



CO₂ REMOVE
research monitoring verification

CO2ReMoVe – An EU integrated project on research into verification and monitoring of CO₂ geological storage

Petra David & Emile Elewaut

Project coordinators

TNO Organization for Applied Scientific Research, The Netherlands



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Why this project ?

- Qualify CO₂ geological storage as a tool in Emission Trading Schemes (ETS)
- Ascertain long term storage safety
- Establish standardized site certification guidelines for policy makers, regulators and industry
- To integrate all available expertise



CO₂ Injection Sites - Main Sites

Sites	Reservoir fluid	Reservoir rock	Cap rock	Depth	EU Projects
Sleipner (Norway)	Saline Formation	Sandstone	Shale	1000	SACS/CO ₂ Store
In Salah (Algeria)	Saline formation/ gas	Sandstone	Shale	2000	
Snøhvit (Norway)	Saline formation/ gas	Sandstone	Shale	3000	CASTOR
Ketzin (Germany)	Saline formation/ gas	Sandstone	Shale	1000	CO ₂ SINK
Reserve Sites - (CIRCUM-) EUROPEAN					
K12B (Netherlands)	Gas (EGR)	Sandstone	Salt	3500	CASTOR
Kaniov (Poland)	ECBM	Coal/Aquifer	Shale	1100	RECOPOL/ MOVECBM
Tarnov (Poland)	Oil/saline water	Sandstone	Shale?	1500?	
International (non-European)					
Weyburn	Oil/saline water EOR	Limestone	Evap	1500	Weyburn 1

Participants and funding partners in CO2ReMoVe

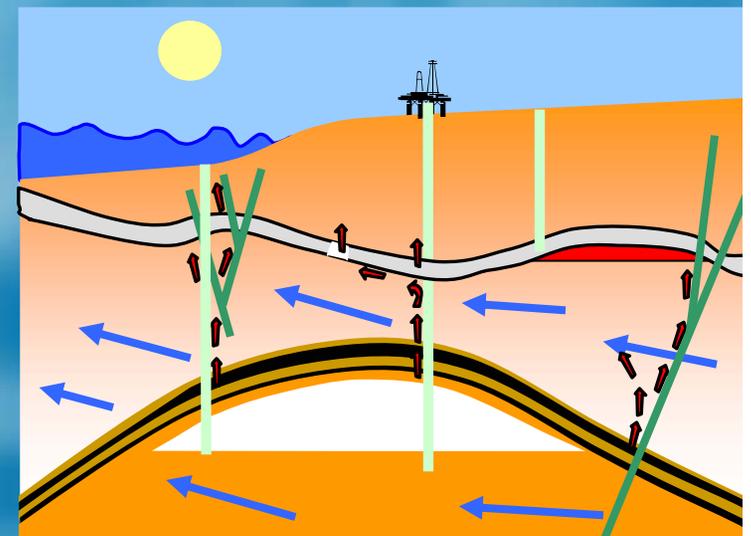
- 27 participants and funding partners from 10 countries

- BGR
- BP
- BRGM
- ConocoPhillips
- DNV
- ECN
- ExxonMobil
- GEUS
- GFZ
- GIG/CMI
- IC
- IEA-AGH
- IFP
- MEERI PAS
- NERC.BGS
- OGS
- Quintessa
- SINTEF
- SLB
- SSR
- Statoil
- TNO
- Total
- URS
- Vattenfall
- Vector Limited
- Wintershall



Monitoring and verification (terms and definitions)

- **Monitoring and reporting:**
The regular or continuous measurement or calculation, directly or indirectly, of CO₂ migration or leakage, and the recording of such results
- **Verification:**
the activities necessary (by independent Third party) to provide assurance of the quality and reliability of the monitored data, by assessing the achieved project results towards predetermined requirements



possible leakage pathways



Generalised workflow for monitoring and verification purposes

Site assessment

- Geological characterization
- Short/long term simulation (fluid flow, geomechanics, geochemistry)
- Risk assessment



