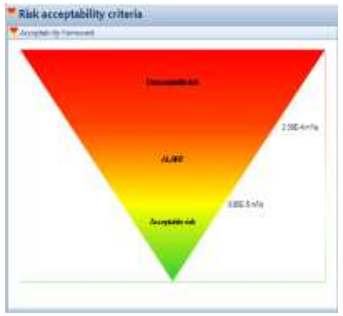
Probability of failure results





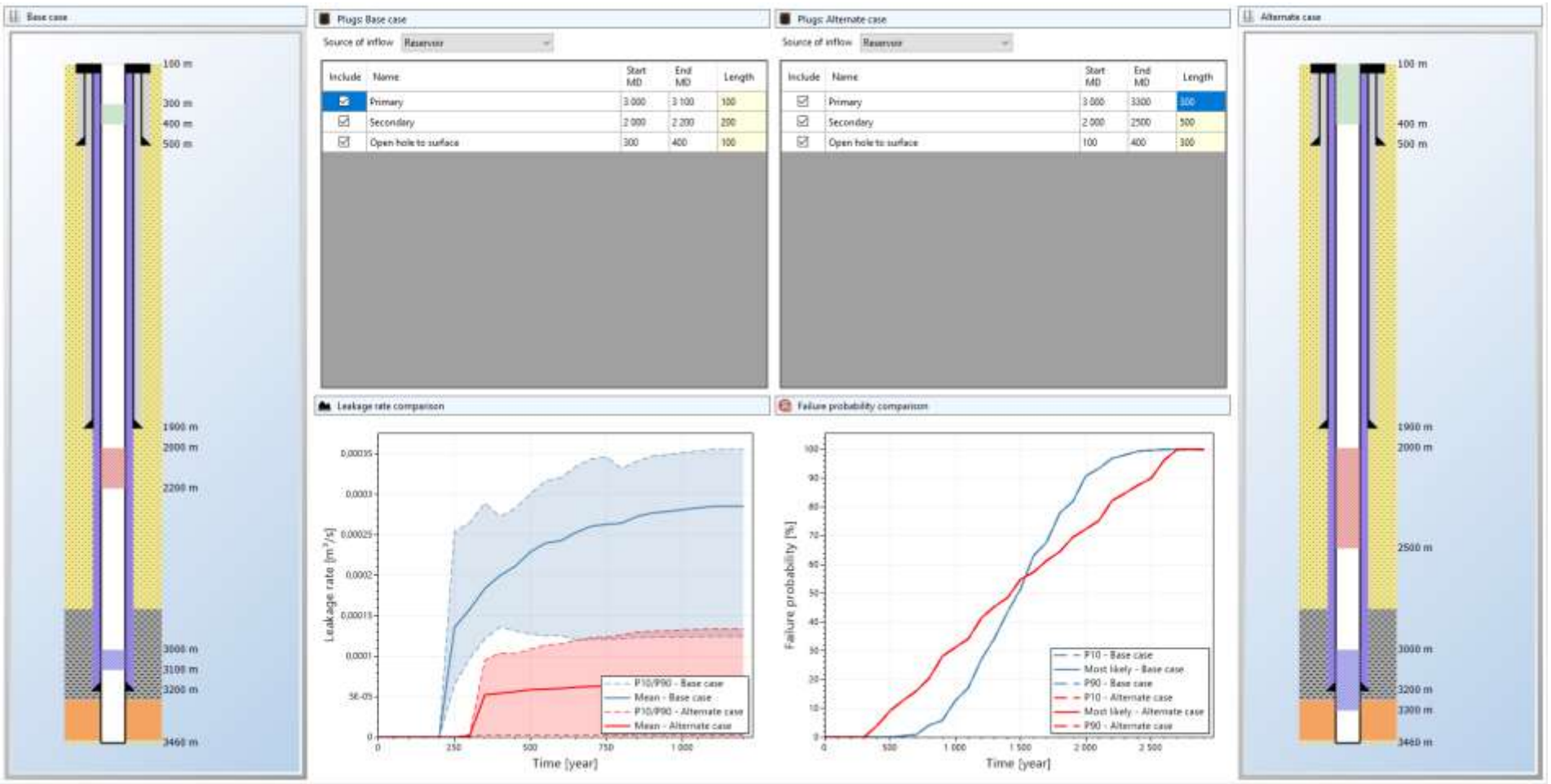


- System or barrier level Mean-time-to-failure
- Importance and relative comparison of barriers



Is risk acceptable?
How can risk be reduced ALARP?

