CO_2 storage: building trust between operator and authorities with a view to transferring residual risk when decommissioning

- a modeller's perspective

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Session F2 (Monitoring)

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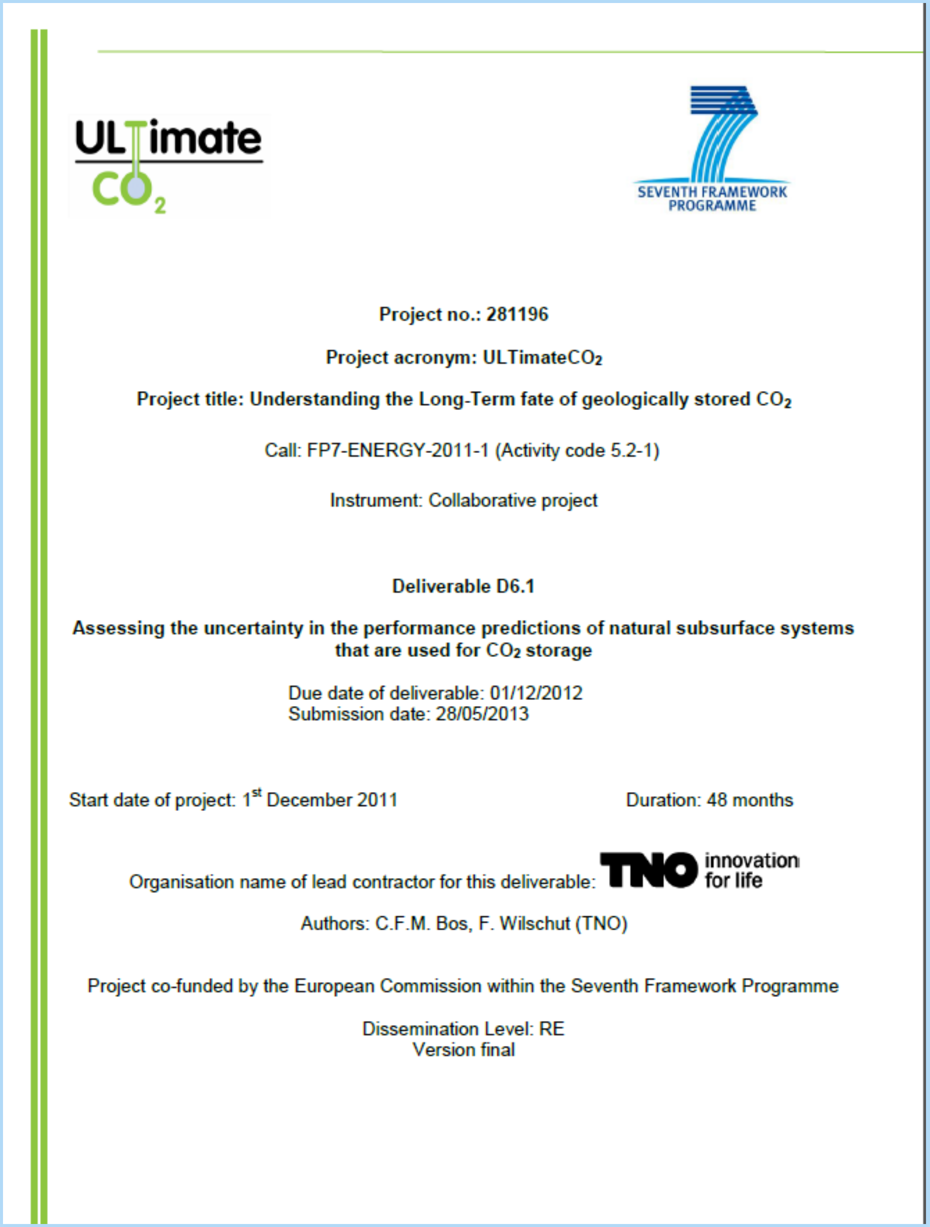
(Understanding the Long-Term fate of geologically stored CO2)

Problem statement

- Forecasting the future performance of a CO_2 storage site is (highly) subjective, but it is required to obtain or prolong a storage license.
- Typically, performance forecasts are made using manpower- and CPU-intensive reservoir simulation models (analytical + numerical) of an ill-determined system ⟶ generating a full suite of possible forecasts, including their relative probabilities and HSE-impacts, is impossible. Choices need to be made. These choices are subjective and generally result in (poorly known, potentially severe) *biases*.
- These biases should be understood and gradually reduced *jointly* by operator & authorities in order to foster *mutual trust and commitment* and have confidence that, when decommissioning, *residual risk* will be agreed & accepted.

