Summary
of the 2019
Cavern Abandonment Workshop

HEIKE BERNHARDT

Workshop| Utrecht | 15 October 2024

Ministerie van Economische Zaken en Klimaat

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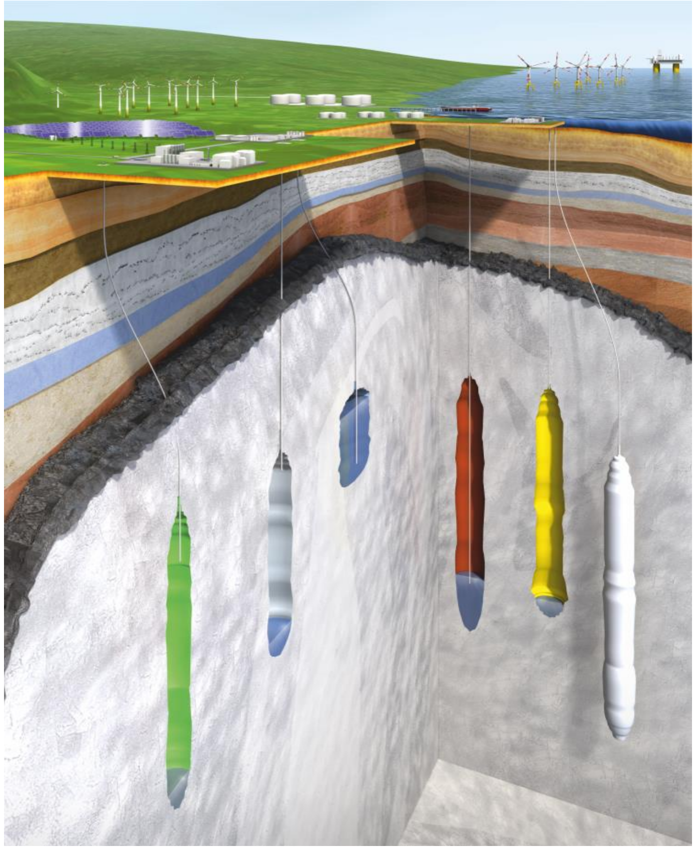
Summary Abandonment Workshop 2019

Agenda

- Motivation
- Sessions and Discussion
- Key Points and Main Conclusions



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Motivation

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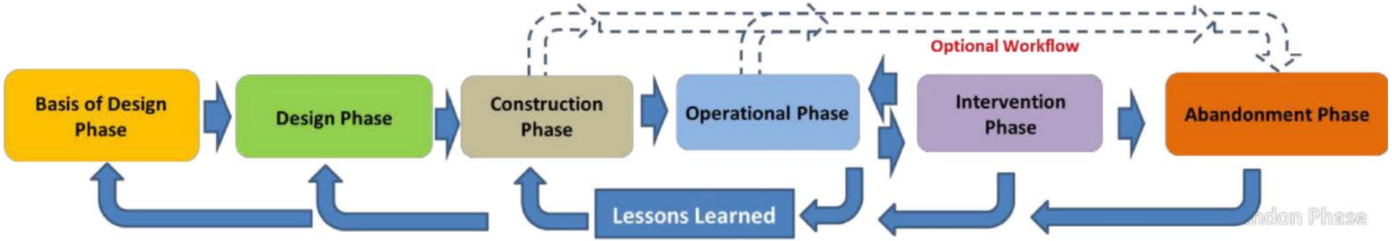
Motivation



Reference: DIN EN ISO 16530 Well Integrity Part 1: Life Cycle Governance

Until now already **long time** of salt mining and **construction of caverns** (existing in various status: from construction to abandoned).

Because of the energy transition **storage of energy is needed** → possibly in salt caverns

In the Netherlands: salt caverns were a result of salt production, but will **development** of salt caverns in future be **solely for storage** purposes?

And **considering the life cycle**: what will be the long-term consequences?