Using results to compare P&A designs



Base case

Alternate case

- The framework allows for comparing the quality of alternate P&A designs, using potential leakage rate or expected time to failure
- Differences could depend on e.g.
  - Barrier material
  - Barrier location
  - Barrier length
  - Failure assumptions
  - +++

Accept existing P&A design or modify?

CO2-SPICER

CO2 Storage Pilot in a Carbonate Reservoir

Norway grants | CO_2 SPICER

CO_2 Storage Pilot in a Carbonate Reservoir

Project title: **CO2-SPICER - CO2 Storage Pilot in a Carbonate Reservoir**

Grant: **The CO2-SPICER project benefits from a € 2.32 mil. grant from Norway and the Technology Agency of the Czech Republic.**
The project is carried out under the KAPPA funding programme for applied research, experimental development and innovation, managed by the Technology Agency of the Czech Republic.

Project duration: **11/2020 - 04/2024**

Project coordinator:

- Czech Geological Survey

Project partners:

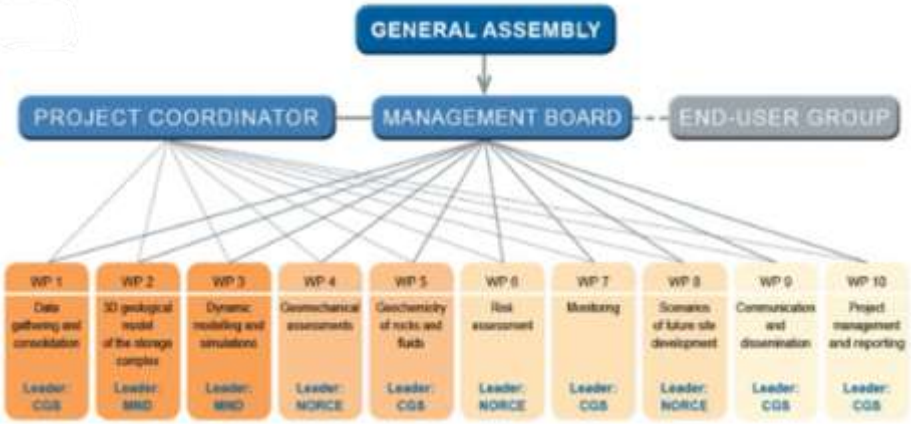
- MND a.s.
- VSB - Technical University of Ostrava
- Institute of Geophysics of the Czech Academy of Sciences
- NORCE Norwegian Research Centre

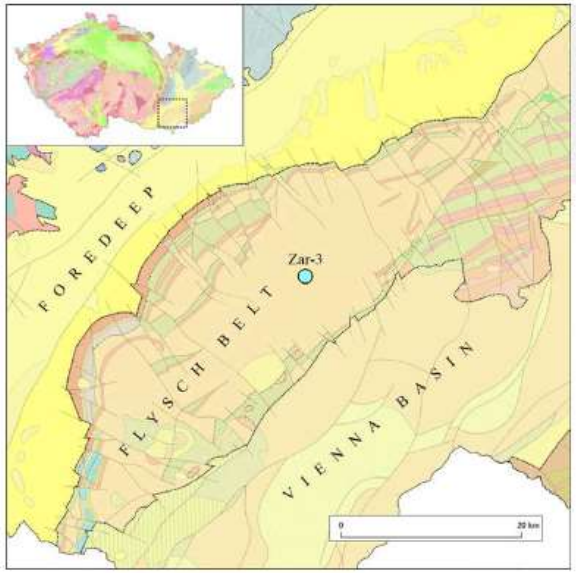
Czech Geological Survey COORDINATOR | MND | VSB Technical University of Ostrava Faculty of Mining and Geology | Institute of Geophysics | NORCE

