



Department of Mineral Fuels
MINISTRY OF ENERGY



CCOP – Norway Program for Enhancing Public Petroleum Management of the CCOP Member Countries (EPPM)

DNV CO2QUALSTORE and other DNV CCS risk management guidelines

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MANAGING RISK

DNV in Brief

DNV an independent foundation

- **Independent foundation** established in 1864
- **Self-owned** with no shareholders
- Stakeholders are represented in our governing bodies and committees
- We use profits to continuously develop our people and our research and innovation

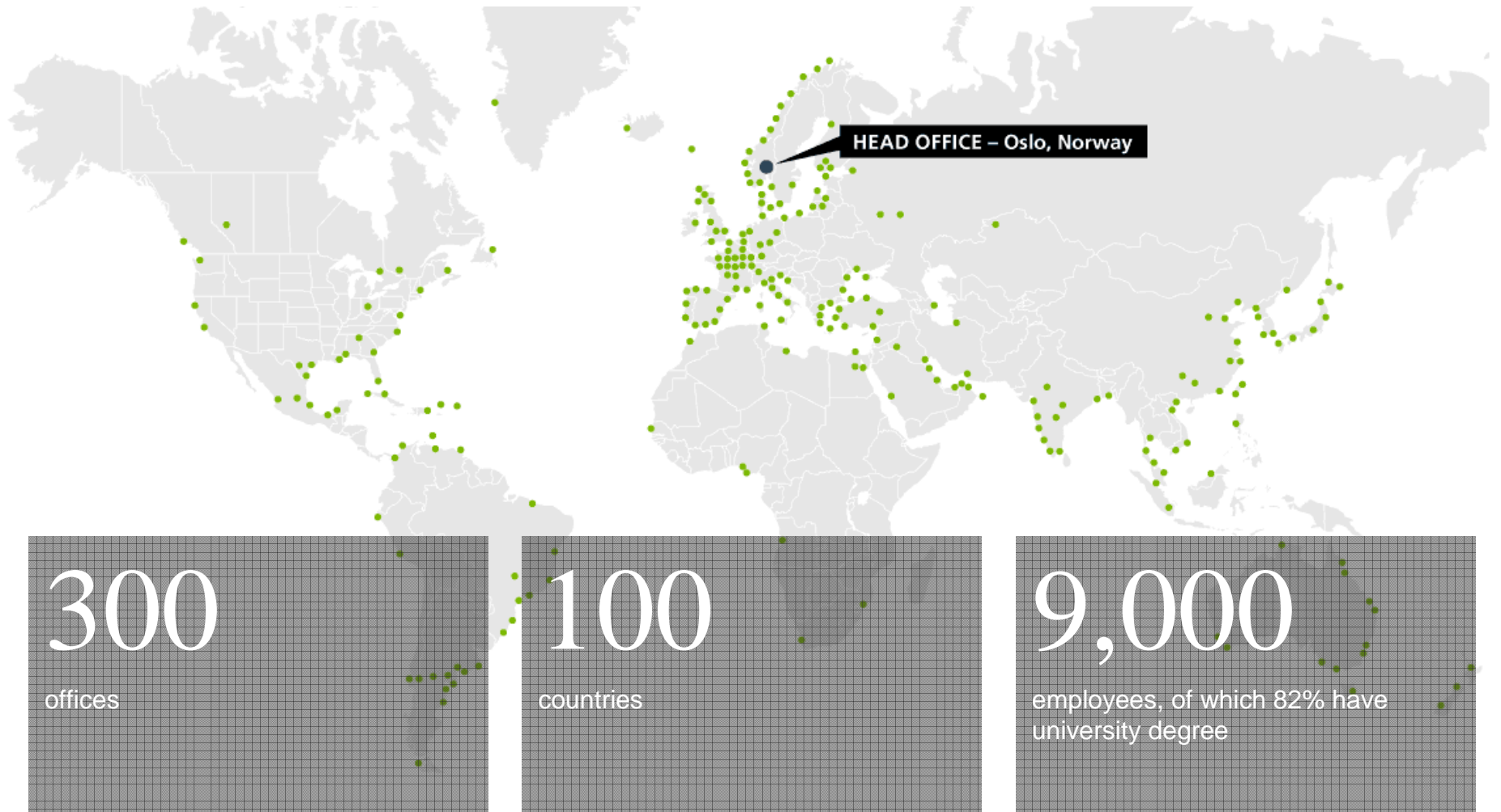
DNV's core competence

identify
assess
manage

risk



Highly skilled people across the world



Impacting climate change issues



1st

Released the world's first standard for qualification of carbon capture technologies

31%

31% of all Clean Development Mechanism (CDM) projects are validated by DNV

75%

75% of the world's offshore wind projects are certified and verified by DNV

Global

Developed a global rating scheme for monitoring ships' environmental performance

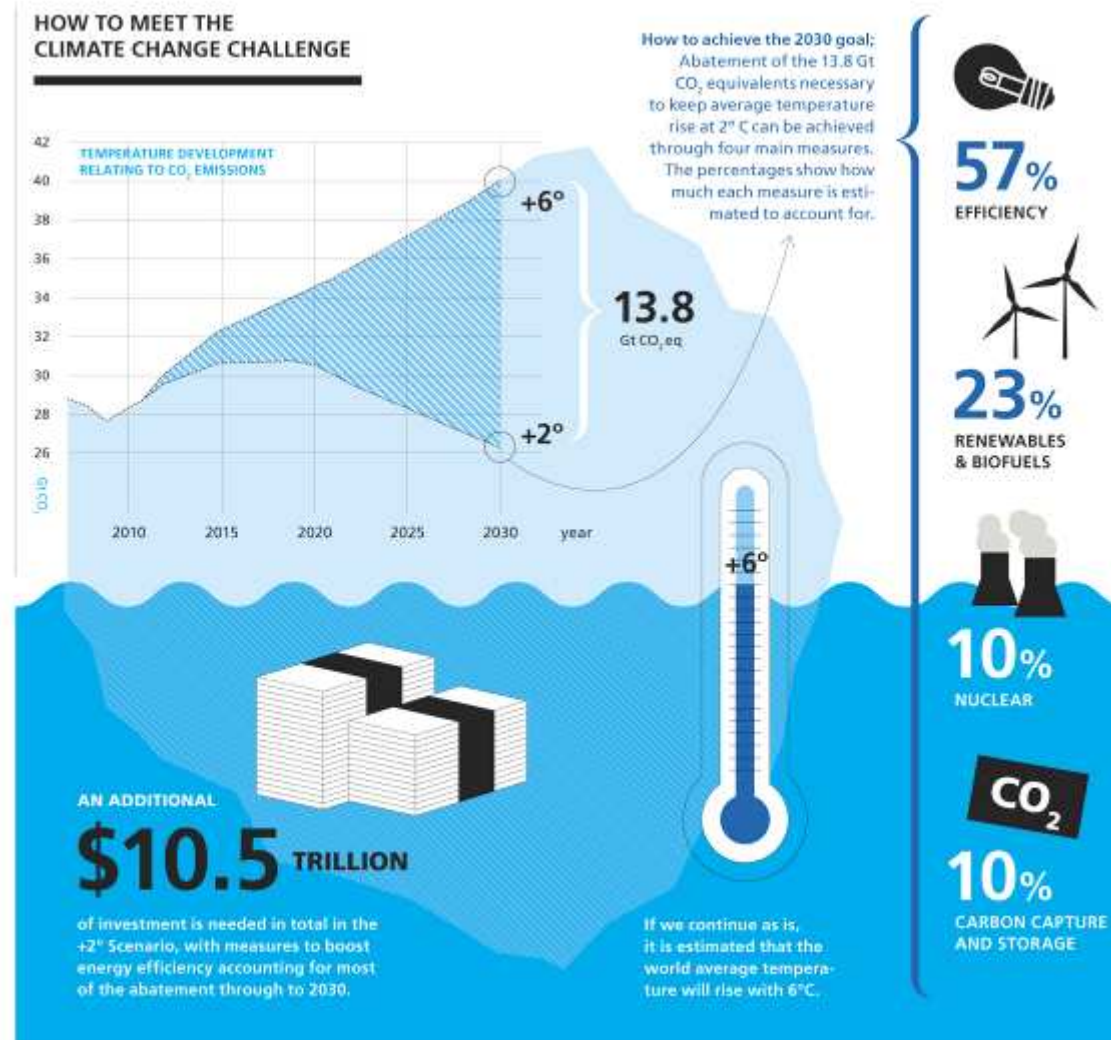
Combat climate change



- **Emission trading** – we validate and verify emission reduction projects
- **Cleaner energy** – we assess and verify clean energy projects – notably within wind energy
- **Carbon capture/storage** – we provide guidelines, assess risks and qualify new technology
- **Energy efficiency** – we provide energy management services addressing both technical and organisational issues

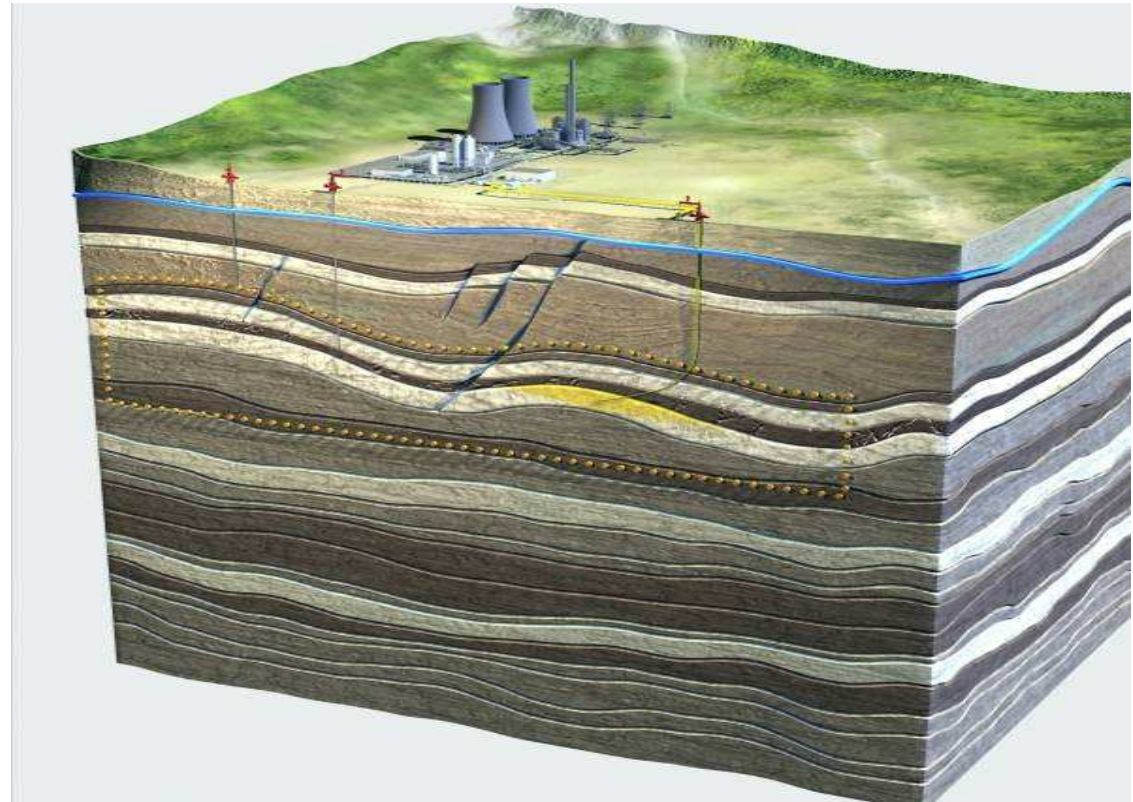
DNV on CCS

CCS - a challenge for industry and society



Where is DNV on CCS?