Design monitoring program



Design leakage mitigation program



Application/Site certification



Acquire monitoring baseline data



Start CO₂ injection



Monitor site

- Acquire monitoring data
- Interpret monitoring data



Update risk assessment

(incl. update simulations)



Update future monitoring program



Update leakage mitigation program and site exit strategy



Repeat monitoring and updates



Eventually site abandonment



CO2ReMoVe objectives

- Develop detailed dataset on prediction and monitoring from real storage sites
- Develop and test methods for base-line site evaluation
- Develop new tools to predict short and long term behavior and risks
- Develop generic risk assessment methodology for different sites and time-scales
- Develop integrated tool for monitoring storage and possible well and surface leakage
- Provide technical recommendations for guidelines for best practice based on scientific and technological information



CO2ReMoVe Project structure

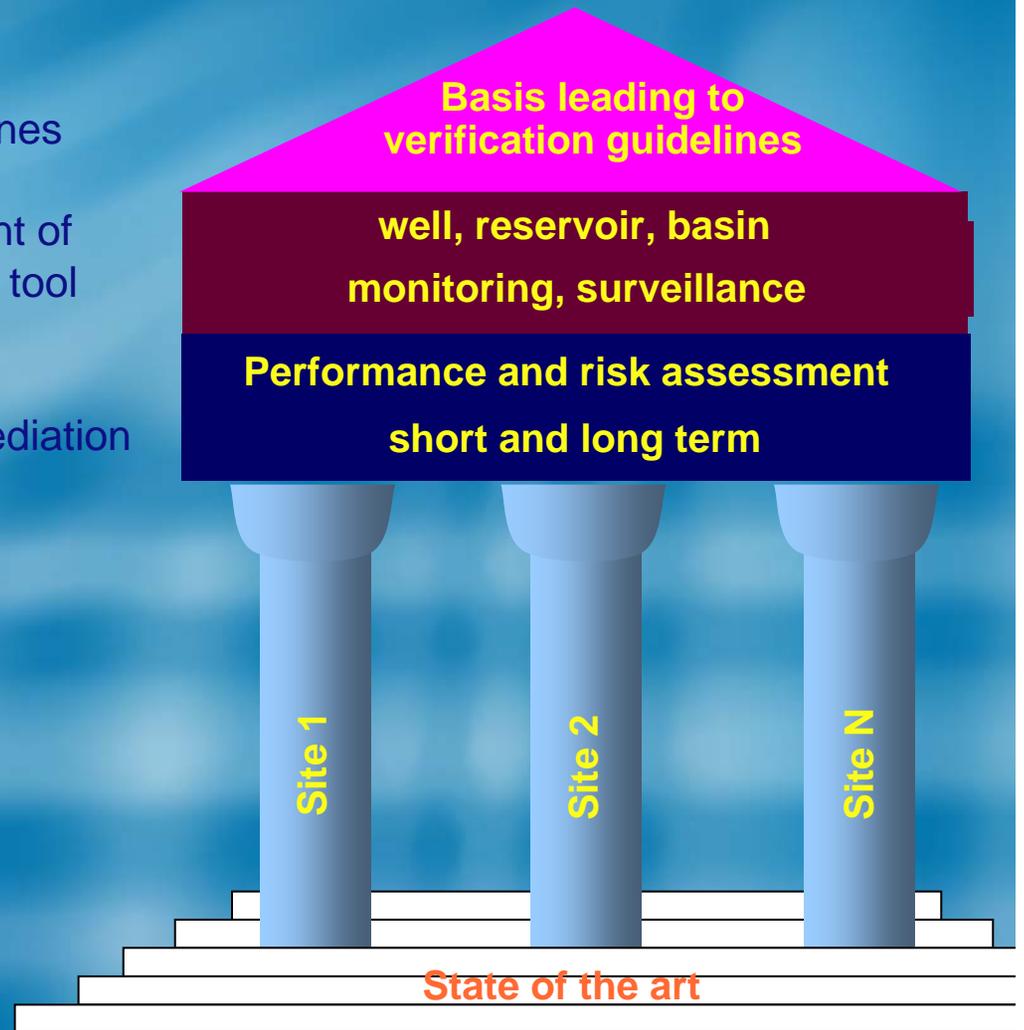
SP5: Dissemination and training

SP4: Best Practice and contribution to guidelines

SP3: Interpretation, modelling and assessment of site monitoring datasets and monitoring tool development