https://co2-spicer.geology.cz/en

CO2-SPICER: Project

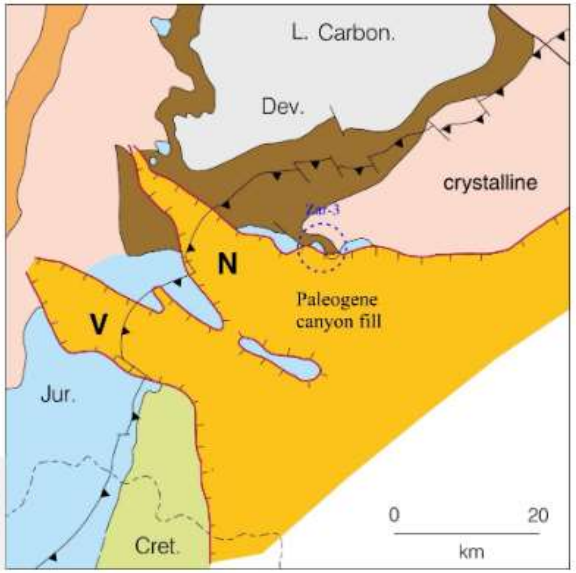
- Main project objective is to prepare implementation of a CO2 geological storage pilot project at the mature Zar-3 oil and gas field in the Czech Republic (achieve implementation-ready stage)
- Main identified leakage risk is from abandoned wellbores
- How would leakage of natural gas or CO2 disperse and impact on surroundings?





Position of Zar-3 site on geological map of the Czech Republic. Source: CGS ArcGIS server map services

(http://www.geology.cz/extranet/mapy/mapy-online/esri).