- Active in R&D on CCS since 2000
 - Contributed in national and international R&D projects
 - Developing guidelines on CCS
- Active in industrialization of CCS since 2006
 - Feasibility studies
 - Qualifying new technology
 - Risk and Reliability Assessments
 - Development of “Best Practices” – DNV Recommended Practices
 - Technology services in the whole value chain



The novelties of CCS

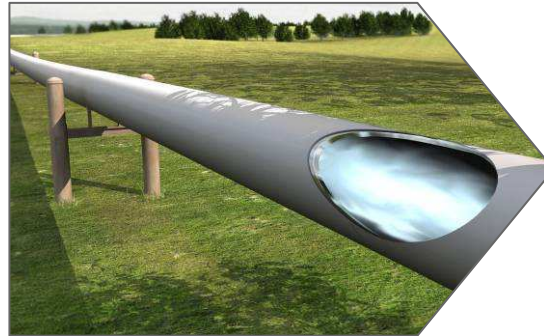
Technical and value chain novelties of CCS

Capture



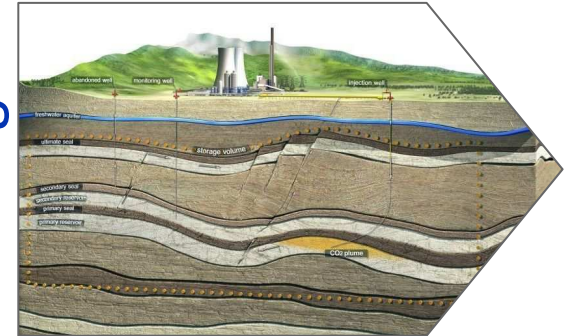
- Fossil power plants
- Natural Gas CO₂ reduction
- Other industrial processes

Transport



- Pipelines
- Ships

Storage



- Depleted oil or gas reservoirs
- Saline aquifers
- Enhanced Oil Recovery (EOR)
- Commercial product

- Cost
- Introduction of new technologies
- Up-scaling
- Accidental discharge and dispersion
- Value of avoided CO₂

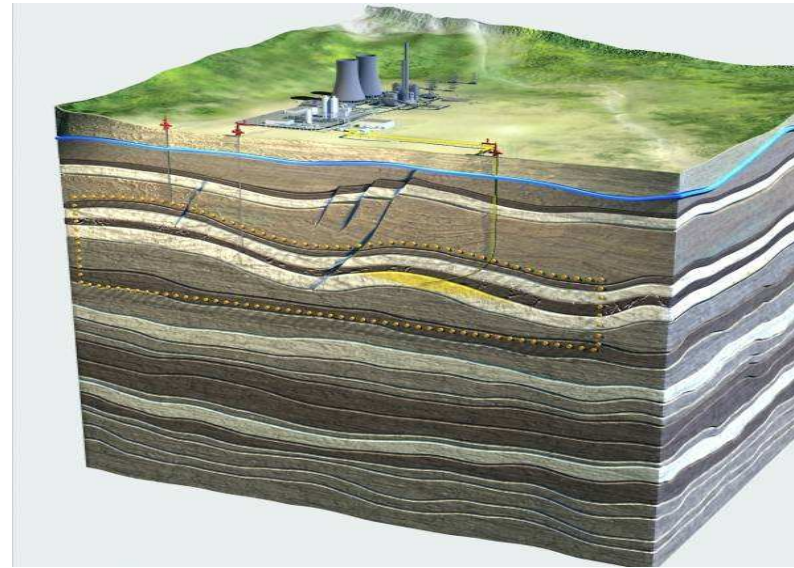
- Corrosion
- Material selection and structural integrity
- Flow assurance and operational issues
- Accidental discharge and dispersion

- Qualification of storage sites
- Permanence of storage
- Well integrity assessment
- Monitoring and verification
- Public concern
- Transfer of responsibility



Main Storage challenge: Safe long-term storage

- There are many EOR* projects and **no leakages reported**
- **Experience with CO₂ storage in aquifers is being gained from the Sleipner and Snøhvit projects in Norway**
- **Main challenges:**
 - Public concern related to safe geological storage
 - Component failure of the injection well causing release of concentrated CO₂
 - Long term leakage into fresh water reservoirs
 - Long term leakage to the environment
 - Loss of intended positive effect
 - Acidification of seawater



DNV project references:

- CO2QUALSTORE JIP – guideline for qualification of storage sites
- Vattenfall – Risk assessment of potential storage sites in Denmark and in Germany
- Gassnova – Environmental Impact Assessment for transport and storage offshore Norway
- Barendrecht Community Council – CCS Knowledge Management

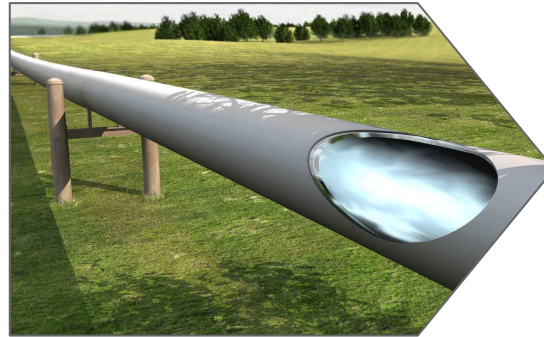
Main value chain challenge: Integrating the value chain

Capture



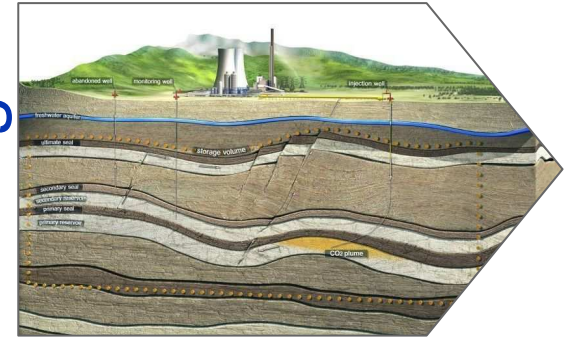
- Fossil power plants
- Natural Gas CO₂ reduction
- Other industrial processes

Transport



- Pipelines
- Ships

Storage



- Depleted oil or gas reservoirs
- Saline aquifers
- Enhanced Oil Recovery (EOR)
- Industrial products

- **Limited experience** from operational CCS value chains
 - Knowledge based on CO₂ for EOR and stripping CO₂ from NG
 - ~ 60 integrated CCS projects in planning phase globally
- **Main challenges:**
 - Lack of **commercial viability**; financial risks, pending on public funding
 - Integration of the technical building blocks; interdependence throughout the value chain
 - Project management; many different technologies, companies and regulators involved
 - Is the CO₂ source and sink reliable

DNV project references:

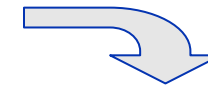
- Gassnova – Independent review of full scale CCS value chain
- Statoil – Energy supply evaluation for Snøhvit LNG (incl. CCS)
- Gassnova – development of management system
- Oil and gas operator – Value Chain Assessment of field development (incl. CCS)