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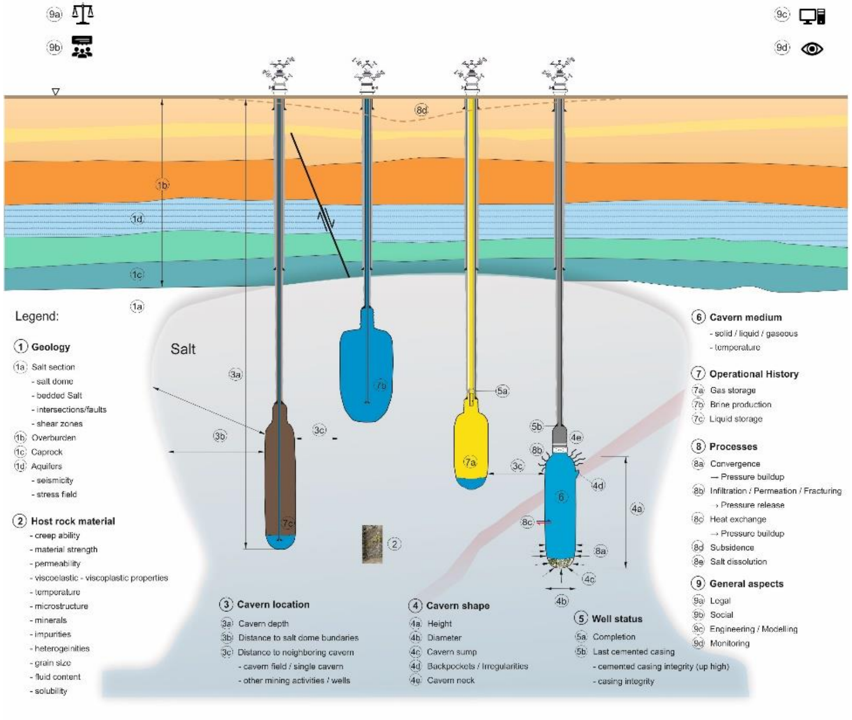
Motivation

Technical Topics…

- Geology
- Rock mechanics
- Cavern Well
- Processes
- Operation



…and beyond

- Legal
- Social
- Science /Engineering / Modelling
- Monitoring

→ Holistic approach required
→ Definition of aims
→ How to find the right approach to address and overcome challenges?

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Sessions and Discussion

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Sessions and Discussions

Session 1

State of the Art

Pierre Bérest & Benoît Brouard Historic overview of cavern abandonment practices
Marinus den Hartogh Operator perspective: Nouryon - TWR and Adolf van Nassau
Bart Hendriks Operator perspective: Frisia – Barradeel
Abel Jan Smit Operator perspective: Nedmag – Veendam
Dieter Brückner Abandonment experiences: Stade caverns, IFG

Session 2

Cavern re-use and surface/subsurface interactions: macro-scale.

Ingrid Kroon Introduction to salt mining in the Netherlands, life-cycle perspective
Dirk Zander-Schiebenhöfer / Marinus den Hartogh Assessing cavern interactions
Tobias Pinkse New developments in cavern and well abandonment – monitoring, backfilling and salt-based sealing materials
Peter-John Stehouwer From Pilot to Large Scale H2 storage at Zuidwending

Session 3

Long-term behaviour of sealed salt caverns: micro- to macro-scale.

Prof. Janos Urai Rock salt rheology and permeation: critical review of existing works and recommendations for improving current practice
Antoine Duquesnoy How to combine science with practice in salt cavern abandonment focusing on HSE issues
Prof. Karl-Heinz Lux Numerical simulation in the framework of salt cavern abandonment

Session 4

Regulatory and legal framework

Gijs Remmelts / Ruud Cino Introduction to salt mining in the Netherlands, life-cycle perspective (regulatory dimension)
Martin Hamer / Johann Schuldt Legal framework in Germany. Lessons learnt
Martijn van Gils Legal framework for underground energy storage under the future Environment and Planning Act and Mining Act

Session 5

Relation to other policy domains

Douwe Jonkers Environment and Planning Act, Subsurface Structure Vision

Jos Mol Stakeholder engagement: the local perspective

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Sessions and Discussion - Introduction

- Wish for safety vs. it is safe
- Uncertainties vs. actual risks
- Perception vs. Facts
- Regaining of trust