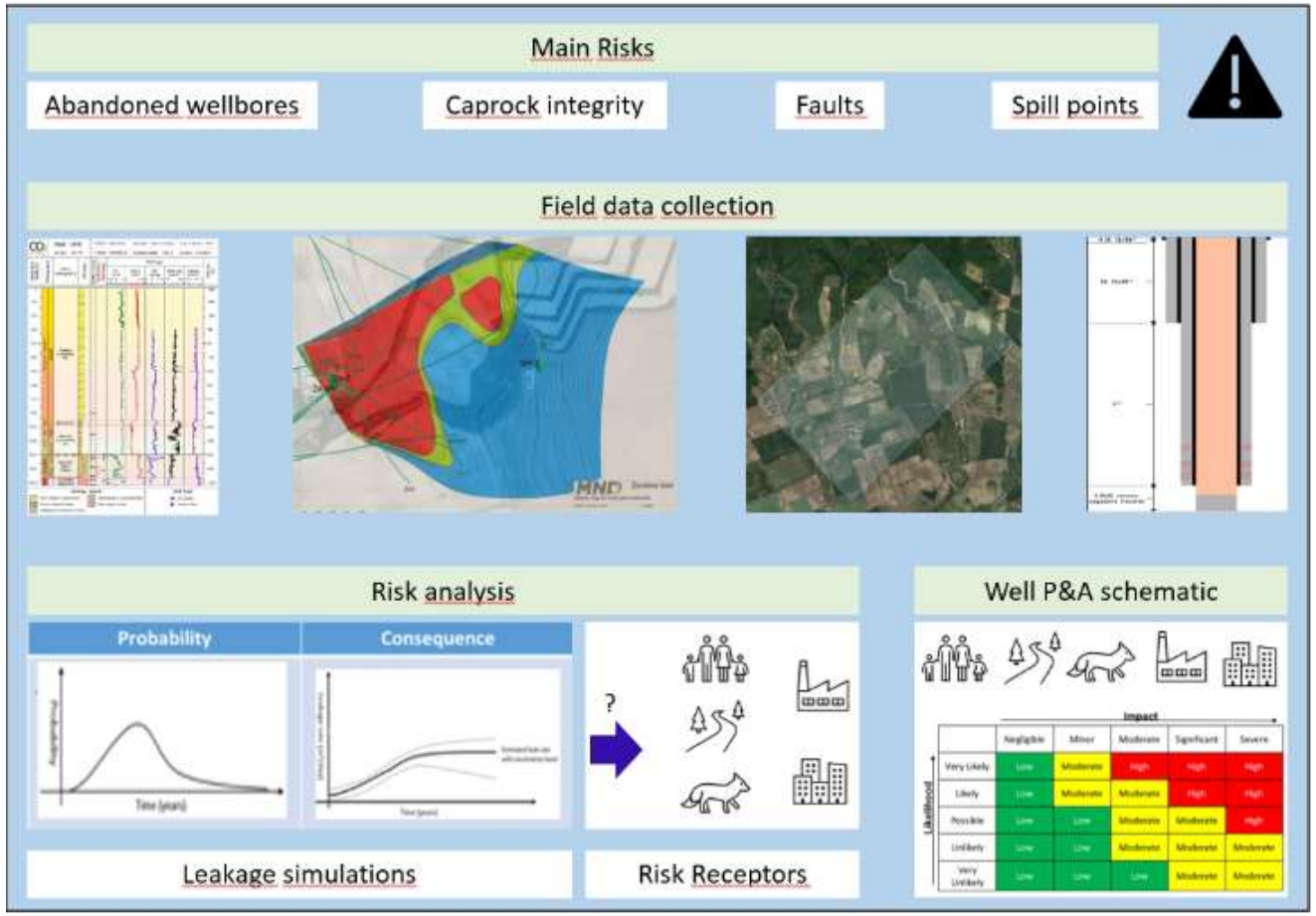


Pre-Neogene subcrop map showing the Nesvacilka (N) and Vranovice (V) paleovalleys. Picha et al. (2006).

https://co2-spicer.geology.cz/sites/default/files/2023-01/Hladik-CO2-SPICER-GHGT-16_22-10-20_0.pdf

CO2-SPICER: Risk analysis

- Collected data will be used to simulate leakage through abandoned wellbores, caprock, faults and spill points, next step will address the risk to various receptors



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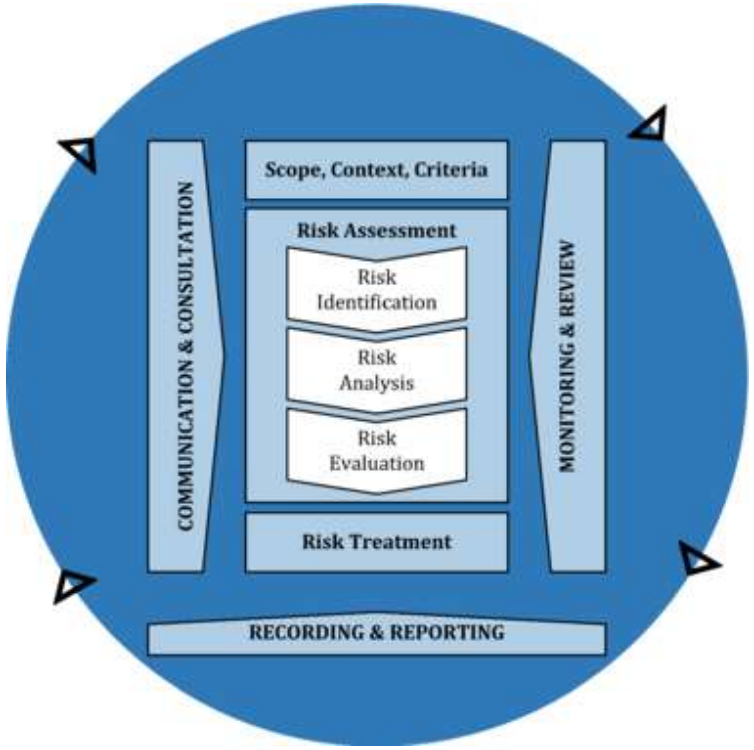
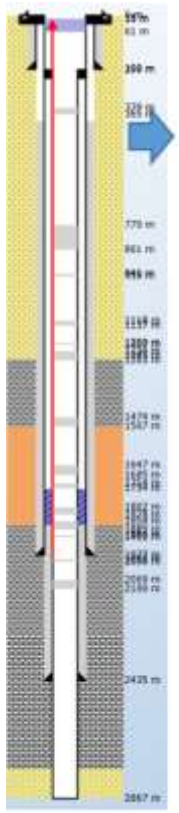
NORCE : WP6 Risk analysis