Outline of presentation

- Some postulates *from a modeller's perspective*
- Sources of uncertainty
  - Including uncertainty due to poorly understood physics (FMCT)
- Learning objective
- Trust building process
- HSSE-SR trends in E&P
- Conclusion



ULTimate CO2

SEVENTH FRAMEWORK PROGRAMME

Project no.: 281196

Project acronym: ULTimateCO_2

Project title: Understanding the Long-Term fate of geologically stored CO_2

Call: FP7-ENERGY-2011-1 (Activity code 5.2-1)

Instrument: Collaborative project

Deliverable D6.1

Assessing the uncertainty in the performance predictions of natural subsurface systems that are used for CO_2 storage

Due date of deliverable: 01/12/2012
Submission date: 28/05/2013

Start date of project: 1st December 2011 — Duration: 48 months

Organisation name of lead contractor for this deliverable: TNO innovation for life

Authors: C.F.M. Bos, F. Wilschut (TNO)

Project co-funded by the European Commission within the Seventh Framework Programme

Dissemination Level: RE
Version final

Ref. ULTimateCO2 report – **"Assessing the uncertainty in the performance predictions of natural subsurface systems that are used for CO_2 storage"**

Including a practical guide to uncertainty analysis using predictive models of poorly known subsurface systems

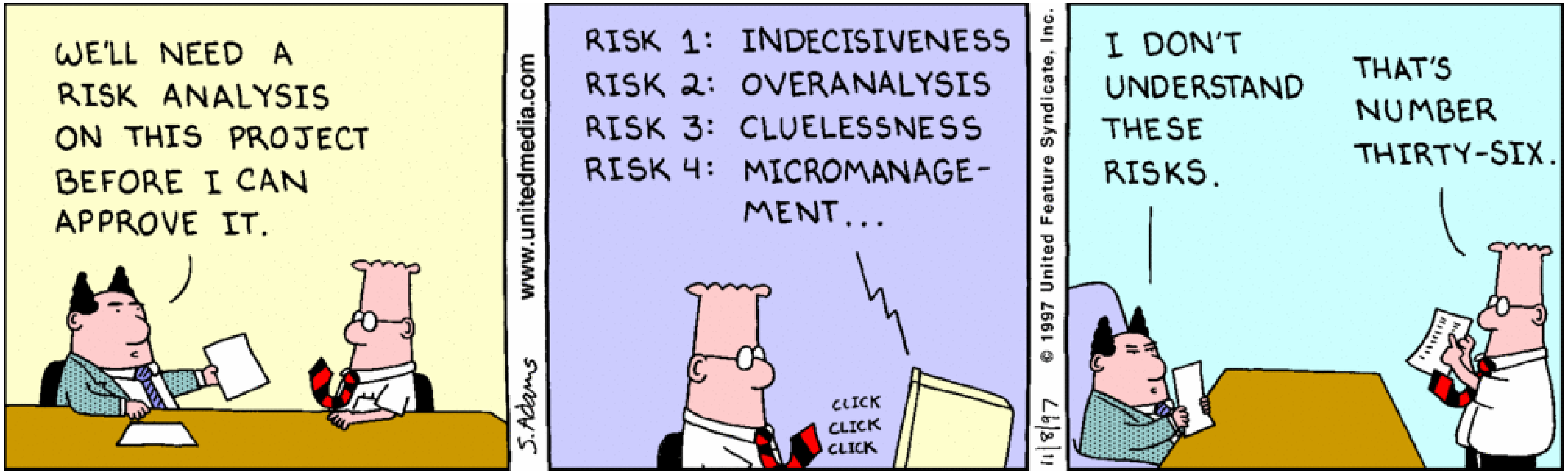
Main postulates & take-aways (1)

- Quantified uncertainty ranges of a CO_2-storage's future performance are inherently uncertain and subjective. This notion should govern one's approach to risk analysis, with *gradual 'learning' about the system* as a primary driver.
- Authorities should see themselves as *life-long (sparring) partners* of the CO_2 storage site's injection operator as they will eventually (have to) take over the site's residual risk when decommissioning.
- Uncertainty / risk assessment of subsurface systems is to be seen as an exercise that obtains its value mainly through *successive modelling studies*. A stand-alone uncertainty assessment is of limited value, as it is inherently subjective. This subjectivity can be reduced by critically comparing successive modelling studies. Authorities have a role in ascertaining the continuity and consistency of such successive studies.

Main postulates & take-aways (2)

- *Under-framing and over-modelling* are common flaws in the uncertainty assessment practice of ill-defined systems. A *formal learning process* is generally missing.
- Ideally, a quantitative probabilistic calibrated FMCT-model of a CO_2 storage site should compute a *pdf of [CO_2]* at any modelled point *x,y,z* at any time step *t* for various operational and exogenous event scenarios. Using probit functions, these arrays of [CO_2] should be transformed into HSE-impact, hence into '*risk*'.
- Depending on the authorities' definition of risk and risk-tolerance, *practical workflows* can be established that reduce the need for comprehensive uncertainty modelling. Reduced-physics, reduced-space and reduced-workflow protocols may give valuable insight at some point in time, but should be *updated* and critically reviewed as new information is being revealed in time.