→ Not only technical

Three key words related to Salt Caverns

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Sessions and Discussion - Statements

Session 1 – State-of-the-Art

- How to handle uncertainties?
  - → existing uncertainties in models – prove by in-situ tests
  - → Use “worst-case-scenarios”
  - → Combination of science and experience essential for practical solutions
  - → Better Input data (e.g. realistic cavern shapes) enables better models
- Caverns are individuals and need individual planning
- Main Aspects Abandonment:
  - → include public regarding relevant time frame abandonment prognosis
  - → Make technical solutions understandable and communicate well

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Sessions and Discussion – Statements

Session 2 – Cavern re-use and surface/subsurface interactions: macro-scale.

- Very Important: Post-Abandonment
  - → Monitoring (correct parameters lead to correct conclusions)
  - → Monitoring already during production / operation
  - → Use micro-seismic as a tool – not public but to enable reactions
- Re-use of caverns: actual challenge to produce hydrogen which can be stored –whereas wide ranging knowledge on storage – including hydrogen – which can be applied

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Sessions and Discussion – Statements

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Session 3 – Long-term behaviour of sealed salt caverns: micro- to macro-scale.

- Is brine leaving the salt dome in itself dangerous?
- How much brine would be a risk?
- Is subsidence in general a risk?

  → In Italy subsidence not a problem, only if sinkhole

  → In Netherlands subsidence in range of mm to be evaluated

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Sessions and Discussion – Statements

Session 4 – Regulatory and legal framework

- For storage and abandonment **clear requirements** (regulation) need to be defined **upfront**
- **Development** of **technical** knowledge should be considered **in legal framework**
- Potential **risks** should be **identified** and **evaluated**
- **Public acceptance** through transparency and inclusion
- **Effective Communication**: say it when there is a **problem** – but also communicate the **positive** things
- Is current legal framework limiting the development of caverns? Yes – also since time period for **liability unknown**

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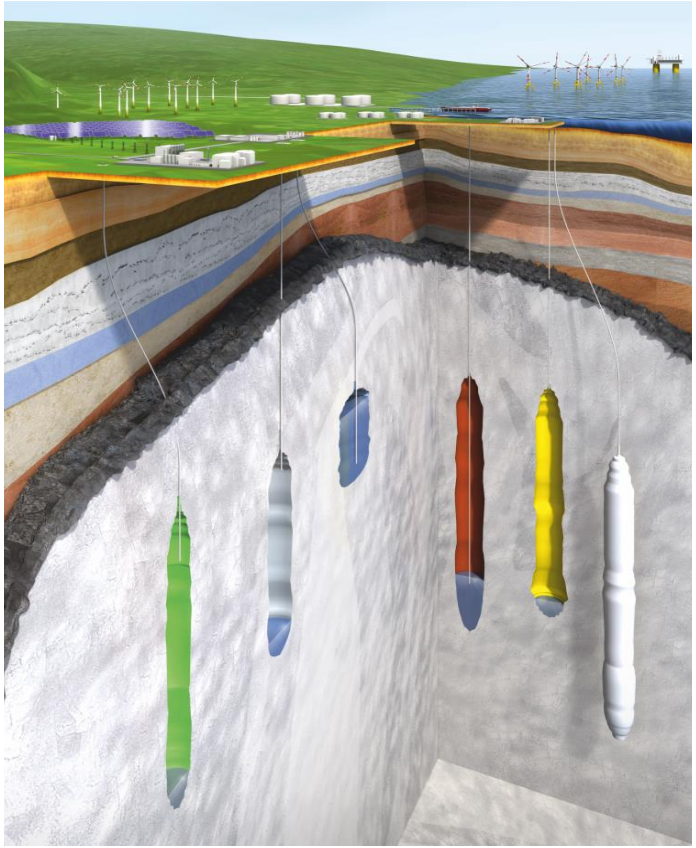
Sessions and Discussion – Statements