ISO31000:2018

CO2-SPICER: Site storage integrity

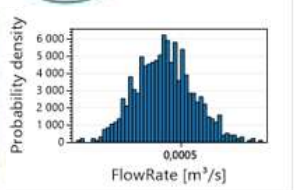
- Determining most likely point of leakage and possible magnitude, as a basis for estimating possible concentrations of released gas

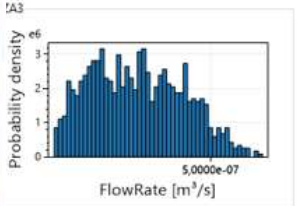


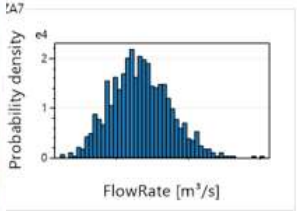
Likely leak path by breaching well barriers

Wellbore locations

P&A Leakage Calculator

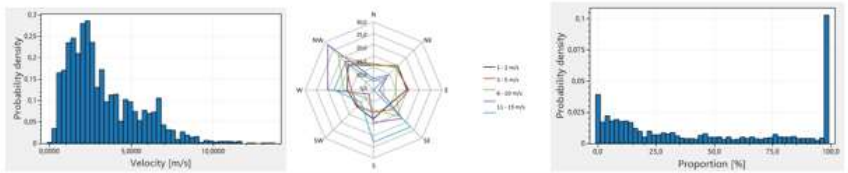




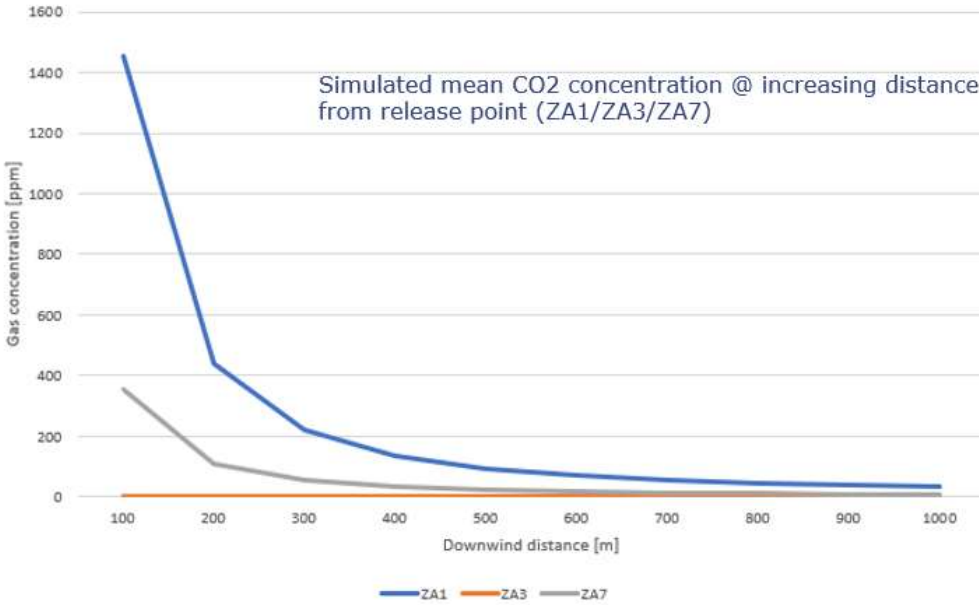


CO2 leakage rate simulations per well

Local metereological data



CO2 concentration vs downwind distance: ZA1 v ZA3 v ZA7



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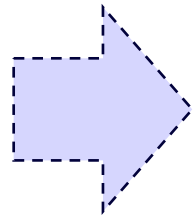