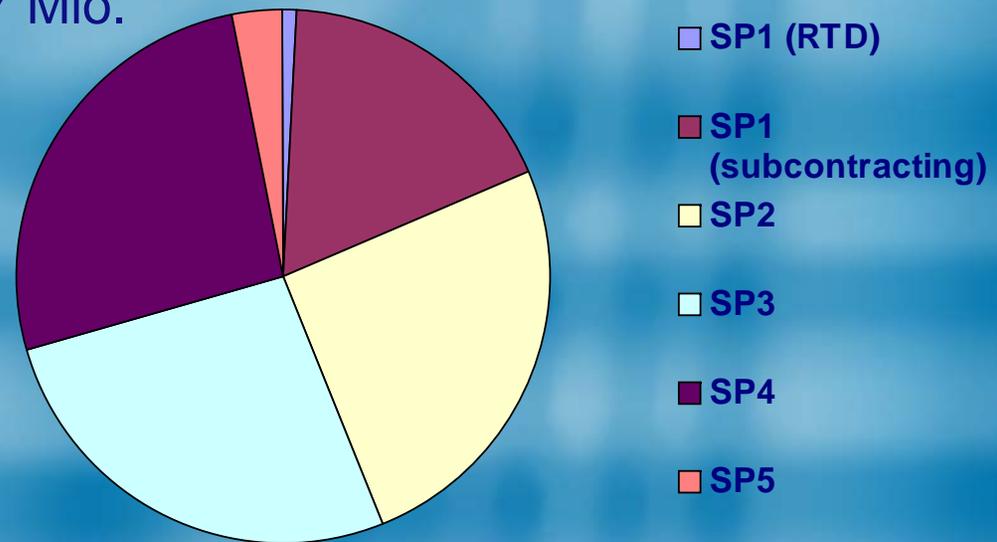
SP2: Site Performance assessment and remediation

