



CO2QUALSTORE - Guideline for Selection and Qualification of Sites and Projects for Geological Storage of CO2

P2W5: Workshop on Mapping of Potential Reservoir for CCS & Selection Criteria, 28-30 September 2010, Bali, Indonesia

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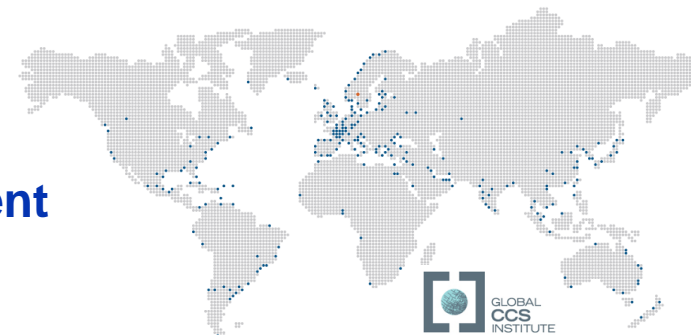


MANAGING RISK

Integrity at the core



- Independent self-owned foundation
 - Established in 1864
- **Safeguarding Life, Property, and the Environment**
- 9000 employees, 100 offices

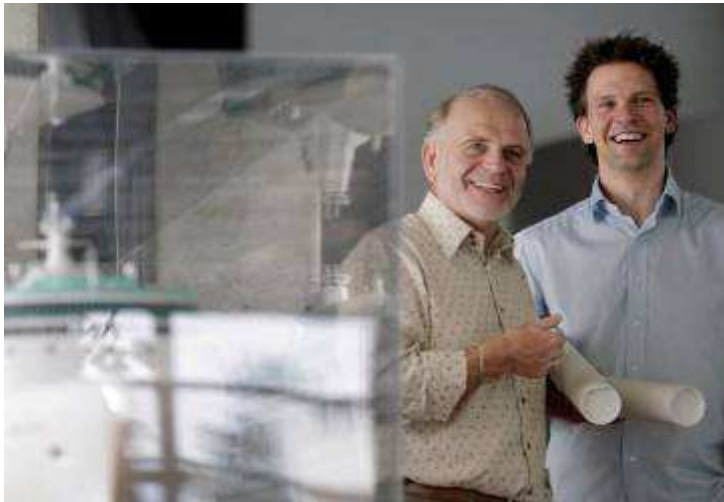


Topics of the presentation

- Introduction
 - Brief introduction to DNV and our CCS engagements
 - The new risk reality
 - Some major challenges in the realization of CO₂ geological storage
 - Why risk-based approach?
- The CO₂ storage guideline
 - The objectives of the CO₂QUALSTORE Joint Industry Project
 - Basic principles of the guideline
 - CCS project examples



Build and share knowledge



- We invest 6% of our revenue in **research and development**
- We take a lead role in joint industry research and development projects
- Through our **standards, rules, recommended practices** and **software solutions** we share knowledge with the industry

DNV's Position within clean technology

Position within the wind industry

- DNV addresses technical, environmental and financial challenges
- Combined expertise in appraising and evaluating risks and opportunities
- We certify wind projects and create new standards
- Qualify new wind technology and do type approval
- Measure and verify wind resources
- DNV is the second largest player in the wind area



Position within emissions trading

- The world's leading greenhouse gas validator
- 35% market share of all CDM projects globally
- Involved in forming new standards for voluntary carbon trading schemes
- Offers a wide portfolio of related services from carbon foot printing to training and risk management of carbon projects



Position within carbon capture and storage

- DNV leads a number of joint industry projects
- Published guidelines on technology qualification, pipeline transmission and storage of CO₂
- Work for EU to establish and manage an industry network to get 10-12 demonstration plants in Europe by 2012
- Work with world's leading CCS players on projects in the entire CCS value chain



Position within adaptation

- DNV has been selected by EU to coordinate investigation into consequences of extreme seas as a result of climate change
- Climate changes integrated into development of standards, rules and requirements for offshore structures
- Both for new design and maintenance of existing structures