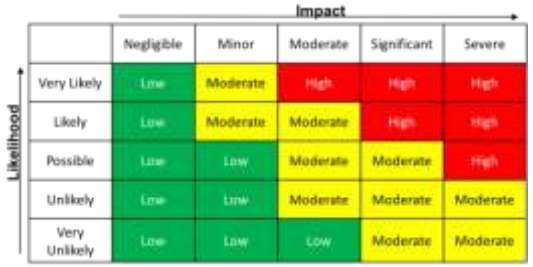
CO2-SPICER: Release scenarios

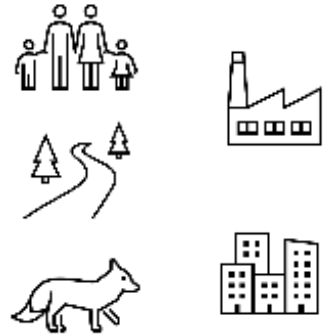
- Release scenarios can in turn be used as a basis for determining possible consequences for risk receptors, and as a basis for evaluating acceptable risk.

Green = [0, 400] ppm CO2; Yellow = [400, 2500] ppm CO2; Red = ≥2500 ppm CO2





	Negligible	Minor	Moderate	Significant	Severe
Very Likely	Low	Moderate	High	High	High
Likely	Low	Moderate	Moderate	High	High
Possible	Low	Low	Moderate	Moderate	High
Unlikely	Low	Low	Moderate	Moderate	Moderate
Very Unlikely	Low	Low	Low	Moderate	Moderate



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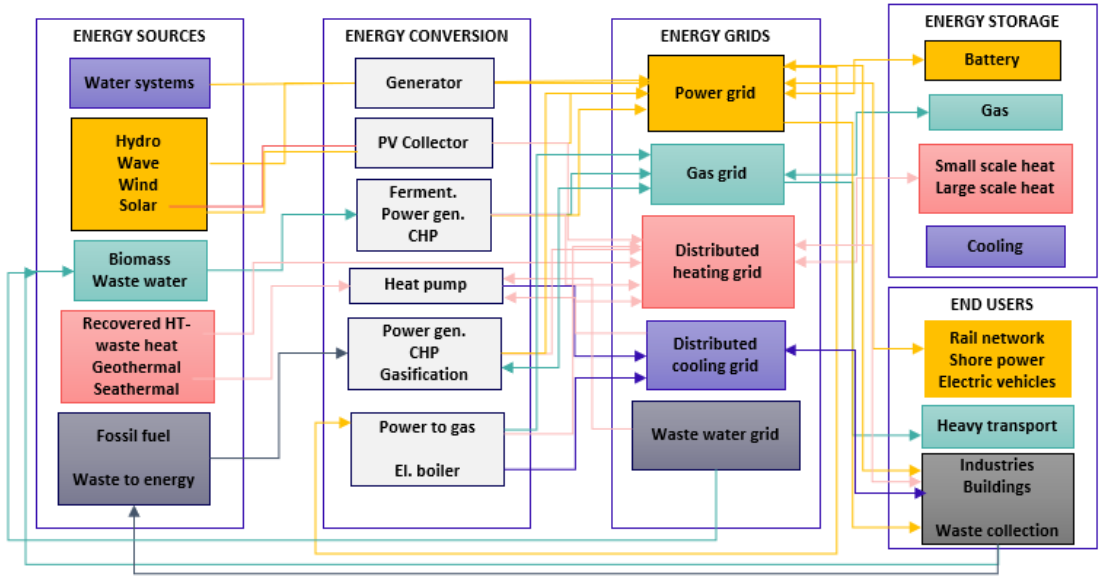
ELEXIA