SP1: Acquisition of site monitoring datasets



Duration and budget

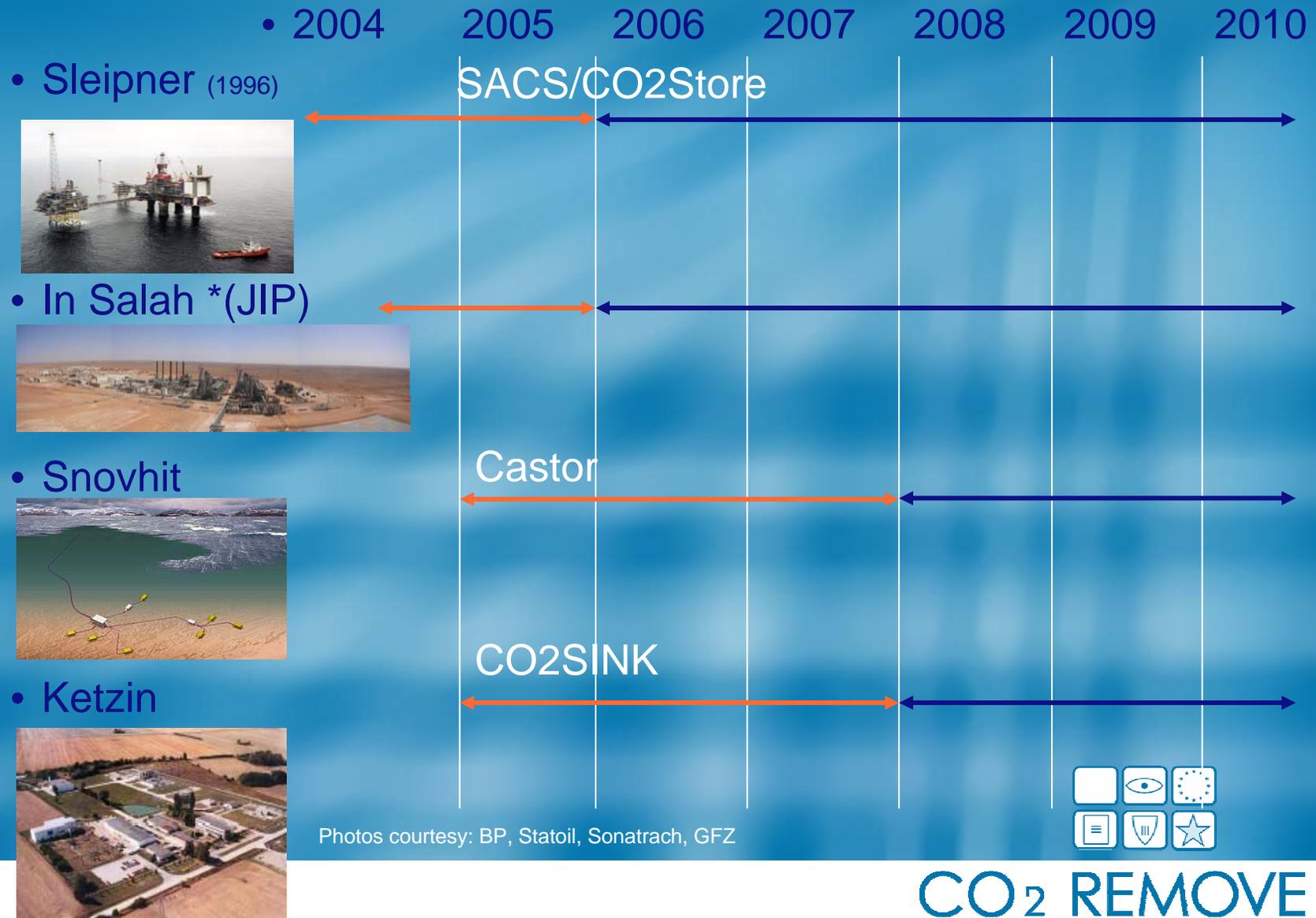
- 60 month starting from 1 March 2006
- Total budget €15 Mio.
 - EU funding € 8 Mio.
 - Industry € 7 Mio.



- Integrated project with 5 sub-projects



CO₂ injection sites monitored in FP6 research projects – main sites



**SP1
Site
Monitoring
Datasets**

**SP2
Performance
Assessment**

**SP3
Monitoring
Interpretation
Development**

**SP4
Best Practice
Guidelines**

**SP5
Training
Dissemination**

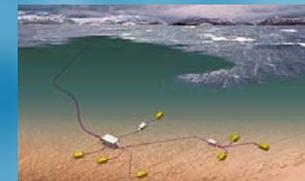
- **SP1 - Acquisition of site monitoring datasets**
- **For 3 major industrial storage sites**
 - Additional to monitoring data acquired by site operators
 - Other existing site geological and monitoring datasets will be made available
- **Laboratory-scale site: Ketzin**
- **Possible opportunities at other sites:
e.g. Karniov, K12B**
- **Future opportunities if beneficial to project**



• In Salah



• Sleipner



• Snøhvit



• Ketzin

Photos courtesy: BP, Statoil, Sonatrach, GFZ



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• **SP 2 - Site Performance Assessment and remediation**

- Developing and testing a comprehensive European methodology and tools for PA and mitigation of geological CO₂ storage
- Predicting short-term and long-term safety and reliability of underground CO₂ storage
- Compiling technical recommendations for the best practice in PA and mitigation
- PA relies on different types of performance indicators:
 - Global level: effectiveness of CO₂ geological storage for achieving CO₂ reduction (related to EU ETS and Kyoto instruments of ET,JI and CDM)
 - Local level: minimization of the impact of possible leakage on health, safety, and environment



1. Common methodological framework

includes:

- Integration of best practice derived from site-specific case studies
- Tool applicability to different CO₂ storage settings
- Level of tool integration and compatibility
- Communication of data and results between individual tools