Risk assessment of storage resource

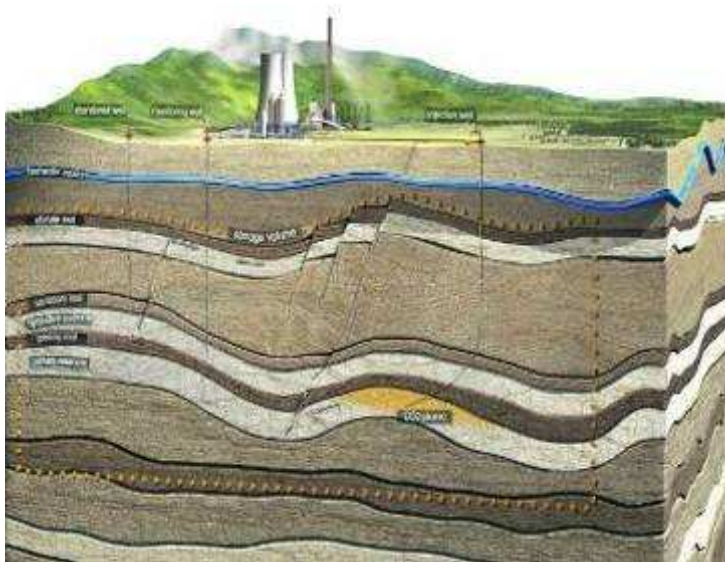
- Capacity
- Injectivity
- Containment



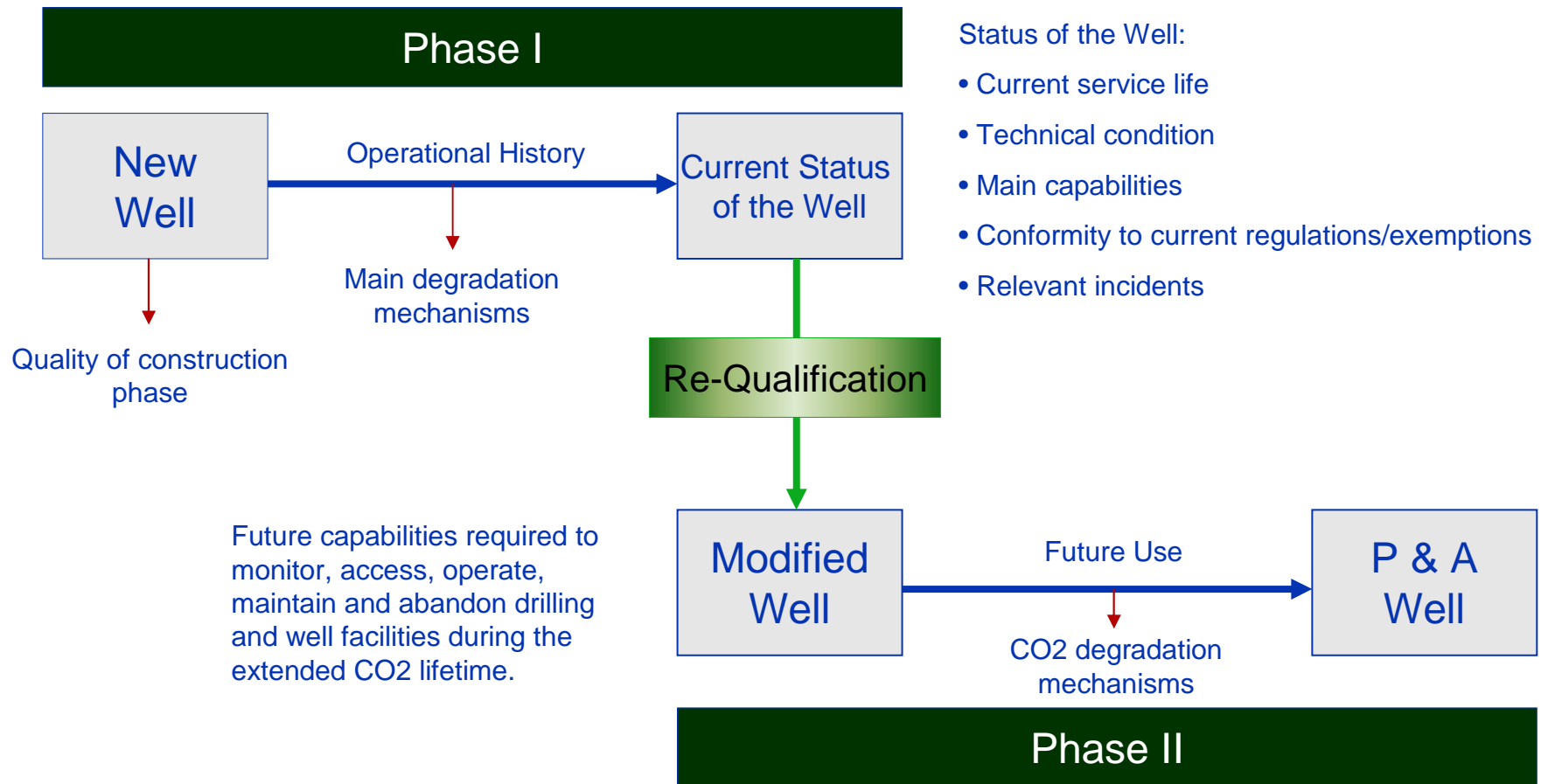
- Faults
- Caprock
- Well integrity



- New wells
- Converted wells
- Abandoned wells



Risk treatment options for wells



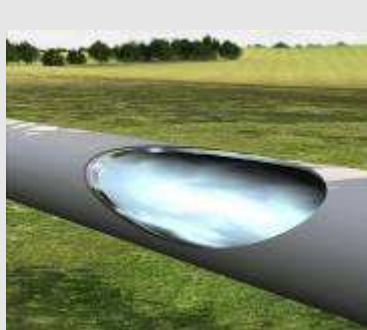
Tools and Procedures

DNV Guidelines for CCS



- **Qualification of new CO₂ capture technology** (First issue: 2008)

JIP Partners: Gassnova, StatoilHydro, Statkraft, Aker
Clean Carbon / Aker Solutions, DNV



- **Transmission of dense, high pressure CO₂ in submarine and onshore pipelines (CO2PIPETRANS)** (First issue: 2009)

JIP partners: Gassnova (50%), Gassco, Vattenfall, StatoilHydro, BP, Shell, ArcelorMittal, Dong Energy, ILF, Petrobras, British Gas

Observers: PTil (NO), HSE (UK), MINEZ (NL)

Sub-contractors: SINTEF, IFE, Polytec



- **Qualification of Sites and Projects for Geological Storage of CO₂ (CO2QUALSTORE)** (First issue: 2009)

JIP Partners: Gassnova, IEA GHG, Shlumberger, Statoil Hydro, Dong, BP, Shell, Vattenfall, RWE, British Gas, Gassco, Petrobras

Observers: Regulators invited

World's first guideline for qualification of CO₂ capture technology

Challenge

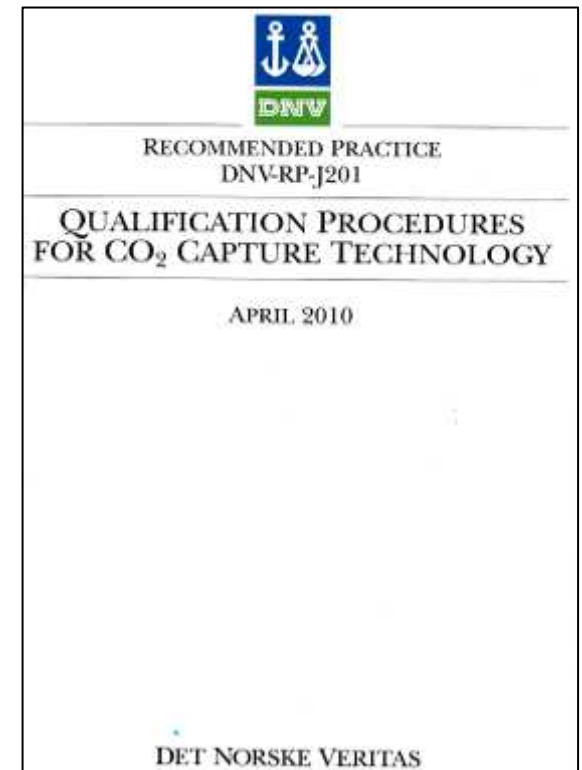
Large scale CO₂ capture technologies are novel
Risk of introducing unproven technology can be high
There is a need to assess the risk in a cost efficient and systematic manner

Approach

Develop Recommended Practice for the qualification of CO₂ capture processes

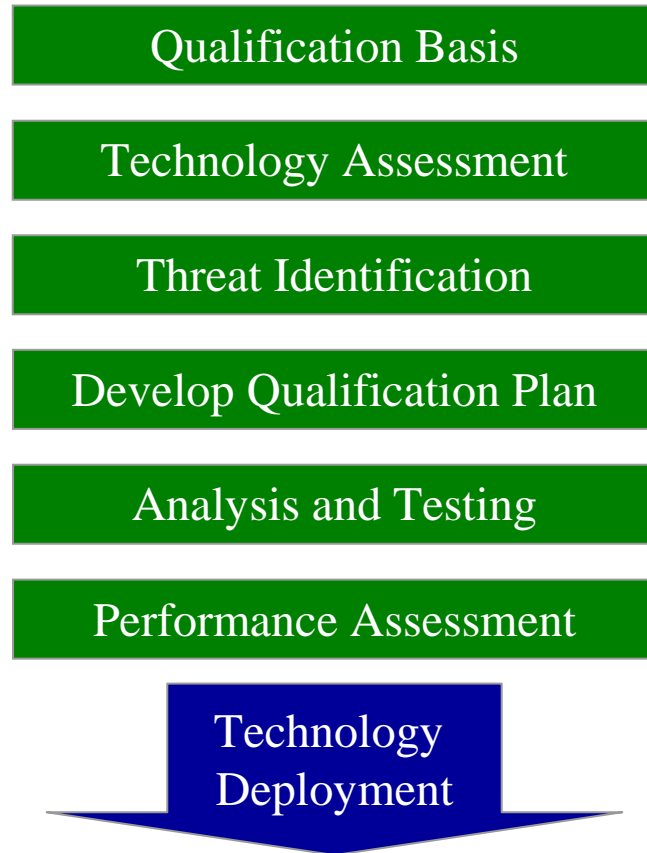
Value

A systematic procedure that explains how to identify, describe, and manage risks
A quantitative approach following a set of sequential steps known as the qualification process