EU

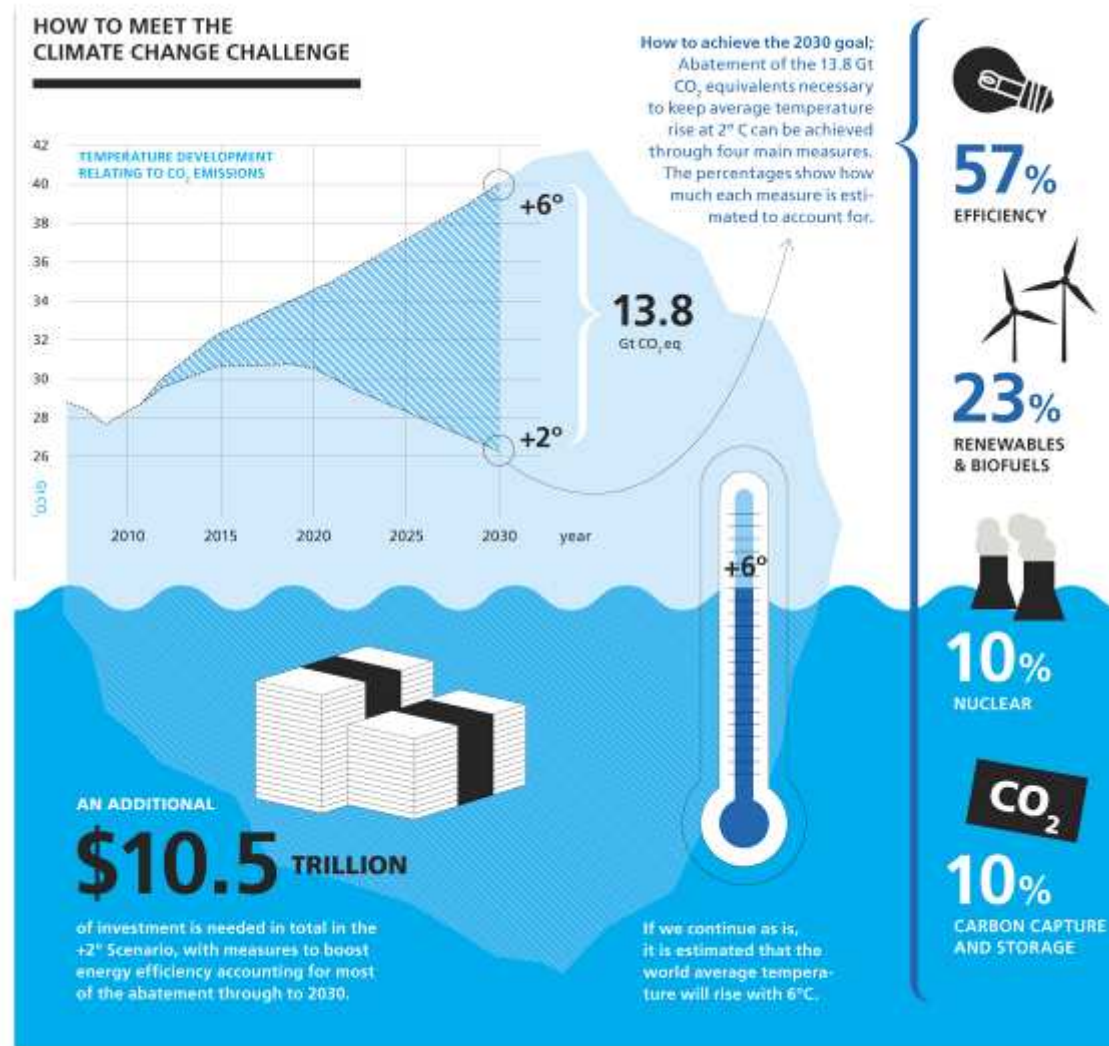
DNV is coordinating EU's investigation into the consequences of extreme seas

Position within energy efficiency

- Leads a number of research projects on energy efficiency
- Large projects with Chinese companies and authorities
- Works with a number of large shipping companies on energy management programmes
- Qualifies new energy efficient ship designs
- LEED certification of 'green' buildings (The Leadership in Energy and Environmental Design **Green Building** Rating System™ is a third-party **certification** program and US nationally accepted