2. Geosphere CO₂ migration tools

- Combination of classical reservoir model and basin /regional scale model
- Incorporate description of CO₂ behavior
 - Multiphase flow
 - Residual CO₂ saturation
 - Phase transfer
 - Diffusion and dispersion
 - Geochemical interactions and geomechanical effects
 - Within the storage reservoir
 - Along leakage pathways up to the ground and see level



3. Integrated Performance assessment tools

- Existing tools
 - Geological modelling tools
 - FEP and scenario analysis tools
 - Short-term Reservoir modelling tools
 - Long-term geo-sphere migration modelling tools
 - Specific (long-term) integrity tools (wells, seal, fault)
 - Long-term) large-scale modelling tools
 - Uncertainty management tools
- Develop comprehensive PA tool
- Particular attention to well and seal integrity



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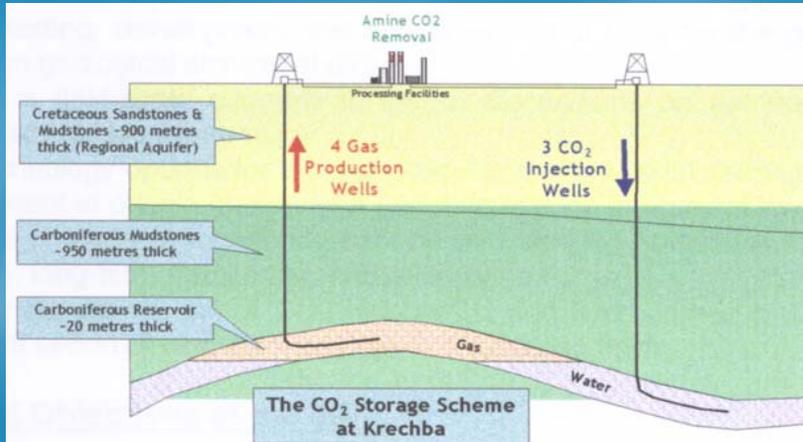
SP3: Interpretation, modelling and assessment of site monitoring datasets and monitoring tool development

1. To demonstrate that the storage site is fit-for-purpose in the sense that its overall performance is such that its greenhouse-gas mitigation function is fulfilled. This may well be also tied into qualifying for emissions credits.
2. To show that the short to medium-term behaviour of the site can be understood and simulated, and from this, enable its longer term behaviour to be predicted with an acceptable level of confidence, such that the site can be closed and liability transferred.
3. To give early warning of potentially hazardous leakage into the shallow subsurface and the biosphere and, in the event of such leakage, to identify and measure CO₂ fluxes reaching the surface.
4. To build public confidence by developing a portfolio of secure, well-monitored industrial-scale storage sites, in a variety of settings.

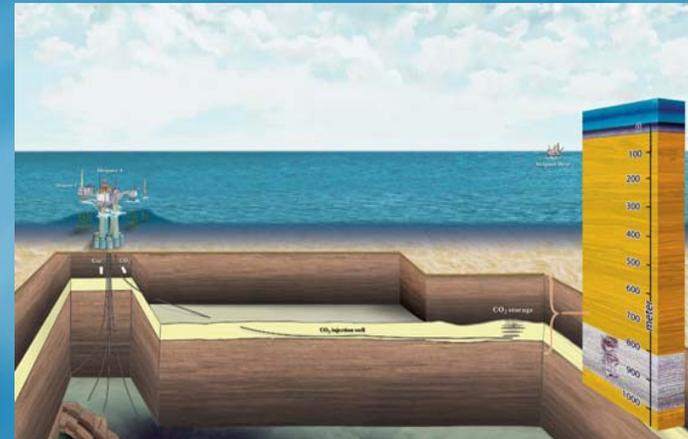


1. Interpretation, modeling and assessment of site monitoring datasets

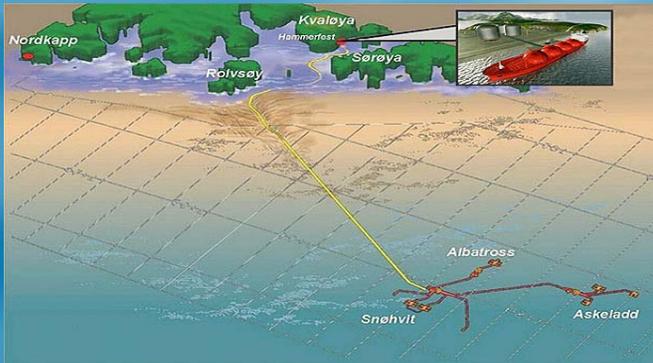
Industrial-scale sites (~ 1Mt CO₂ year⁻¹)