Reliability of energy supply across sectors and vectors

ELEXIA T2.3.4: High-level concept

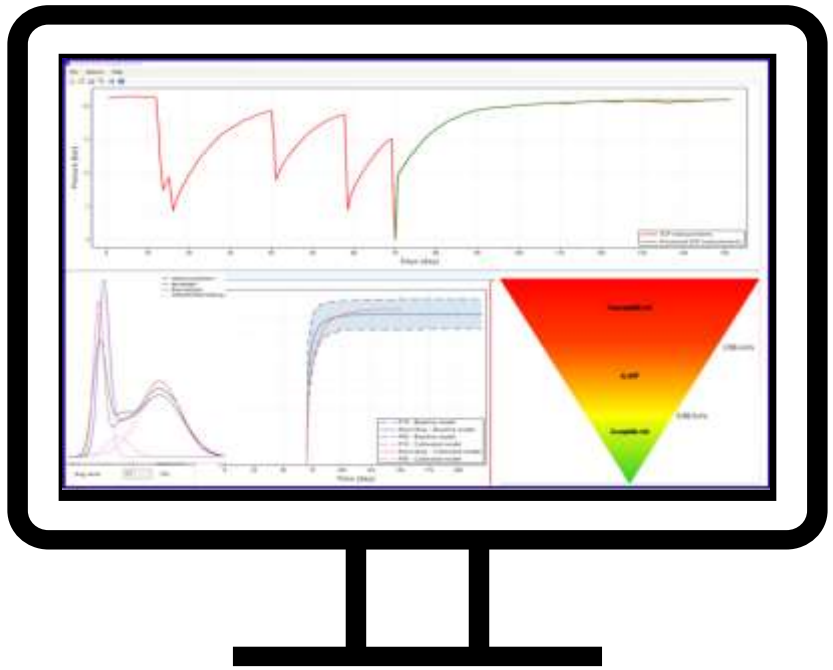
Real world: Interactions between energy system components



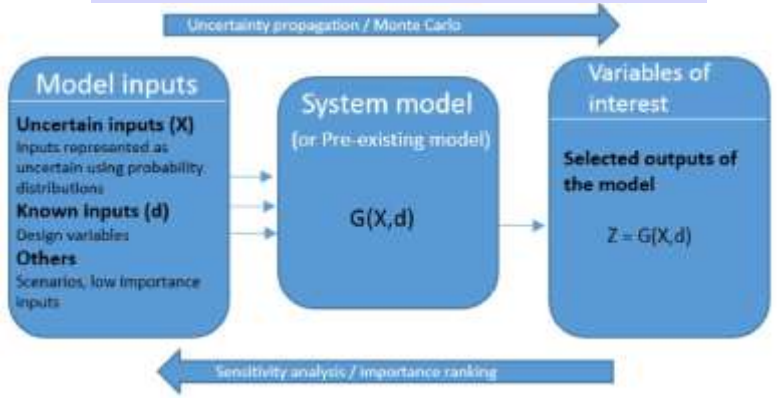
Based on ELEXIA proposal, Fig. 1

Decisions/Changes

Simulation results:
Decision support
Contingency measures
Maintenance planning
Optimization