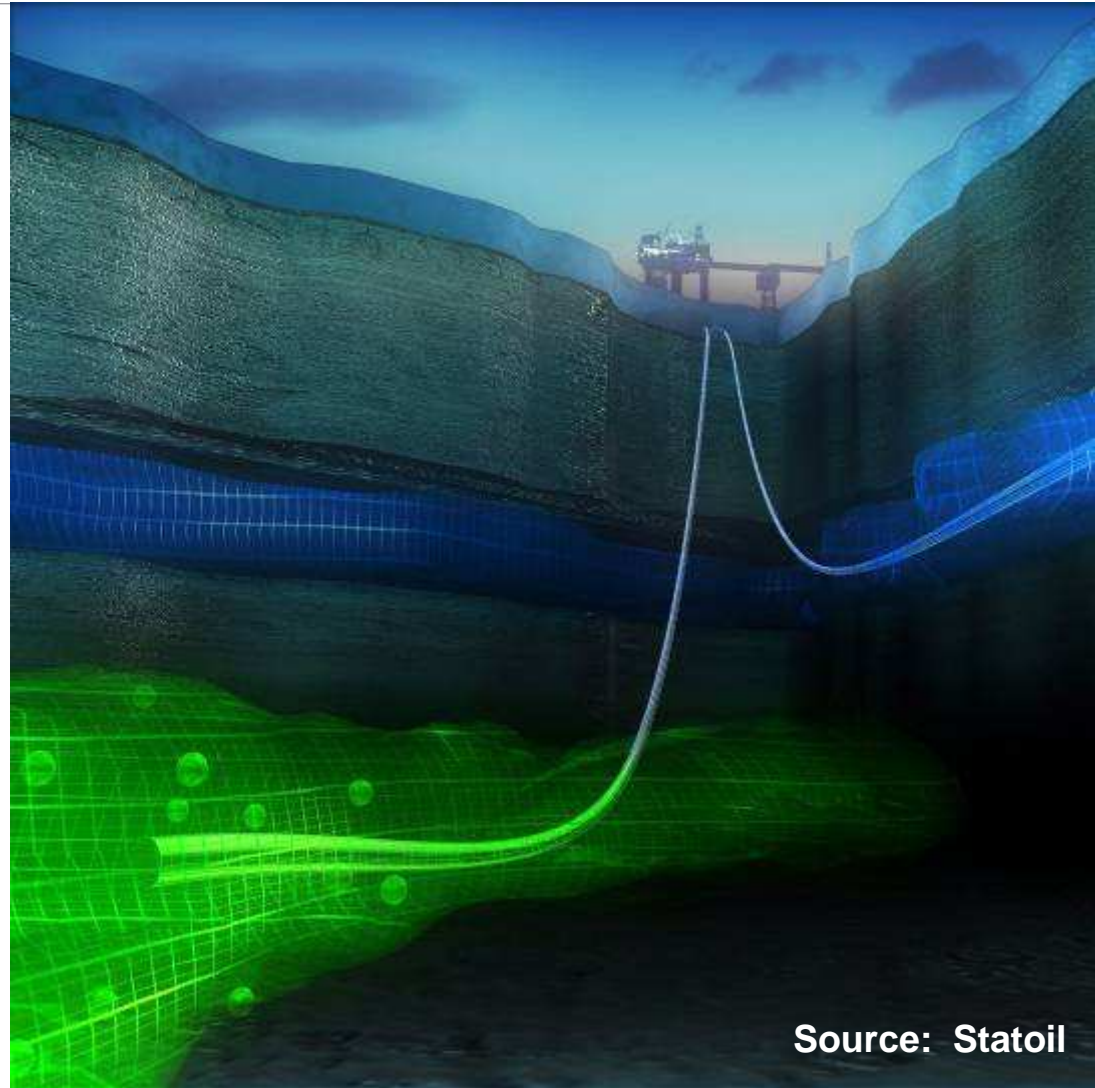


CCS - a challenge for industry and society



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



DNV at the forefront of global CCS developments

- **Assisting the EC** in managing the European CCS Demonstration Project Network for knowledge sharing (www.ccsnetwork.eu)
- **Developing guidelines** that meet real-world demands through collaborative public/private projects
- **Facilitating a dialogue** on CO2 storage between German industry and regulators
- **Supporting the Alberta Department of Energy** on CCS knowledge sharing
- **Supporting implementation of CCS** projects in Australia and ME
- ***DNV is proud to be at the forefront of global CCS developments and benefit from Norway's pro-active role in this field***