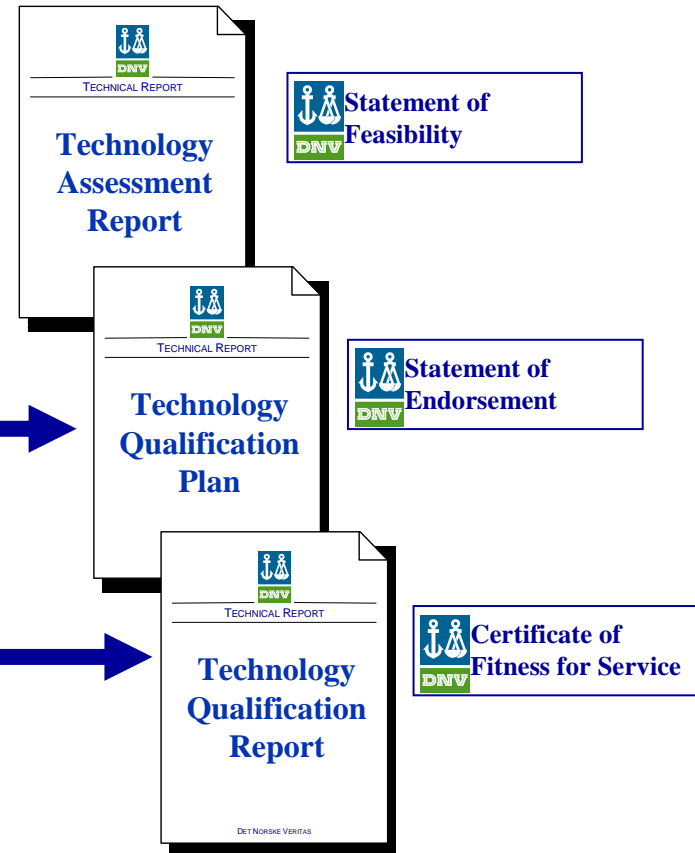


Qualification of New Technology DNV RP A203

Qualification Work Process



DNV deliverables



World's first guideline for CO₂ pipeline transport

Challenge

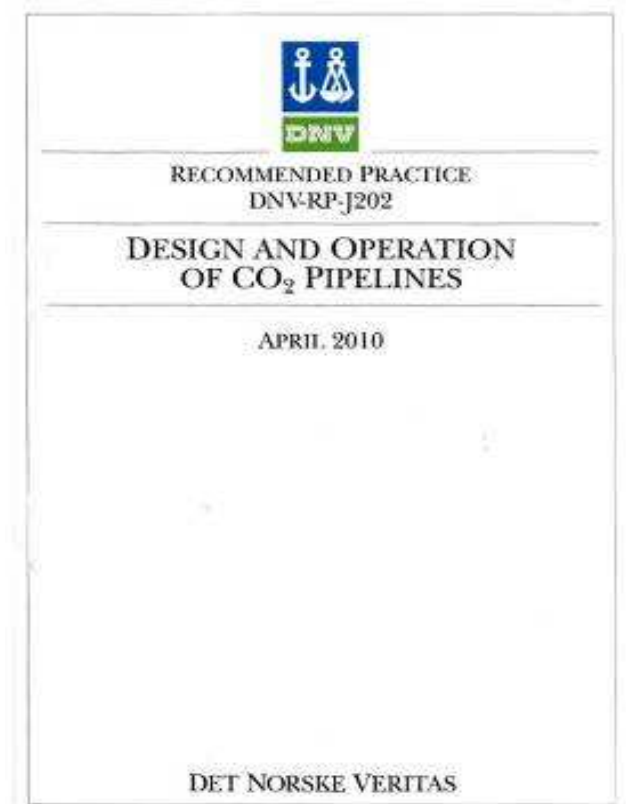
Little experience in pipeline transportation of dense phase CO₂
Current pipeline standards are not fully applicable

Approach

Develop Recommended Practice for transmission of dense phase CO₂ in onshore and submarine pipelines
Based on several technical studies and collected industrial experience
Complement to existing standards with CO₂ specific guidance

Value

The 1st industry guideline for Safe, Reliable and Cost-Effective Transmission of CO₂ in pipelines

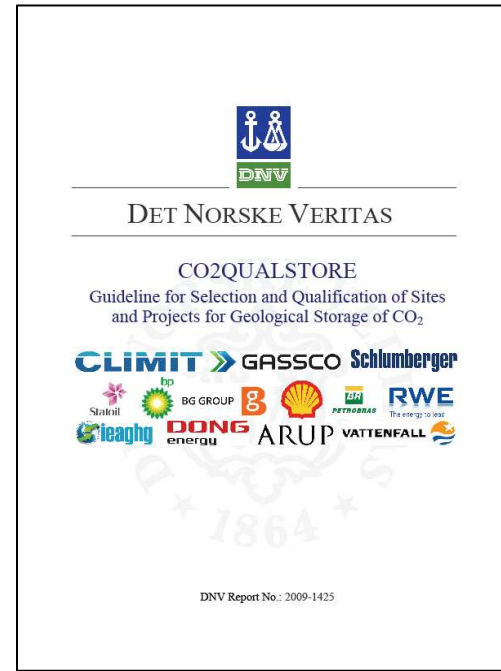


World's most comprehensive guideline for CO₂ storage

Challenge → Need for unified, recognized and publicly available best practice guideline for storage sites globally

Approach → Develop Guideline for a risk-based qualification process for geological storage sites for CO₂
Tested through CCS demo project case studies

Value → A protocol for safe, reliable and cost-efficient development of geological storage sites for CO₂
Provide project developers, regulators and verifiers with a common methodology for assessing safety and reliability of potential storage sites.



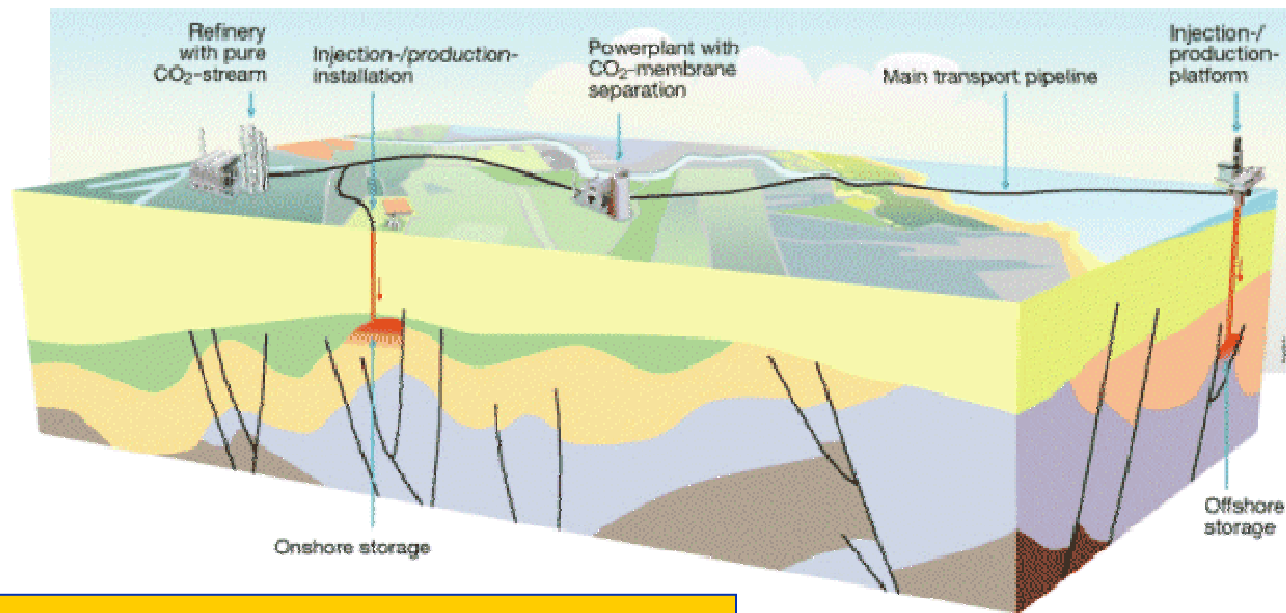
What makes CO₂ storage different?

Key questions – Geological storage of CO₂

What will be the net amount of CO₂ emissions avoided ?

For how long is CO₂ removed from the atmosphere ?

Is this cost – beneficial ? And for whom ?



How to create trust and confidence among stakeholders ?

What is an acceptable risk of uncontrolled CO₂ releases ?

Which projects and sites qualify ?

Challenges

- Need to move from R&D and demos to **large scale CCS** and do this **fast**
- Need **confidence** in geological storage of CO₂ as a trustworthy option to mitigate global warming
- Need unified, recognized and publicly available **best practice guidelines** for global use in specific projects

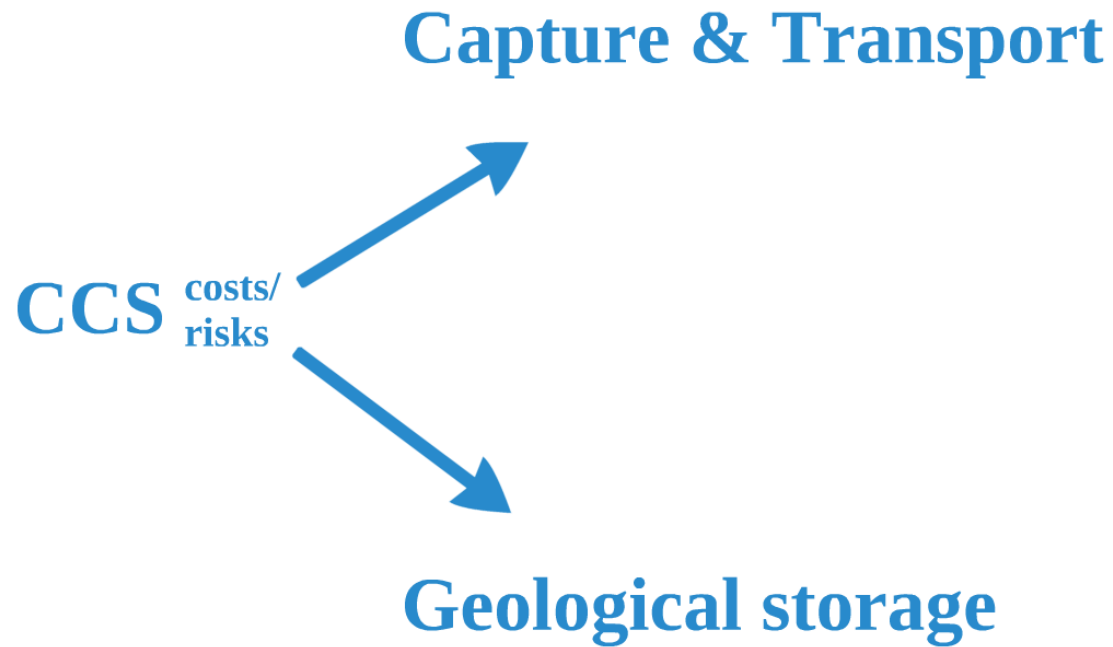
”There is a need for common international methods for CO₂ storage **site selection, monitoring, verification and risk assessment**”

IEA Technology Roadmap for CCS (2009)



DNV's approach to the challenge

Where are the costs & risks?