In Salah: >1 Mt (1900 m depth, onshore)



Sleipner: >8 Mt (900 m depth, offshore)
Laboratory-scale – <0.01 Mt CO₂ year⁻¹ - Ketzin: 700 m depth onshore



Snohvit: 2900 m depth offshore



Photos courtesy: BP, Statoil, Sonatrach, GFZ



Monitoring methods

- Subsurface monitoring
 - Seismic methods:
 - 4D seismic
 - Well seismic, VSP
 - Cross well seismic
 - Micro-seismicity
 - Non-seismic and borehole methods:
 - Electro magnetic
 - Gravity
 - Well fluids
- Surface and near surface monitoring
 - Soil gas
 - Ecosystems
 - Shallow geochemistry
 - Satellite remote sensing



2. Innovative Monitoring Tool development

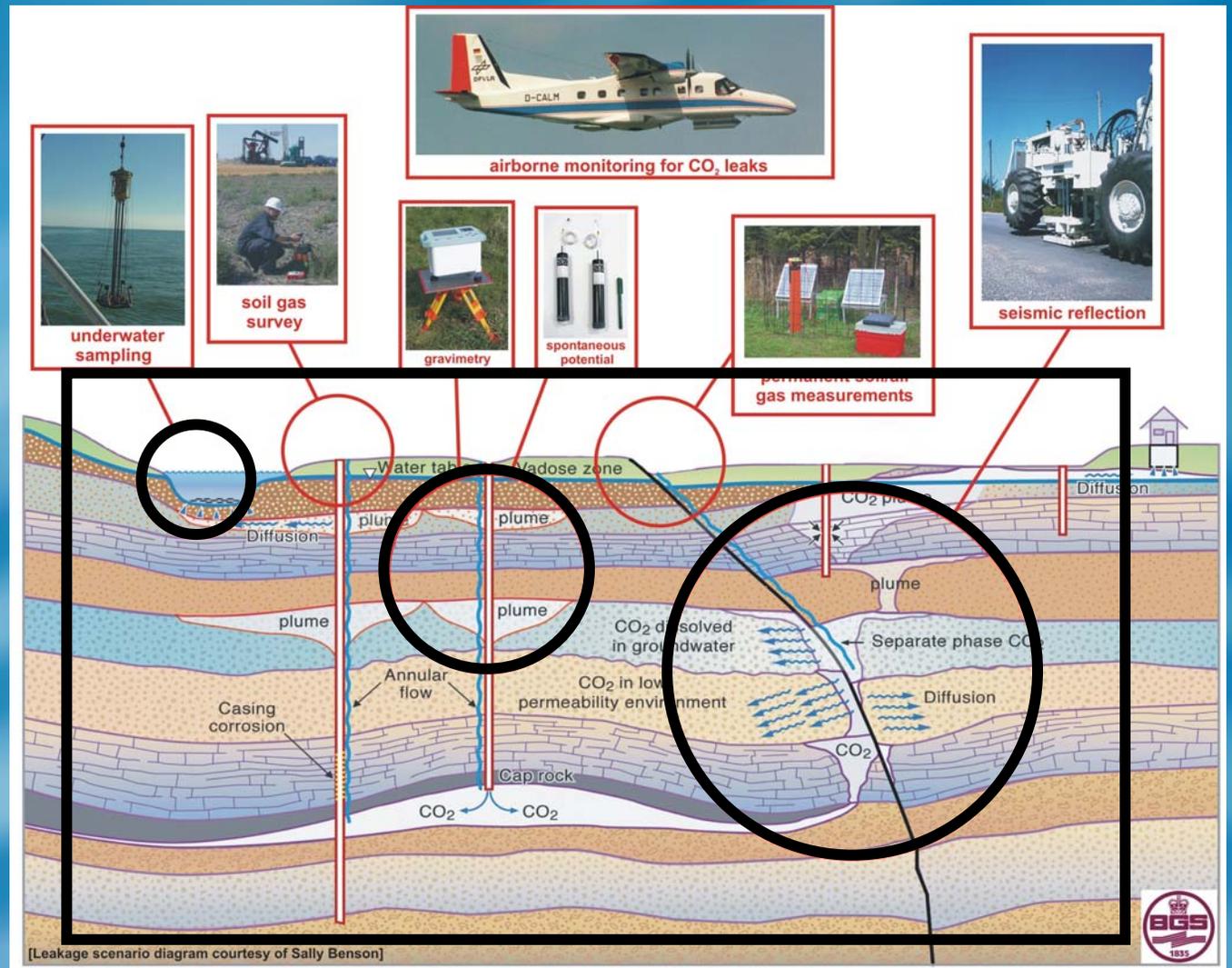
Underwater and atmospheric fluxes

Electrical (SP)

Advanced seismic

Integrated monitoring
Software platform

Linked to CO2GeoNet



3. Tool comparison and development of generic monitoring strategies

- Compare similar tools in different storage settings
- Evaluate complementary (cost-effective) tool combinations
- Generic site monitoring strategies for a range of storage scenarios
- Provide key information for HSE (SP2) and Regulatory requirements (SP4)



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- **SP4: Best practice and contribution to guidelines**

- **Objectives:**

Contribute to bridging the gap between the assurance that state-of-the-art monitoring technology and verification can provide, and the assurance of technical performance required by CCS stakeholders.

- **Work plan:**

Gathering of technical/scientific experience from specific sites, and simultaneous building of frameworks for the requirements for risk assessment, mitigation procedures, and monitoring methodologies.

- **Expected outcome:**

Set up the technical background for a regulatory system which enable member states to issue Emission permits and licences to store CO₂.