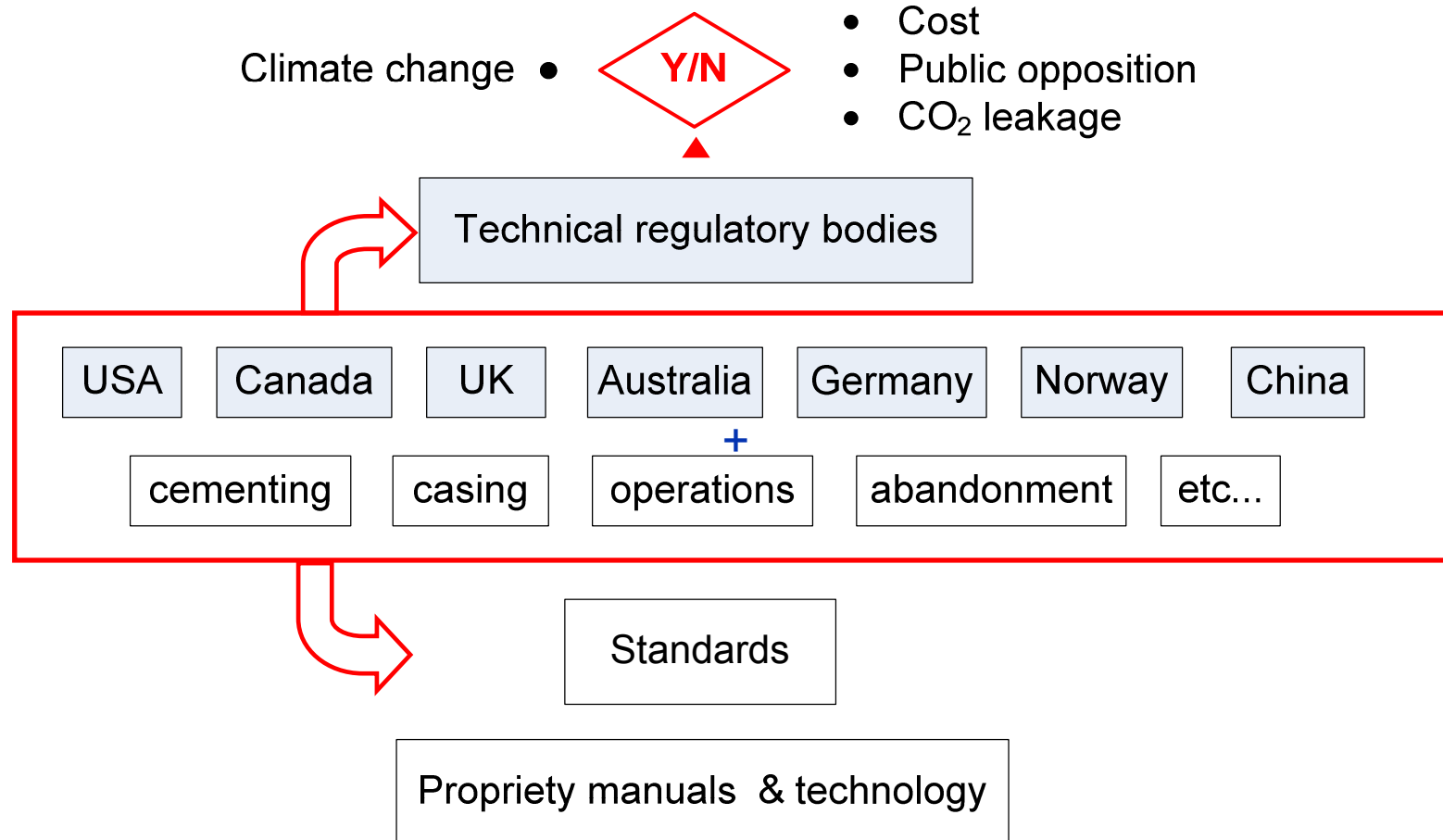
CCS – Challenge of public acceptance

- Recent experience demonstrates that issues around **public awareness and public trust in CCS can be obstacles to deployment** of the technology.
- **CCS projects contain a number of features that contribute to increasing public concern**; unfamiliar technology, high costs and unclear benefits.
- Whilst the goal of reducing global climate change may be attractive, **any perceived risks with CCS will typically be local and of more immediate concern to the affected population.**

To build confidence in CCS as a trustworthy option to mitigate global warming, it is important that CCS projects are implemented in a clear and transparent way that stakeholders can accept, where benefits and risks are balanced and well communicated.

DNV provides decision support for regulators & industry

Political decision to fund CCS?



The new risk reality

Climate change – high frequency of extreme wheather



Global warming

Xinhua, January 30, 2010

China allocates fund to fight worst drought in Southern China in 50 years

China has earmarked 50 million yuan (7.35 million U.S. dollars) of emergency fund to help South China fight the worst drought in 50 years, the Ministry of Finance said on Friday.

The money will go to the southwestern Yunnan Province and Guangxi Zhuang Autonomous Region in restoring agriculture production and making sure people and livestock have adequate drinking water supply, the ministry said.

The drought affected 2.91 million people and 1.48 million large livestock in Yunnan, while up to 57.5 percent of crops, or 21.24 million mu (1.42 million hectares), in the southwestern province were also affected.

In Guangxi, more than 80,000 people in Donglan County suffered water shortage, local authorities said Wednesday