Session 5 – Relation to other policy domains

- **Questions** to be expected **from the public**:
  - Is it safe? – how do you know? - how sure are you?
  - Will I be compensated
  - Why here? Why do we need this?
- There is a lot of information – but very technical – **good and understandable information** necessary
- Who should and can **communicate** the information **in the right way**?
- **New rules** should be developed **together** with the public



Key Points and Main Conclusions

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Key Points and Main Conclusions

- Effects and Risks
  - Effects related to salt caverns are subsidence, leakage of brine and foreign materials – depending on individual cavern characteristic
  - Risk free world is not possible – but uncertainties can be limited – how much risk is acceptable?
  - Monitoring during whole cavern life cycle to learn about effects
  - Individual risk assessment and specific abandonment plans desirable

- Challenges
  - Biggest challenge actually non technical – but social / legal challenges
  - Regaining of trust
  - Addressing potential gaps in relation to salt mining, abandonment and re-use; Effects, technical solutions, regulations, legal framework, relation to other policy domains.
  - How long do we want to be protected from risks? Time frame: 2 generations, 10 000 years, even million years?
  - How long will operators be liable?

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Key Points and Main Conclusions

- Technical Aspects
  - In-situ test show that after abandonment there will be: Thermic expansion of the brine (causing the pressure to rise), Creep/convergence of the cavern (causing the pressure to rise), Micro-permeation: infiltration of the brine into the salt (causing the pressure to drop)
  - Material science can help in cavern engineering
  - Study the micro to macro scale processes that influence the long-term behaviour of salt and evaluate the implications and recommendations for abandonment.
  - Backfilling is a proven method in Germany and can prevent caverns collapse (sink hole), leakage of brine and severe subsidence.
- Regulation
  - There is a need for: Standard procedure for activities during the whole life cycle of a cavern (production, monitoring, closure and abandonment). Clear regulation about liability.
  - There is no obligation to re-use caverns for storage.
  - According to the current law it is not allowed to develop a salt cavern without using the produced salt.

Resume of the workshop: Regulatory and technical requirements for responsible abandonment and re-use of salt caverns.

11 & 12 November 2019, Utrecht, the Netherlands, Organized by TNO-AGE, DEEP.KBB and the Ministry of Economic Affairs and Climate Policy

Rationale

Since 1911 about 300 salt caverns have been developed in the Netherlands for salt production, 10 of which are currently used for storage. Many more caverns are possibly needed in the coming decades for salt production or storage of matters such as renewable gases. Concerns regarding long-term safety after closure raise the need to review abandonment practices and regulatory framework for existing and future caverns.

→

Question

What are the key challenges and hurdles concerning the abandonment of salt caverns from both technical and regulatory point of view?

→

Expert workshop

November 2019 TNO and DEEP.KBB organized a two-day workshop to discuss the current state of affairs regarding the regulatory and technical requirements for responsible abandonment and re-use of salt caverns. Participants were operators, policy makers and international industry and scientists.

State of art

- Historic abandonment practices
- Operator perspective
- Abandonment experiences

The Dutch caverns are all in different life-cycle phases, from development to closure. Many caverns are awaiting the proposal and approval of a (customized) closure plan.

In NL salt is produced through solution mining in four different geological settings: i) 400-500 m deep salt beds with disc-shaped caverns, ii) 500-2000 m deep salt pillars with cigar-shaped caverns iii) >2400 m deep salt cushions with rapidly converging caverns, and iv) 1500 m deep highly soluble K-Mg salt layers with irregular network of connected caverns.

Known incidents are related to roof collapse (sink holes) of old caverns in type i) and pressure-drop (brine escape) incidents in type iii) and iv).

Type ii) caverns are mainly envisioned for storage of renewable gases.

Cavern re-use and surface/subsurface interactions: macro-scale

- Life-cycle; technical
- Caverns interaction
- New developments abandonment
- H_2 storage pilot

The cavern life-cycle recognizes 5 phases: i) development/production, ii) storage (optional), iii) closure/suspension, iv) abandonment, v) mitigation. Monitoring is considered a prerequisite for all of these phases.

The structural integrity of an cavern depend on various aspects, e.g.: geology, cavern and well design, placement in clusters, cavern use and closure strategy. This asks for an interdisciplinary approach.