Risk based guidelines for CO₂ storage

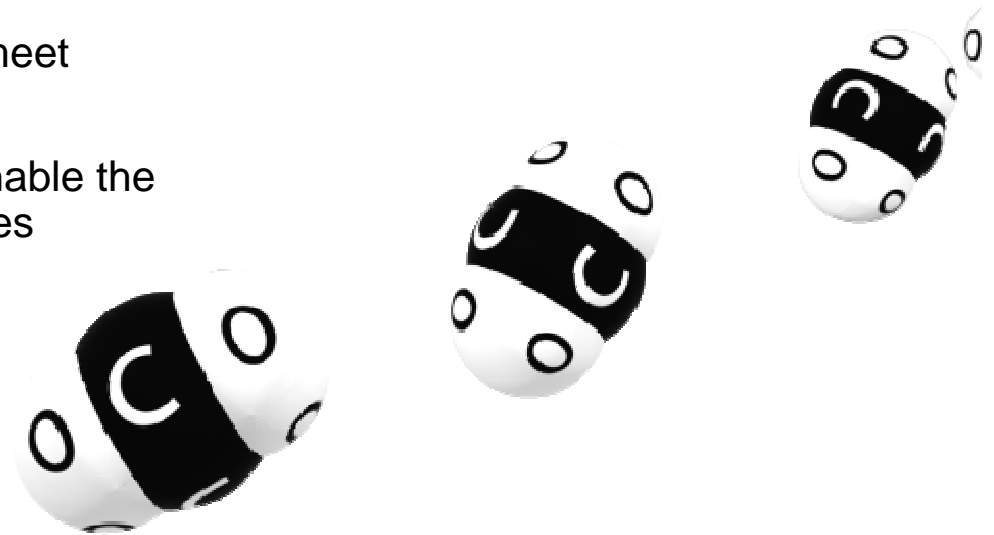
Provides project developers with

- A transparent basis for decision-making to meet internal milestones and decision gates
- Guide to set performance targets that will enable the granting of relevant permits for individual sites
- Predictable operating conditions



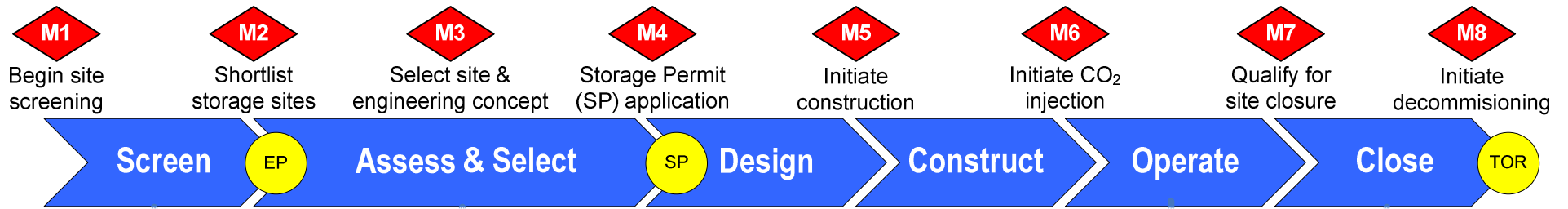
Provides regulators/authorities with:

- Standardized guide to verify that sites have been selected and assessed as suitable for geological storage of CO₂
- Basis for development/implementation of national regulations aligned with industry best practice, directives and other national regulations



DNV's CO2QUALSTORE & CO2WELLS guidelines

The guideline structure & major project milestones

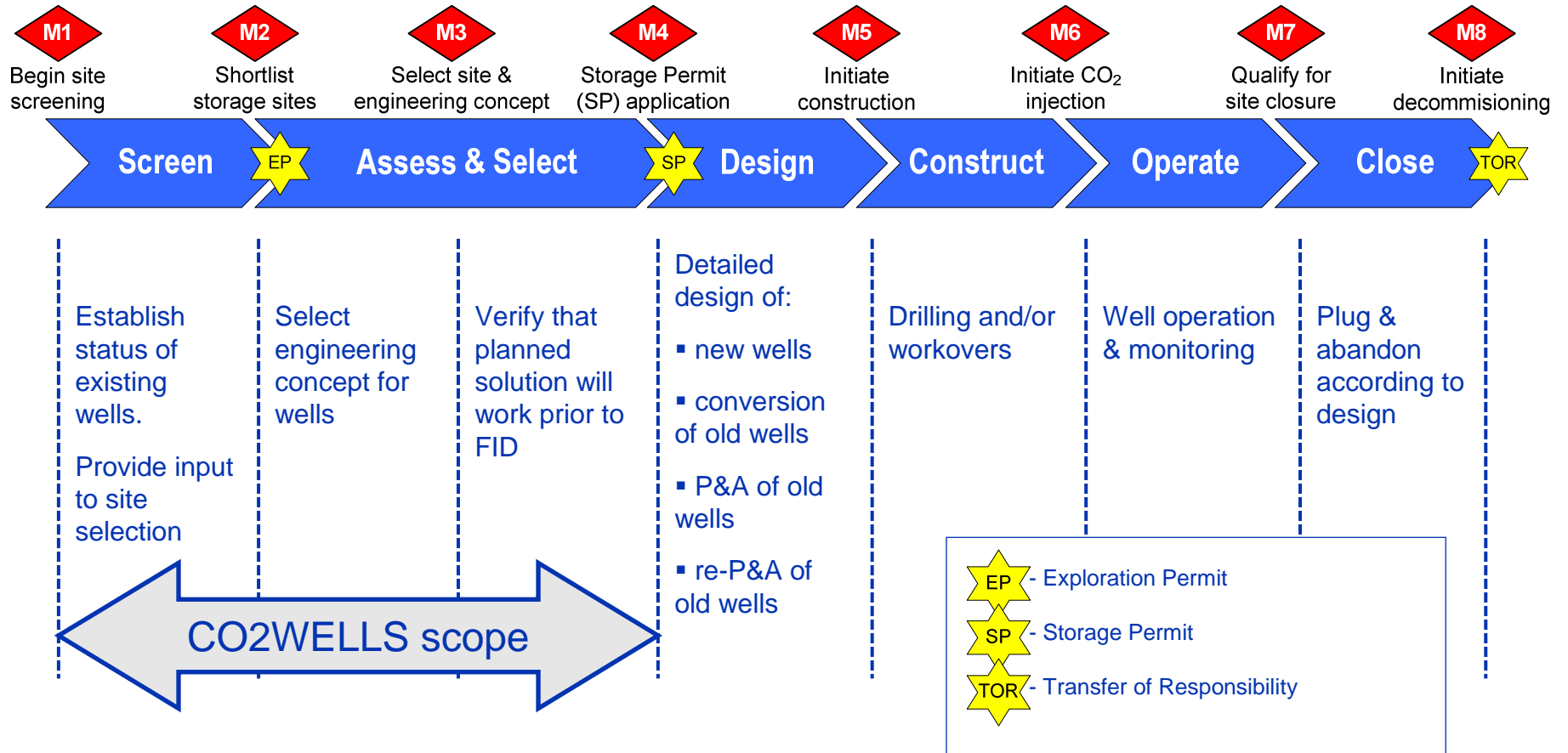


Key differences: Risk Management - MVAR - Reactive Transport Modelling - Geomechanics - Well Integrity			
<p>Identify potential storage sites in a given region that, based on a high level evaluation, are anticipated to serve as secure sites for long term storage of CO₂.</p> <p>Deliverables:</p> <ul style="list-style-type: none"> List of identified sites that are considered eligible for further characterization Basis for granting of exploration permit 	<p>Characterize a storage site in sufficient detail to enable site and engineering concept selection and storage permit application.</p> <p>Deliverables:</p> <ul style="list-style-type: none"> Site and engineering concept Performance targets Site development plan Basis for granting of storage permit 	<p>Verify that the CO₂ storage project has been operated in compliance with regulations and permit conditions, and continues to provide safe long-term storage of CO₂.</p> <p>Deliverables:</p> <ul style="list-style-type: none"> Updated performance targets and site development plan Basis for renewal of storage permit 	<p>Guide the process of providing evidence to support transfer of responsibility and liability from the project developer to a national or state authority.</p> <p>Deliverables:</p> <ul style="list-style-type: none"> Agreement among operator and regulator that the conditions for transfer of responsibility have been met.

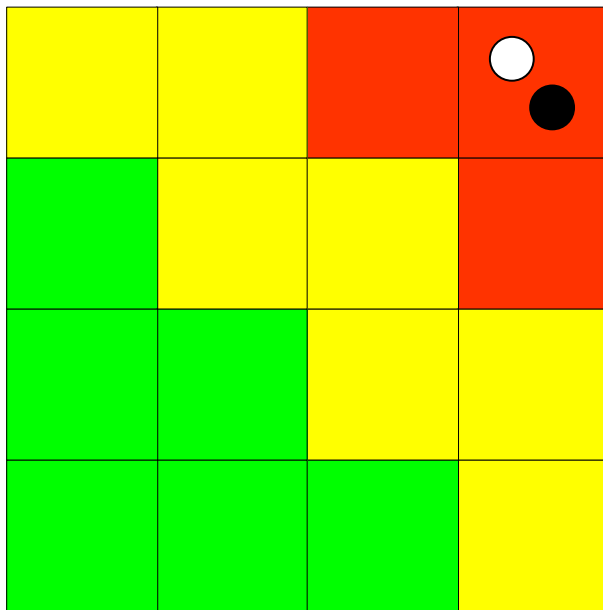
Monitoring, Verification, Accounting and Reporting (MVAR)

<p> Qualification Statements</p> <ol style="list-style-type: none"> Statement of storage feasibility Certificate of fitness for storage Certificate of fitness for closure 	<p> Permits issued by Regulator</p> <p>EP – Exploration Permit SP – CO₂ Storage Permit TOR – Transfer of Responsibility</p>
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Drilling & well activities