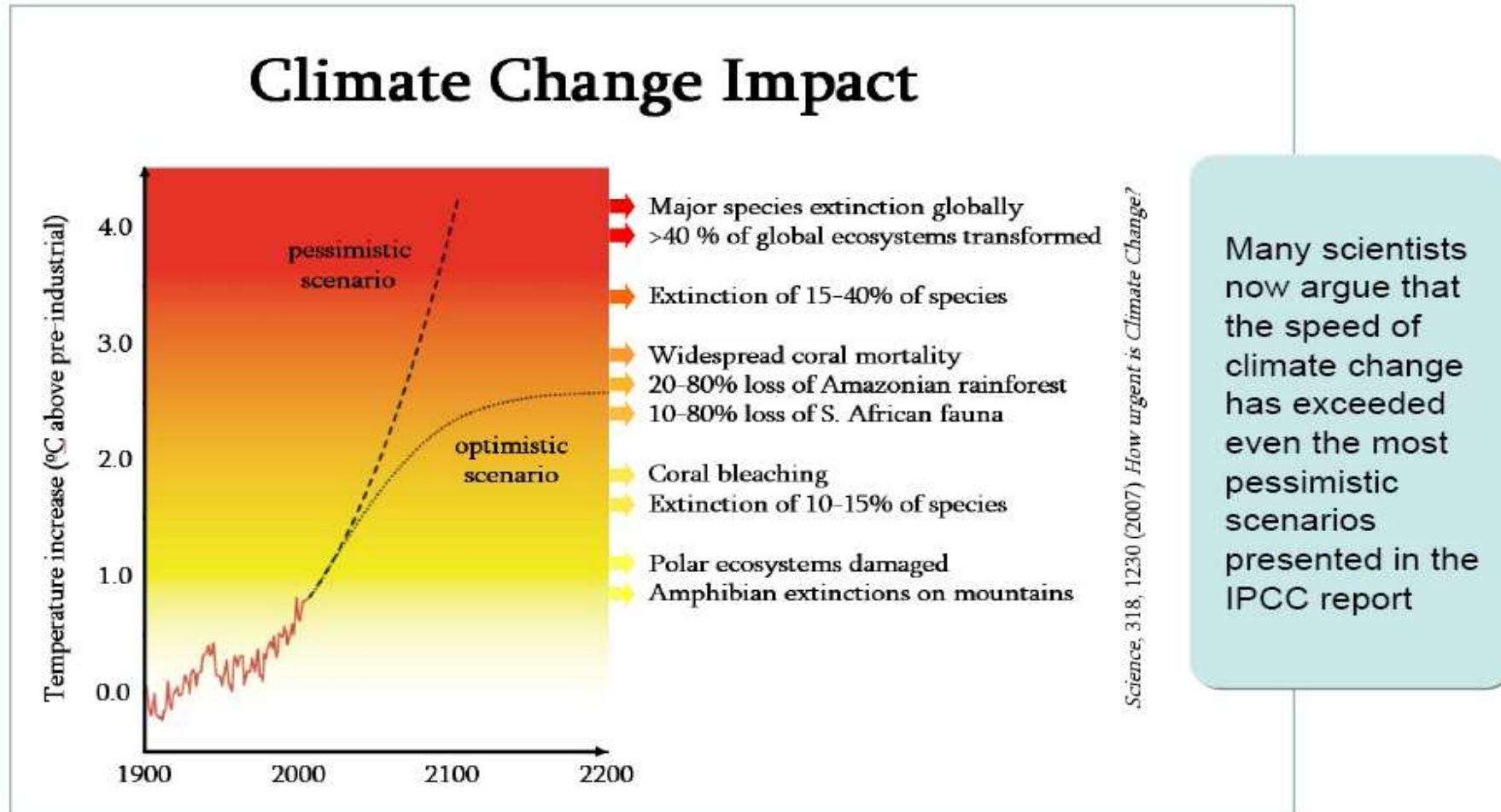
Severe drought in China

China devastated by floods

- Huge floods in southern [China](#) have killed at least 132 people and displaced 800,000, the government said today as the annual storm season picked up ferocity.
- More than 10 million people have lost property, been injured or suffered a cut in power or water supplies as a result of the week of torrential rain across Guangdong, Fujian, Guangxi, Jiangxi and Sichuan.
- Many of these areas have gone from one extreme to another, according to the government. Earlier this year, south-east China endured its worst drought in living memory, but in the past week, some places have been inundated with three times the average rain for this period.
- With thousands of houses destroyed and businesses and power lines put out of action in Guangdong and Fujian – the industrial hubs on the coast – the ministry of water resources estimated the economic damage at 14bn yuan (£400m).