In special situations, backfilling may prevent integrity or stability problems with poorly designed caverns (e.g. roof collapse, sink holes, leakage of brine, strong subsidence).

Pilot projects to investigate large fast cyclic H_2 storage >> risk identification, design verification and evaluation of well and cavern integrity.

Long-term behaviour of sealed salt caverns: micro- to macro-scale

- Rock salt rheology and permeation
- Combine science and practice
- Numerical simulation

Processes after closure:
That increase pressure (P) >> thermal brine expansion and convergence of the cavern. That decrease P >> micro-permeation and fractures (deeper caverns).

In deep caverns P builds-up towards geostatic P, resulting in possible fractures. Possible mitigation >> release brine resulting in subsidence. In shallow caverns P stays below geostatic P.

Recommendation: incorporate material science in cavern engineering >> predict convergence and brine migration after closure.

Progress in understanding of basic mechanisms, physical modelling, numerical simulation, understanding of load-bearing system. Recent insight in role of heterogeneities (rheology). Further improvement is still needed.

Regulatory and legal framework

- Life-cycle; regulatory
- Legal framework Germany
- Legal framework underground storage

The life-cycle phases should be consistently reflected throughout the regulatory framework (e.g. early recognition and progression of closure aspects through phases).

Given future developments, storage should be integrated as optional phase in the salt cavern life cycle.

Legal requirements for cavern closure in Germany: closure plan, compliance with other environmental laws, financial securities.

When storage becomes prime motive for caverns current NL legal framework is not fit for purpose. E.g. disposal of brine is not allowed and optimal caverns dimensions for storage are suboptimal for production purposes.

Relation to other policy domains

- Subsurface structure vision
- Local perspective

How to manage and prioritize all subsurface activities? E.g. potable water, mining, storage, geothermal energy etc.

Good alignment between national and local governance is essential.

What are acceptable risks? And who is liable and for how long? What are the benefits and how are they distributed?

Public acceptance is an important challenge. Re-build trust in government >> by early and open communication, a transparent process, expectation management and clear and accessible knowledge.

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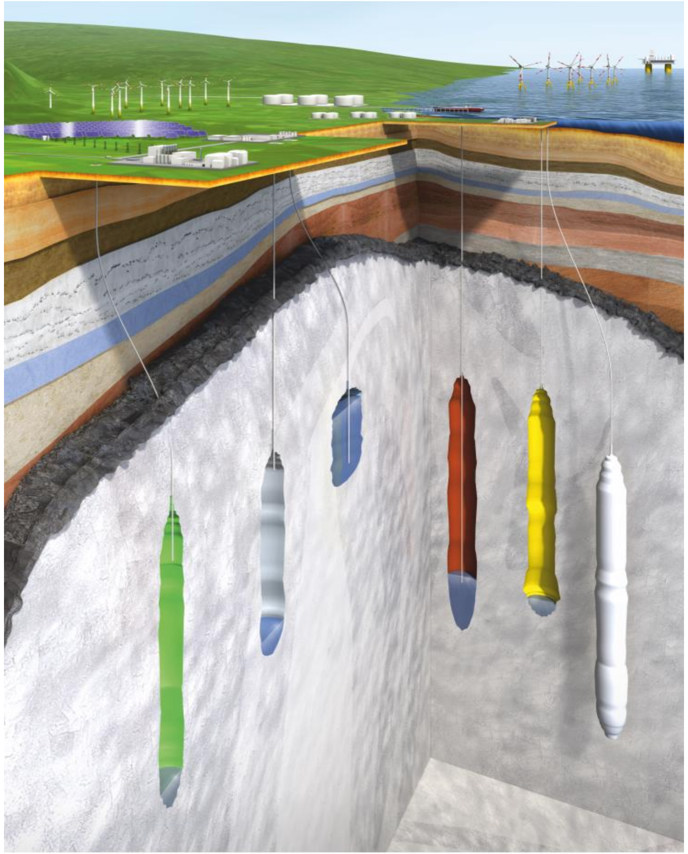

Any Questions?

We look forward to interesting discussions!

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