Integrity of existing wells



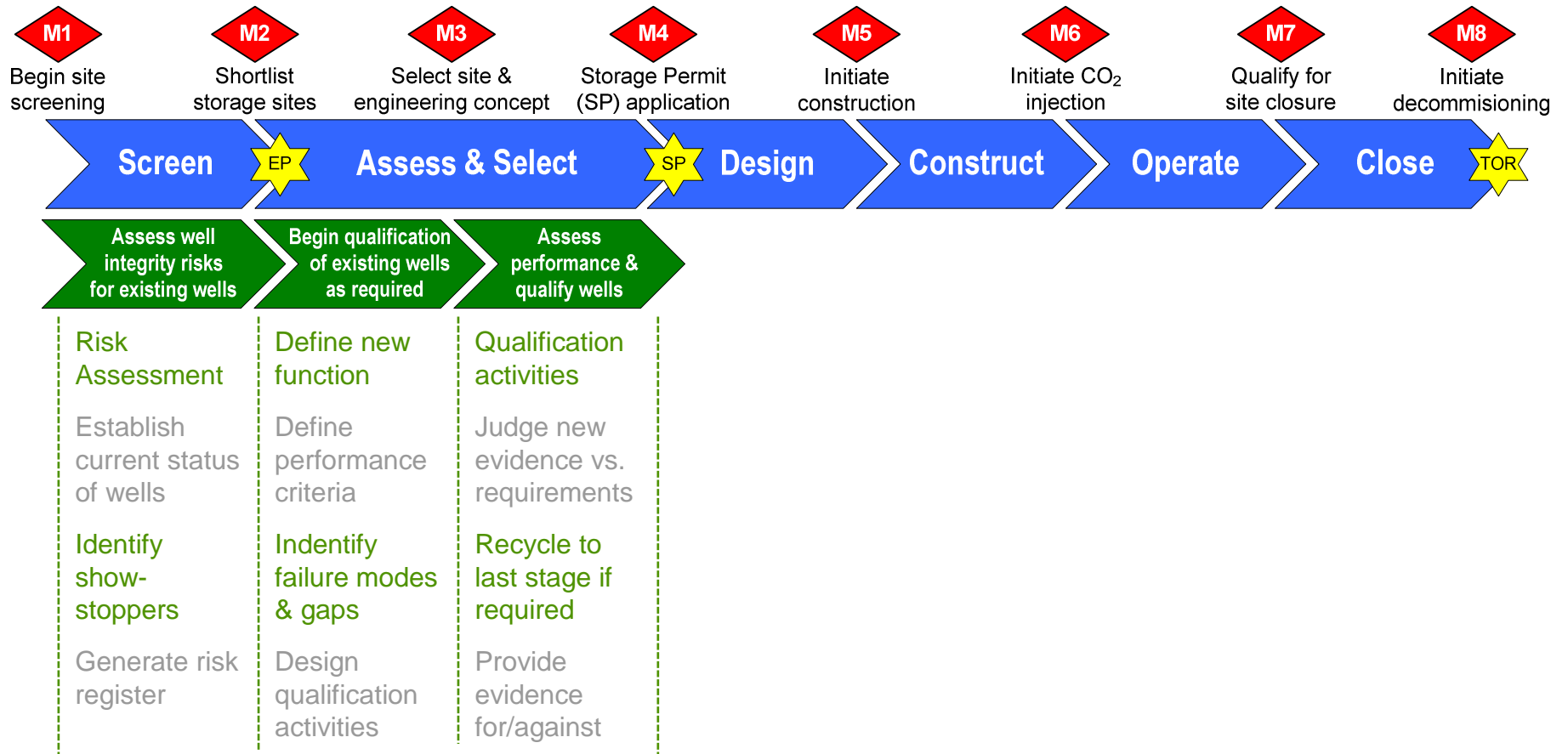
The risk of leakage through existing wells often ends up in this corner due to:

- uncertainty or lack of evidence;
- known poor condition.

Both causes result in an obstacle to investment and project development.

The CO2WELLS guideline seeks to address both causes in a transparent and systematic manner.

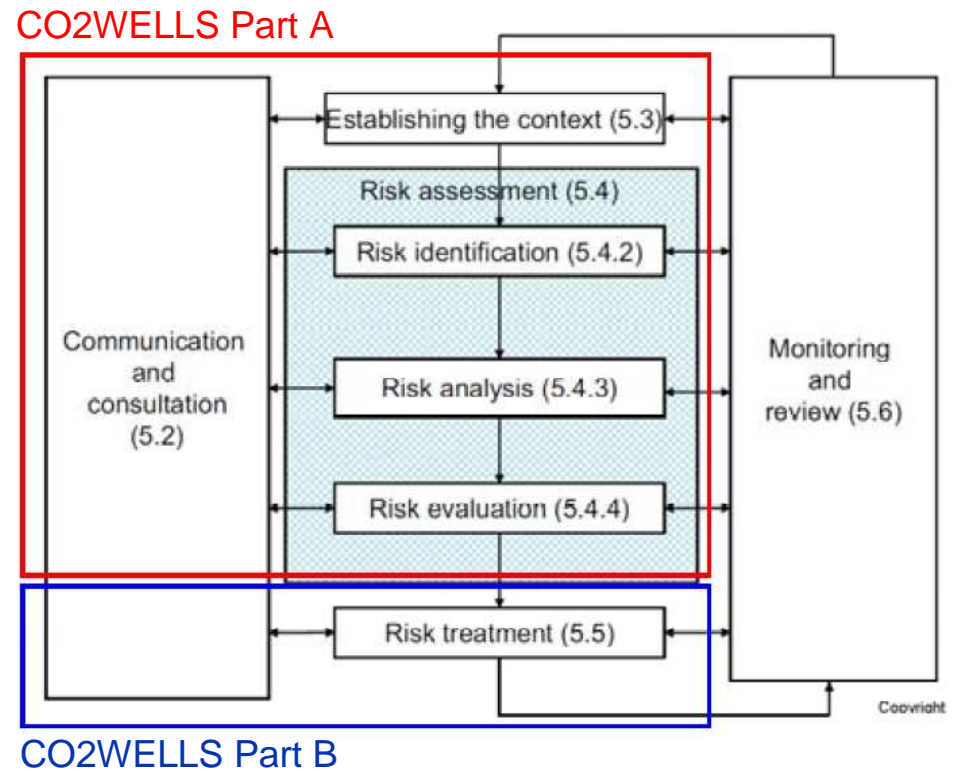
CO2WELLS guideline workflow - overview



Risk assessment context

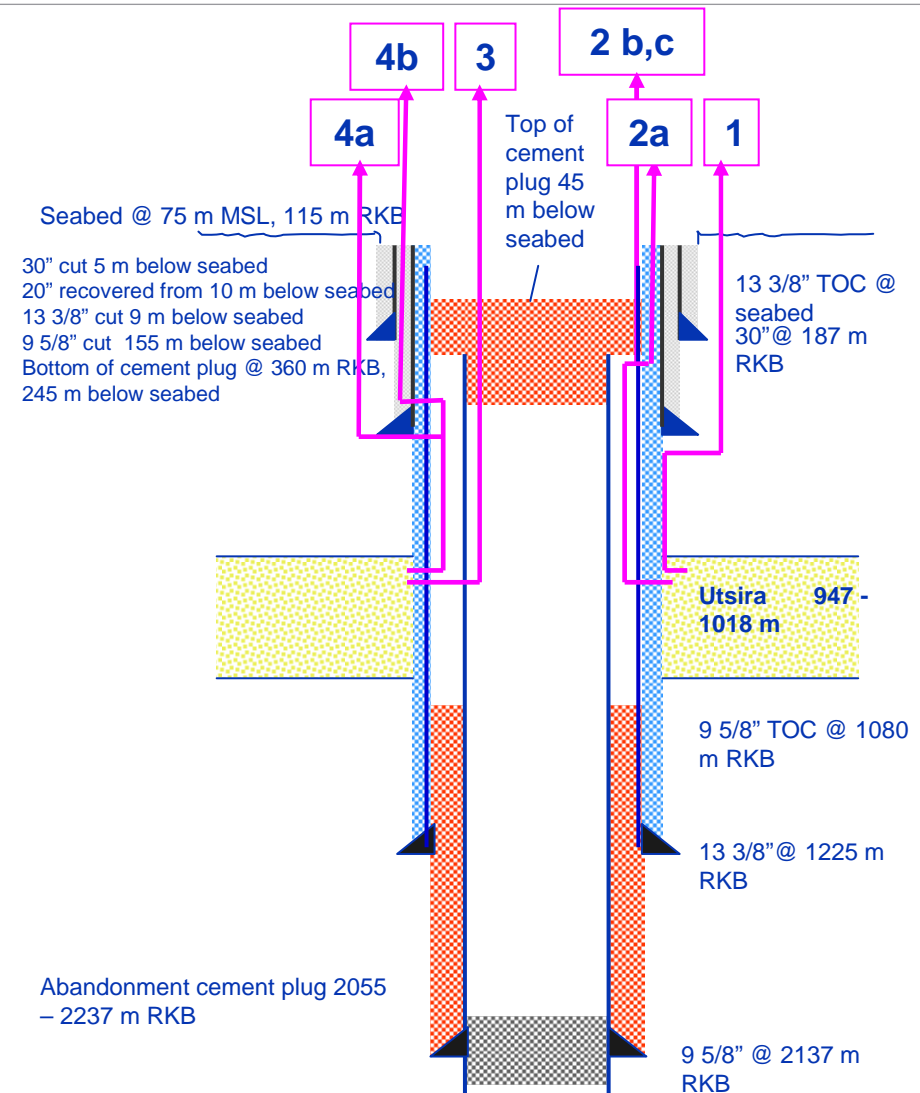
Risk assessment approach based on:

- NORSOK D010
- ISO 31000 Risk Management
- DNV RP A203 for Qualification of New Technology
- CO2QUALSTORE



Norwegian study

- 2 offshore P&A wells
- potential CO2 storage site
- Neither well found to be suitable for exposure to CO2 in present state
- Two independent barriers inside the storage complex are required



CO₂ storage: CO2QUALSTORE + CO2WELLS

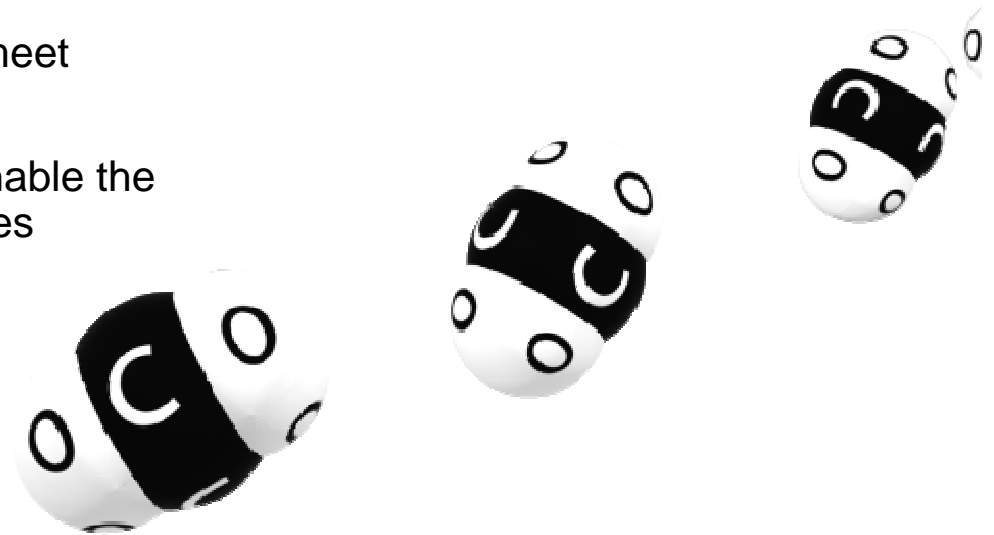
Provides project developers with

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Provides regulators/authorities with:

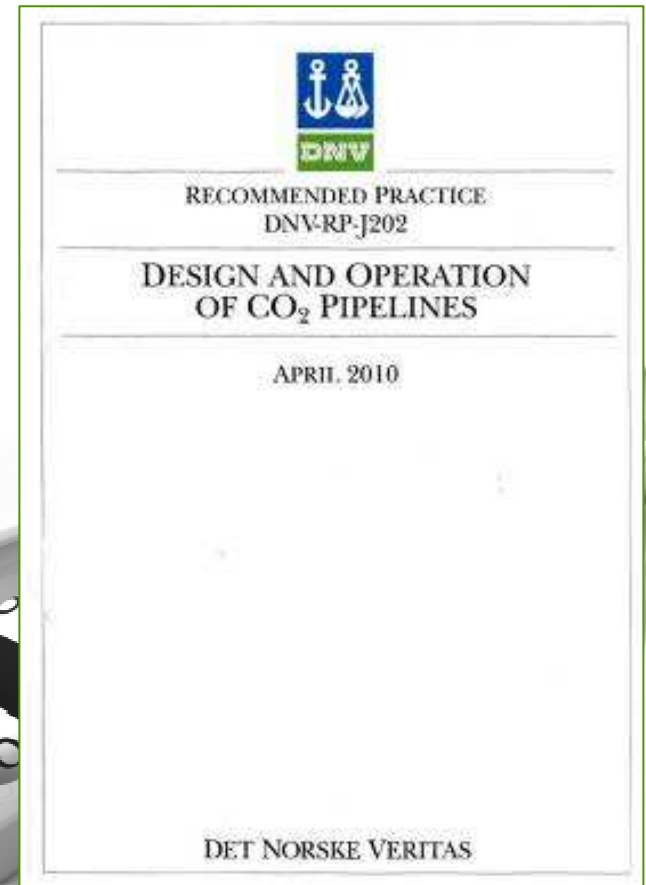
- Standardized guide to verify that sites have been selected and assessed as suitable for geological storage of CO₂
- Basis for development/implementation of national regulations aligned with industry best practice, directives and other national regulations



Ongoing JIPs on CCS

CO2PIPETRANS

- Overall objective:
 - To provide guidance on *safe, reliable and cost efficient design, construction and operation* of CO₂ pipelines
- Two phased approach:
 - Phase 1: Gather existing knowledge into a guidance document
 - Phase 2: Close the found knowledge gaps to a adequate confidence level



CO2PIPETRANS Phase 2

- **Objective:** Close significant knowledge gaps and update the Recommended Practice
- **Scope of Work:**
 - WP 1 – Dense phase CO₂ release modeling validation data
 - WP 2 – Full scale crack arrest testing
 - WP 3 – Corrosion
 - WP 4 – Material compatibility (elastomers/polymers)
 - WP 5 – Examine effects of contaminants on the phase diagram
 - WP 6 – Hydrate formation/ Water solubility
 - WP 7 – Public Communication and Interaction
 - WP 8 – Update of Recommended Practice
- CO2PIPETRANS phase 2 is an *enabling* project to support implementation and promote public and regulatory acceptance of CCS
- **Fast track** project with 2 years schedule



CO2WELLS JIP project 2010-2011: developing a common risk management guideline for existing well stock

Client Partners: Joint Industry Project

Project name JIP CO2WELLS

Challenge

The lack of a recognized framework for risk evaluation of abandoned wells currently poses a barrier to cost-efficient implementation of CCS in regions that have been subject to O&G activities.

A framework will help project developers to A) demonstrate adequate management of wells within the storage site, B) provide predictability regarding transfer of responsibility and C) develop cost efficient solutions by re-use of existing infrastructure and wells for CO₂ injection.

DNV's approach

- Develop a specialised risk assessment methodology for existing wells at potential CO₂ storage locations based on ISO31000
- Adapt DNV RP-A203 to the qualification of wells for exposure to CO₂
- Frame the guidance in the context of the CO2QUALSTORE guideline

Value to the client

The guideline should provide a tool for independent validation and verification, and contribute to build confidence among regulators and stakeholders in risk informed approaches to selection and management of storage sites.



MANAGING RISK

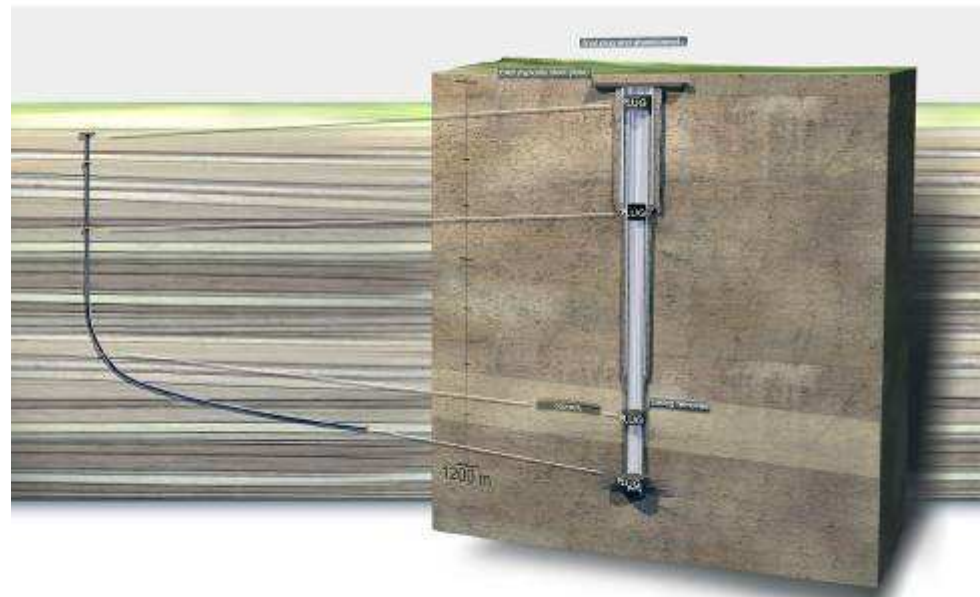


Main objectives of CO2WELLS JIP

- 1) Build on the framework described in the CO2QUALSTORE guideline.
- 2) Develop a specialist procedure for risk assessment of existing wells at candidate storage sites.
- 3) Use the risk assessment results as the basis for qualifying existing wells for exposure to CO₂ and potentially conversion to injection or monitoring wells.

Wells that penetrate a CO₂ storage site represent potential leakage paths through the cap rock.

Whilst the integrity of new wells can be controlled and known, the integrity of existing wells may represent a large and uncertain risk factor.



Issued for hearing in May 2011 ...



DET NORSKE VERITAS

CO2WELLS

Guideline for the risk management of existing wells at CO₂ geological storage sites

Looking ahead.....

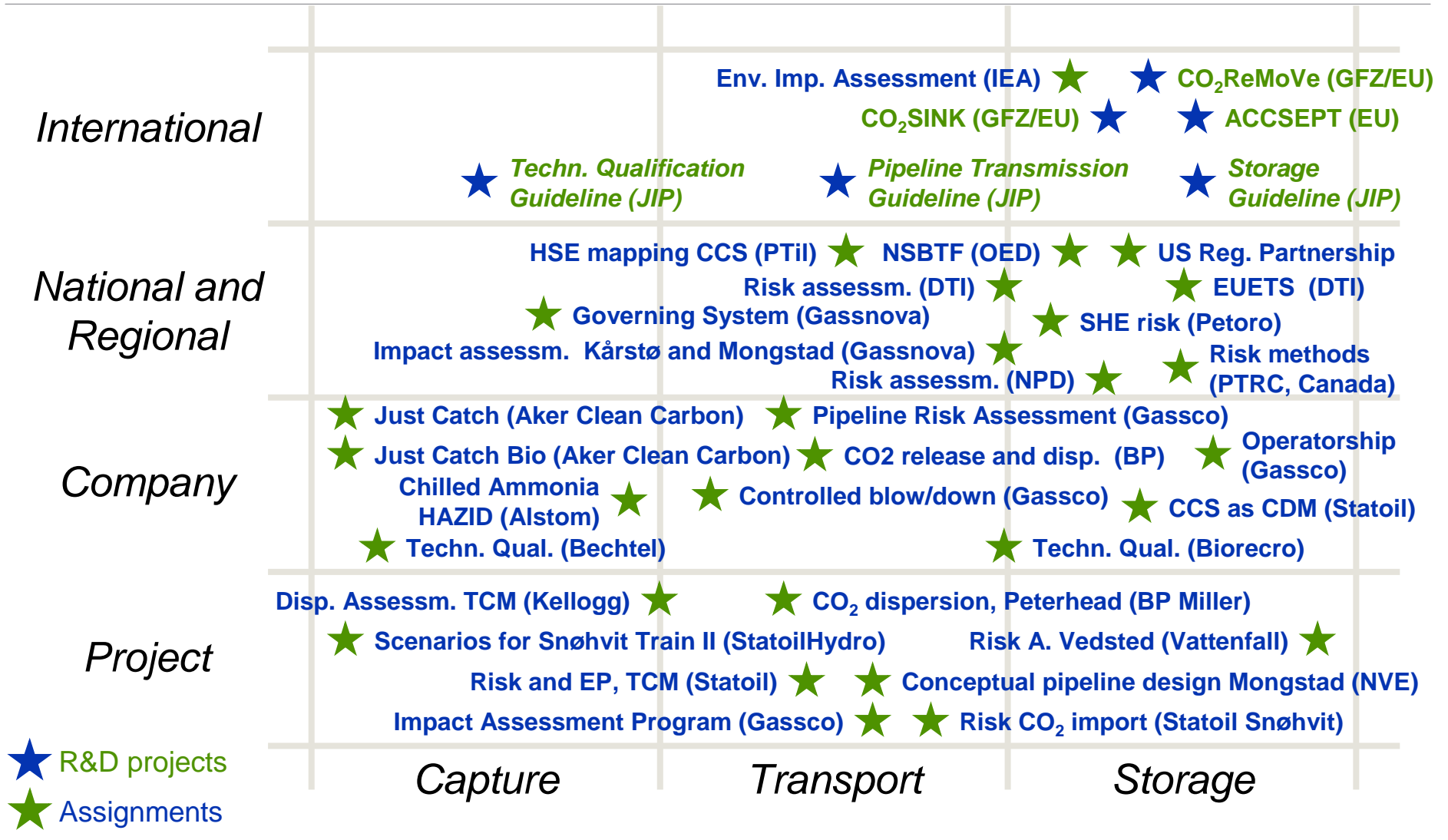
June 2011: Guideline will be published on DNV and GCCSI websites

September 2011: DNV will be issueing a draft Recommended Practice (RP) for CO₂ storage based on:

- **CO2WELLS guideline**
- **CO2QUALSTORE guideline**

Project References

DNV engagements throughout the CO₂ value chain



Assist the European Commission in establishing the CCS project network

Client EU Commission, Directorate-General Transport and Energy

Project name The European CCS project network (2009-2011)



Challenge

Stimulate construction and operation of a set of CCS demonstration projects by 2015 (commercial size power plants, coal or gas fired covering the complete CCS value chain, with possible funding from EU includes Emission Trading Scheme, European Recovery Plan, Member State governments).