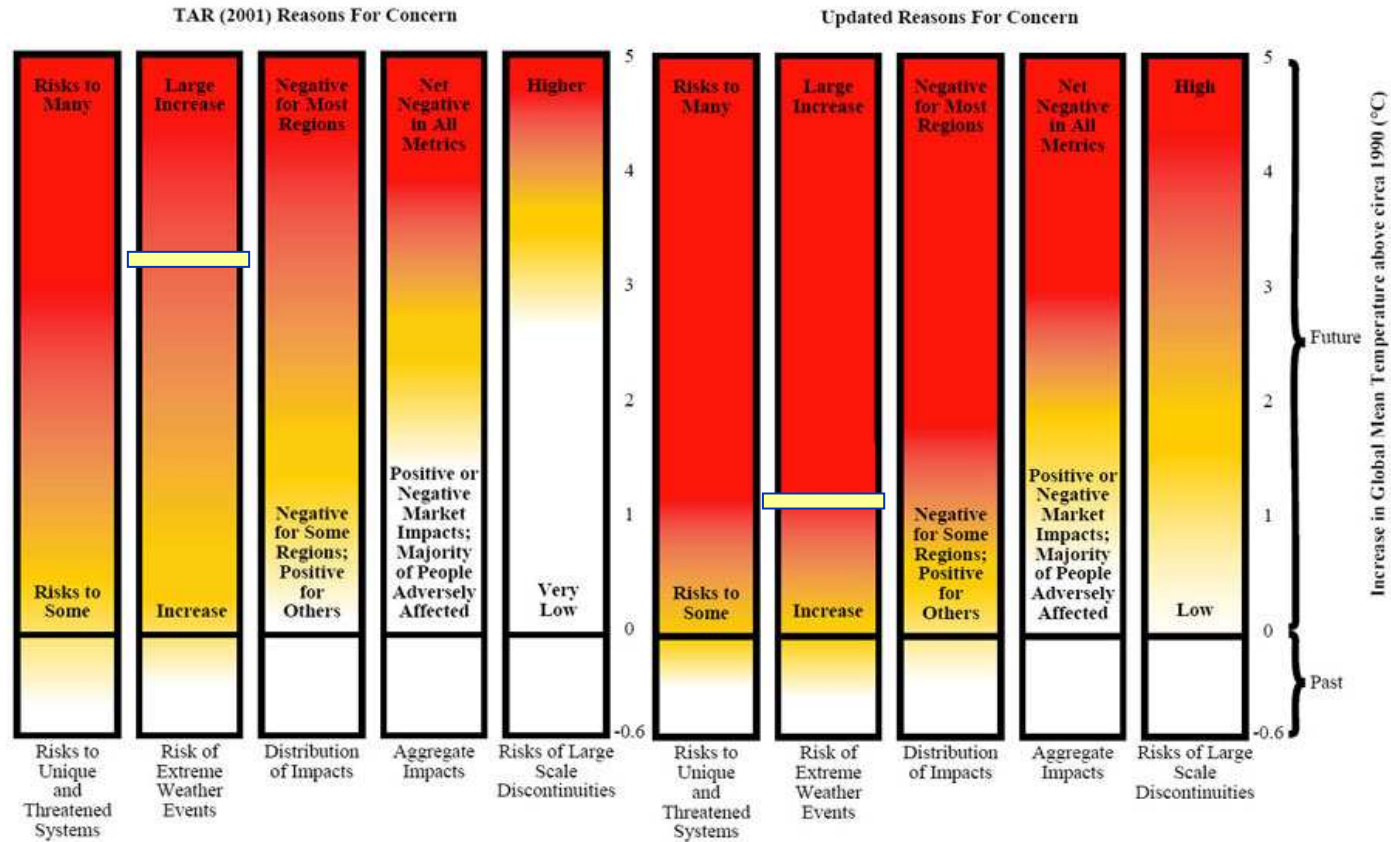


Effects of global warming



Intergovernmental Panel on Climate Change 4th Assessment

Effects are more severe than expected 9 years ago...



Current expectations:
 Only above 1 °C increase is expected to cause increased risk of extreme weather events!

Carbon Capture and Storage – The solution?

Capture



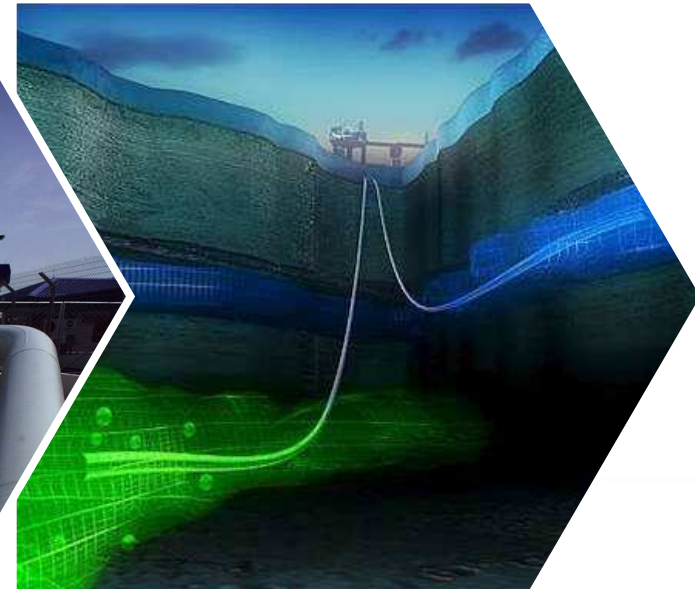
- Fossil power plants
- Natural Gas CO₂ reduction
- Other industrial processes