Model representation: Energy supply reliability

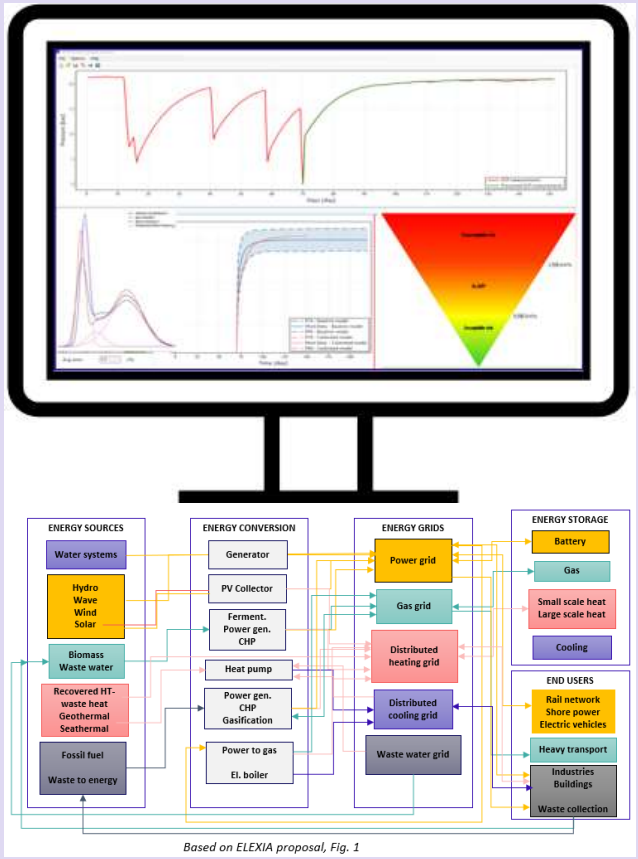


Model implementation: Software for scenario simulations

Co-funded by the European Union

Model utilization

Security of supply prototype software



Based on ELEXIA proposal, Fig. 1

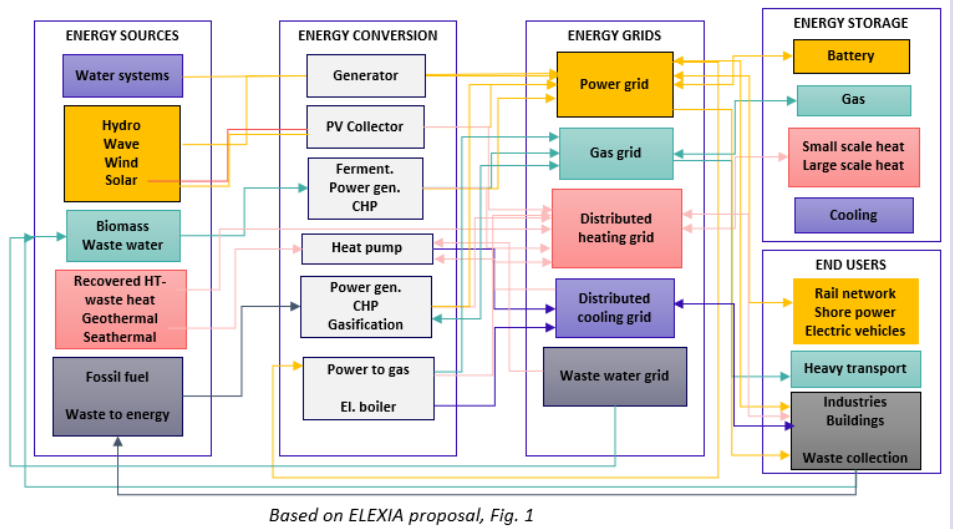
Simulation results

Which failures are most critical?
Failure impact on energy supply
Varying conditions impact on energy supply
What is expected time to detect and repair failures?
System vulnerabilities
Operation optimization potential
Maintenance optimization potential

Decision making:

Measures to reduce system/component failure probability?
Measures to increase redundancy?
Measures to optimize maintenance strategy?
Measures to detect failures?
Measures to increase resilience/flexibility?
Measure to improve outage restoration?
Measures to reduced uncertainty?

Proposed changes



Based on ELEXIA proposal, Fig. 1

Thank you. Takk. Merci. Gracias. Obrigado.

Eric Ford
erfo@norceresearch.no

norceresearch.no

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