Objective of RA / uncertainty analysis: avoid Catch-22



- *Support decision-makers* (i.e. storage operator and competent authority):
  - Storage operator: support FID, risk mitigation decisions + support MMV
  - Authority: support licensing decision, support liability transfer decision

- If authority does not *understand* liability risk, he will not take-over the liability when decommissioning storage site. If operator cannot trust authority to eventually take-over the liability, he will not invest (no FID).

Sources of uncertainty

A. Parameter uncertainty
B. Model uncertainty
    1. Non-linearities
    2. Multi-physics (F, M, C, T)
    3. Model simplifications (e.g. analytical model)
    4. Upscaling
    5. Truncation (FE, FD)
C. Measurement uncertainty
    1. Input parameter
    2. Observed system response
D. Workflow uncertainties
E. Exogenous events

More description in hidden slides

Learning

- Learning, in case of predictive modelling, is demonstrated by the systematic *reduction of the mismatch* ('delta') between model forecast and actual values, and the *reduction in forecast range*.
  - Ref. weather forecasting learning process
  - Note: E&P is not (yet) good at it!!

- Learning *through repeated model updating* is the *main objective* of the uncertainty assessment practice. Learning which types / sources of uncertainty contribute most to the 'deltas' is key in convincing the authorities, prior to decommissioning, to take over the calculated residual risk / liability.

Trust building process

between operator and authorities

Stand-alone study workflow

1. Frame the problem	2. Set-up quantitat. models	3. Generate range of outcomes	4. Perform Sensitivity Analysis	5. Apply Decision Criteria
•Agree dec. crit. •Agree decisions •Agree scenarios •Construct tree •Prune tree •Agree tree	•Agree models •Populate model •Agree stoch. parameter pdf's & scenario prob. •Agree / est. correlations •Agree KPIs •Agree risk def.	•Est. MC run parameters •Pdf's of KPI's •Quantify risks •Assess impact on portfolio •Est. utility fct, risk tolerance	•Tornado etc •Fine-tune decision altern. • Test robustness of decis: - model input - process par - utility fct - dec.sequence •VoI, VoF, ROV	•Describe process •Propose optim. solution + impact on portfolio •Report •Monitor •Update model

- From E&P "Decision & Risk Analysis" process

Update existing study using new information

1. During injection phase, update model with new information.
2. Test whether *new information* results in *increasing* the quantified uncertainty on the predicted performance.
   - *Or whether updated P_{50} falls outside former P_{10}-P_{90} range*
3. If it does, re-visit the modelling frame
4. If uncertainty is being reduced, then no re-framing required.
   - *In any case, update models if improved physics have been researched and can be modelled.*

- *Important*: agree how to quantify predicted performance uncertainty!
  - This is *also subjective*. (Discuss)
  - Authorities should understand what operator does and trust that process is not being manipulated.

Some additional observations

- Re-use of fields for CO_2, e.g. depleted gas fields, depleted oil fields
  - Re-use + adaptation of existing reservoir simulation models to predict CO_2 storage performance.
  - May be problematic in case of transfer of ownership / operator
  - Avoid starting from scratch! But even with long *production* history, still lot to be learnt to improve CO_2 *injection* performance predictions.
- Industry standards for performance forecasting using models would be helpful
  - SPE is currently working on production forecasting guidelines

Lessons from E&P: HSSE-SR trends in E&P

(ref. JPT March 2013 – R. Moreau)

- Systematic approaches and processes are essential to providing assurance to stakeholders
- Enhancing technology and science to solve HSSE-SR challenges is a prerequisite
- Increased sharing of lessons learned and standardizing of HSSE-SR approaches across companies beneficial and critical
- Transparency with external stakeholders is a must
- Risk assessment is a powerful way to tackle increasingly complex HSSE-SR issues; management of risks should be everyone's job
- Mgt of SR, including continuous engagement with stakeholders, is increasingly becoming a mainstream business imperative
- HSSE-SR leadership translates to good business performance

Conclusion

- Quantified uncertainty ranges of a CO_2-storage's future performance are inherently uncertain and subjective. This notion should govern one's approach to risk analysis, with *gradual learning* about the system as a primary driver.
  - Learning about storage site through *successive* modelling studies
  - Total system approach with gradually reducing quantified forecast uncertainty using *iteration* (throughout the injection phase and MMV phase, to update modelling frame)
  - Starting point is a *good modelling definition of risk* and *performance uncertainty*
- Trust building between storage operator & authorities is a prerequisite for investing. A formal, joint modelling process is required to handover, eventually, residual performance risk to the authorities.

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