Transport



- Pipelines
- Ships

Storage



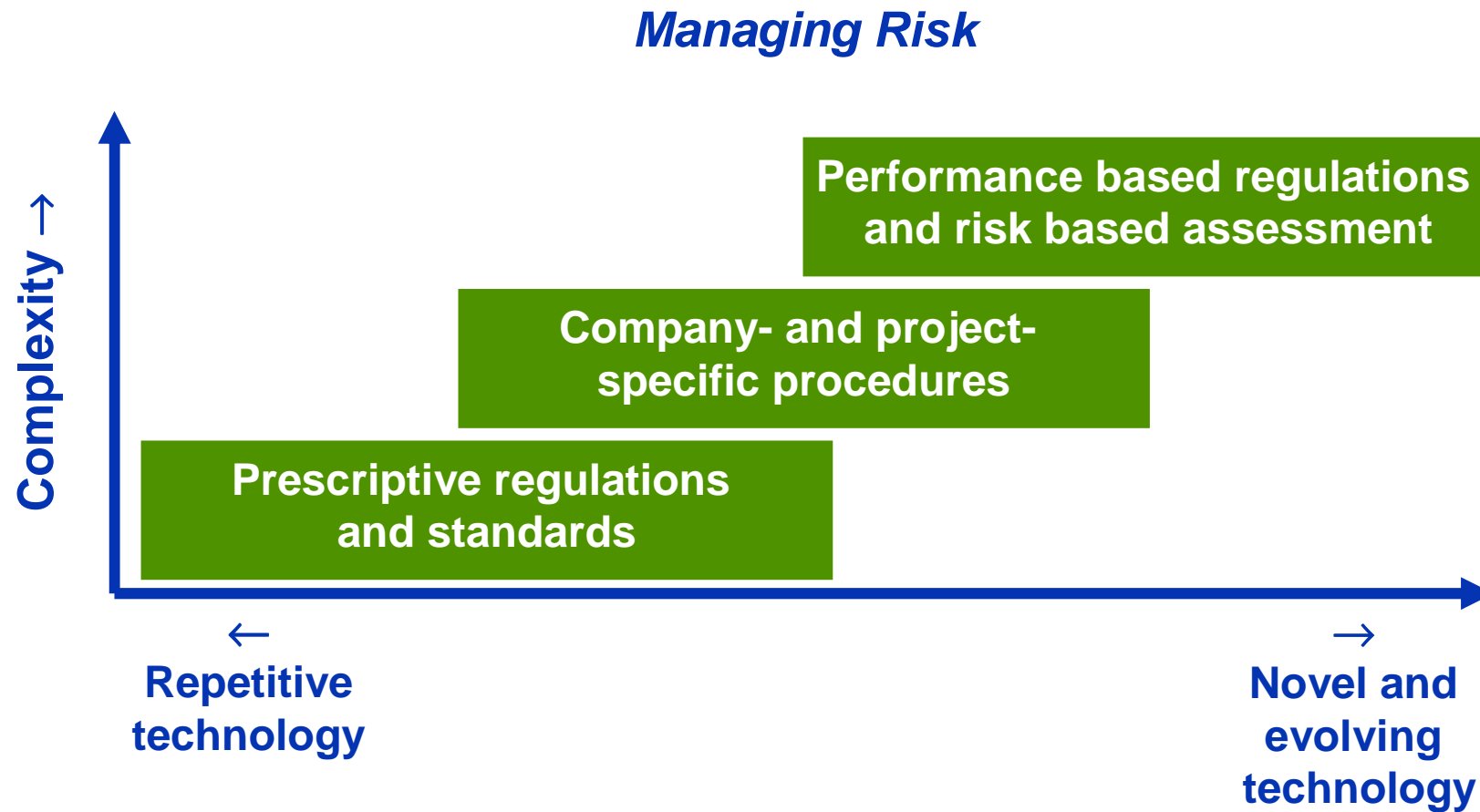
- Empty oil or gas reservoirs
- Saline aquifers
- Enhanced Oil Recovery