The intention is to develop a catalogue of pragmatic proposals for performance standards, to assist future EU and national regulatory efforts.



SP4 Headlines

- Link up to the work of other SP's
- Assess the technical conditions for CO₂ storage
- Study the technical requirements for greenhouse gas emissions
- Study international/national technical requirements
- Study relevant literature under development (IPCC etc.)
- Cover the legal aspects and the need for regulations (Field/ECOFYS report of June 2005)
- Deliver input for EU and national regulators



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SP 5: Dissemination and training

- Disseminate information about the project and its results to industry, scientists and engineers, the public, decision makers and other stakeholders in Carbon Capture and Storage
- Contribute to technology transfer
- Offer training on CCS and project products
- Produce a published project summary report
- Produce scientific papers on the project and its results
- Obtain and encourage feedback about the project and its results

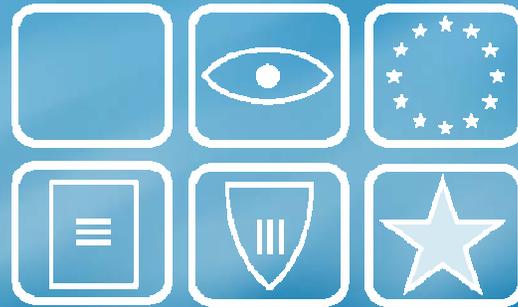


Conclusions

- Development of integrated and generic prediction and monitoring tools for CO₂ migration and/or leakage
- Results in a 'numerical laboratory', built using most advanced simulation and prediction software and stochastic uncertainty analysis software and database systems
- 'Library' will be made available to regulatory bodies, industry and auditing service providers for licensing and certification of future CO₂ storage sites
- Provide scientific and technological information to develop recommendations to be used by regulators/policy makers to formulate a consistent and internationally acceptable standard for HSE, CDM, JI and ETS
- Requires excellent co-operation and communication between participants of different sub-projects



Thank you for your attention!



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