Generation of early benefits from a coordinated European action by creating a network of CCS demonstration projects.

DNV's approach

Establish and managing an industry CCS network, building towards the establishment of a European Industrial Initiative.

Establish the qualification criteria for participation, compatible with selection criteria for funding and monitoring of the participating projects/members and liaison with the EC.

Facilitate knowledge sharing, disseminate best practices, branding the network, establishing websites (confidential part, public part, virtual exhibition space, observatory). Public awareness and international cooperation.

Value to the client

An active knowledge sharing network consisting of a diversified portfolio of demonstration projects representing different capture technologies, transport solutions, and storage sites.

Exchange of information and experience from large-size industrial demonstration of CCS technologies. Maximize ECs impact on further R&D and policy making. Optimize costs through shared collective actions. Shortened time to commercially viable CCS.



Note: Co2Qualstore is applied as a guide for development of EU's CCS Storage directive

Technology Qualification Management: Advanced carbon capture technology

Client Aker Clean Carbon
Project name Technology Qualification



Challenge

Aker Clean Carbon is leading a development project for capture of CO₂ from a natural gas power plant.

The solution involves several novel aspects, including possible use of new chemicals, to significantly reduce costs and energy consumption.

DNV's approach

DNV was engaged by Aker Clean Carbon to assist in the management of the qualification according to DNV-RP-A203, DNV used a structured approach to identify potential modes of failure and ensure that these are adequately addressed. Failure mode analysis was performed in workshops with expert personnel.

Value to the client

DNV has ensured that the process follows the principles of RP A203, ensuring the stakeholders that the technology qualification is managed according to a systematic process. DNV delivered a transparent and structured documentation of the qualification, increasing the various stakeholders' trust in the technology.



Quantitative risk analysis of CO₂ pipeline

Client	Gassco
Project name	Risk analysis CO ₂ pipeline from Kårstø to Utsira or Sleipner A ('09)



Challenge

To identify potential personal-, environmental- and material risks, in the operational phase of the project

To document to all parties involved that the HSE risks in the project is within acceptable level, or if not;- describe risk reducing measures.

DNV's approach

DNV organized and facilitated a HAZID (HAZard IDentification) workshop for identification of risks involved. Based on the HAZID and a barrier analysis the quantitative risk assessment (QRA) was carried out including frequency estimations and consequence assessment.

Value to the client

Risk results were provided as Societal risk to 3rd party, Individual risk to 3rd part to the most exposed person. Risk to material and environment was also coarsely estimated, and expressed by the total pipeline leak.

The quantitative risk analysis performed is a vital part of the client's risk management process.



Coarse Risk Assessment (RA) of the potential storage site for Vattenfall's CCS demonstration project in northern Denmark

Client Vattenfall AB
Project name Coarse Risk Assessment (2008)



Challenge

Retro-fit capture plant to Nordjyllandsværket coal-fired power station close Aalborg, Denmark.
 CO₂ to be stored in the Vedsted geological structure.

DNV's approach

Assessed the current state of knowledge about the Vedsted geological formation and it's suitability for CO₂ storage, through expert workshop and early Risk Assessment (RA).
 The work to follow draft procedures from the DNV JIP on qualification of CO₂ storage sites.

Value to the client

Identified hazards, safeguards and major uncertainties and gaps in knowledge and ranked these in order of significance.
 Documented the RA process carried as input to the documents that Vattenfall intends to produce for Danish authorities.

Why go for Aalborg - Vedsted?

100% Post Combustion
 1.8 mio tonnes CO₂ pro annum

Vedsted geological structure
 *Expected storage capacity >100 million tonnes
 *Transport via pipeline

Advantages at Aalborg-Vedsted

- Short distance from plant to storage facility
- Most efficient power plant in the world
- Safeguards future for power plant

Project Risk: Full scale CCS at Kårstø and Mongstad

Client Gassnova SF – the Norwegian public enterprise for CCS

Project name Full scale CCS at Kårstø and Mongstad

Challenge

Full scale capture, transport and storage in FEED phase at Kårstø and Mongstad (TCM).

Independent review (IPR), and identification of main risks (budget, time, design basis, procurement- and overall project strategy)

DNV's approach

Systematic review and evaluation of main risks.

Systematic remediation options considered and proposed.

Value to the client

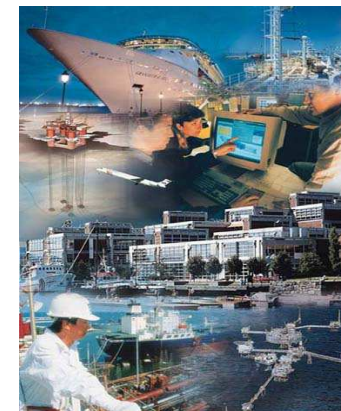
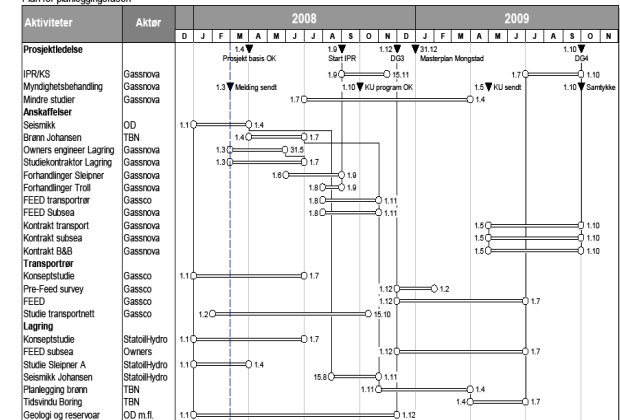
Project specific risk management.

Improved project execution and performance



GASSNOVA

CO2 Transport og Lagring
Plan for planleggingsfasen



CO2QUALSTORE workshop for Qatar Shell

Client Qatar Shell

Project name CO2QUALSTORE workshop in Doha, September (2010)

Challenge

Qatar is a major oil and gas producing nation with 15% of current world reserves of natural gas. CO2 emissions are set to soar over the coming years and Shell is one of the IOC's keen to facilitate the development of CCS in the country. Their challenge has been to create an open dialogue with Qatar Petroleum around the technical and regulatory requirements to storage site screening.

DNV's approach

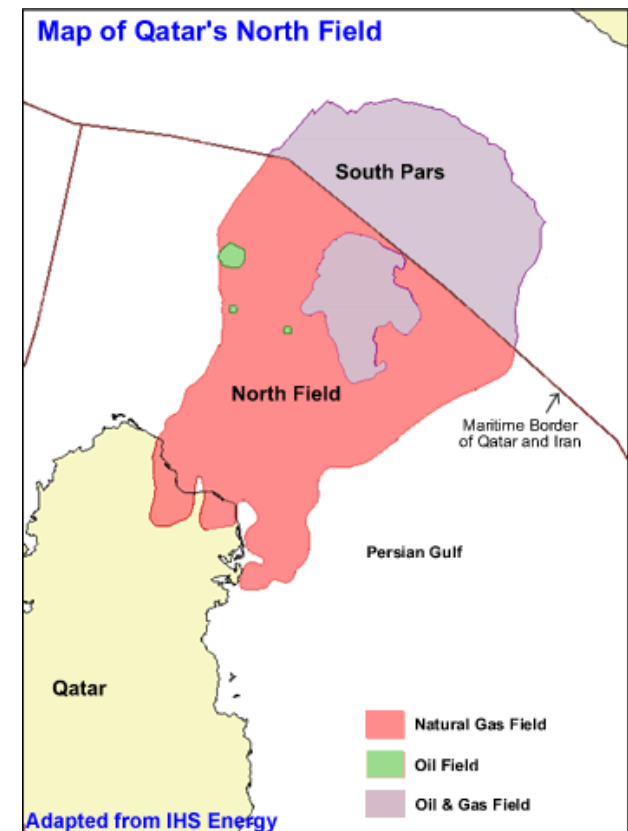
DNV's involvement in this workshop was crucial to ensuring Qatar Petroleum's involvement; they came to learn more about the CO2QUALSTORE guideline and how it is applicable in Qatar. DNV presented the guideline in detail and facilitated workshop sessions around the Screen and Assess & Select stages.

Value to the client

Qatar Shell have expressed a very high degree of satisfaction with the workshop and the quality of discussion achieved with Qatar Petroleum.



قطر للبترول
Qatar Petroleum



Independent Project Review for ZeroGen CCS

Client Australian Coal Association / ZeroGen CCS

Project name Independent Project Review (2010)

Challenge

The ZeroGen CCS project in Queensland is funded by the Australian Coal Association Low Emissions Technology Fund (ACALET) and the Queensland Government. ACALET requested that the project received an Independent Project Review (IPR) in order to check project progress and investment.

DNV's approach

DNV was engaged to facilitate a technical review of the CO₂ transport and storage elements of the integrated gasification combined cycle (IGCC) power plant project using the CO₂QUALSTORE guideline as a template for CCS project development.

Value to the client

ZeroGen and ACALET have expressed a high level of satisfaction with the IPR and DNV's role. The findings have been used to support a re-evaluation of the project schedule and will form the basis of an ongoing engagement around project reviews.



CCS in Asia

- **Ongoing project – “Road Map for CCS in Thailand”** – including two feasibility studies for onshore (EOR) and offshore (EOR) – DNV CCS consultant/expert resource
- Potential feasibility study in Taiwan for coal fired power plant – “CCS roadmap for TPC”
- Potential feasibility study in Indonesia for coal fired power plant – potential financial support from Norwegian government

CCS under CDM

- Following the COP 16/CMP 6 conference in Cancun, DNV welcomes the **United Nations Framework Convention on Climate Change** (UNFCCC) decision that carbon dioxide capture and storage (CCS) will be eligible as project activities under the clean development mechanism (CDM).
- DNV considers that CCS is a strategically important technology for upholding sustainable growth whilst reducing carbon dioxide emissions.
- Whilst technical challenges remain, DNV believes that the **main barriers to wide scale CCS deployment lie in the regulatory and financial gaps** that must be closed to enable commercial operations.

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