Challenges in the realisation of CO₂ storage

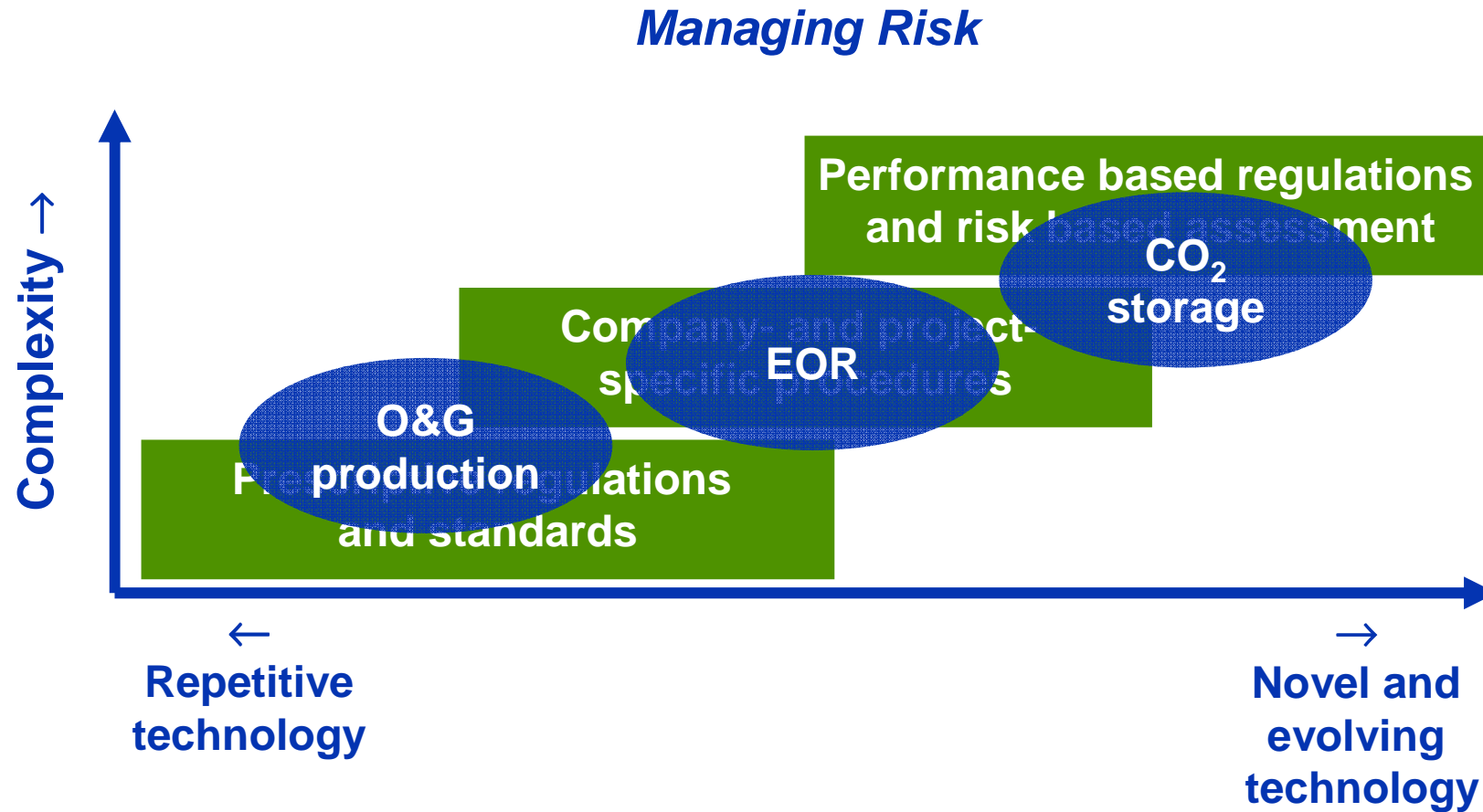


- Legal and regulatory framework **not yet in place**
 - **Public awareness of CCS** as a safe and important means to mitigate global warming **needs to be established**
 - **Trust between the stakeholders:** Regulators / Operators / Public **needs to be established**
 - Hand-over of liability from Operator to Government after closure of storage site – **actual project cases**
 - **Need for evidence for how to convincingly ensure containment** of CO₂ for thousands of years
- ... and more

Why a risk-based approach?



Why a risk-based approach?



Motivation for initiating the CO₂QUALSTORE JIP

- **Goal 1: Unified industry practice**
 - Recognized **best practice** guidelines for global use that support **regulations**
 - Efficient implementation of **legal and regulatory CCS frameworks** internationally
 - Using concurrent **best engineering practice** and BAT (best available technology)
 - **Manage risks** (and uncertainties) **throughout storage life**

- **Goal 2: Accelerate implementation – move from demos to large scale CCS**
 - Define **predictable operating conditions**
 - Convert **current knowledge and experience** from R&D and Pilots into recommended practice and guidelines.
 - **Learn by doing** through risk based qualification and verification processes.
 - **Identify knowledge** gaps and help prioritise further R&D.

- **Goal 3: Public acceptance**
 - **Confidence in CCS** as a trustworthy option to mitigate global warming
 - **Predictable and transparent implementation** to meet expectations of stakeholders
 - Balance and communicate **benefits and risks**

CO2QUALSTORE JIP: Objectives

CO2QUALSTORE has developed a guideline for selection and qualification of sites and projects for geological storage of CO2

Main objectives of the guideline:

- provide developers, regulators and independent verifiers with a **common protocol** for assessing the safety and reliability of geological storage sites for CO₂
- provide a **structured and transparent approach** to decision making that documents the basis for granting a storage permit
- be **performance based** with a sufficient level of detail to be a useful working guide for industry actors
- be **consistent with regulations** that are emerging for governing CO₂ storage in Europe, the USA, Canada and Australia
- **guide the dialogue** between project developers and regulators, relevant stakeholders and third parties



GASSNOVA



StatoilHydro

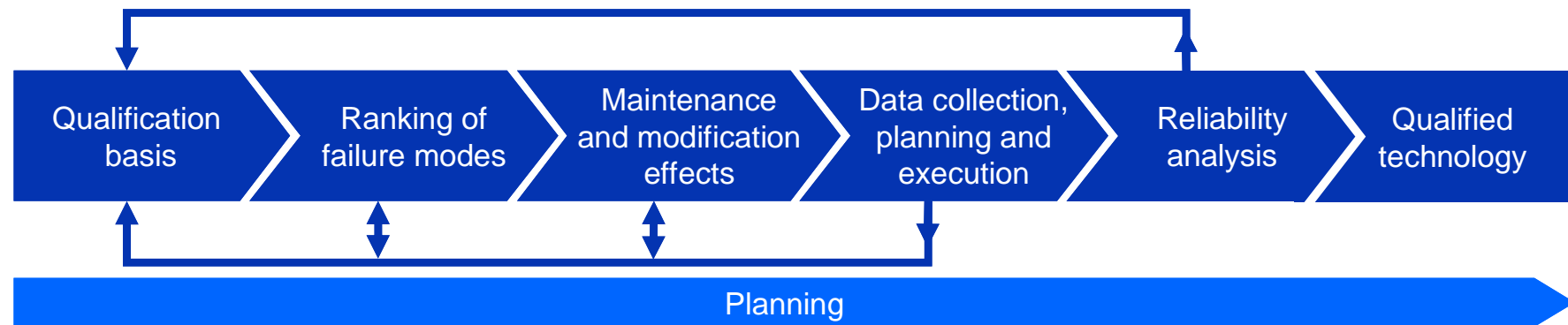
Schlumberger

DONG
energy

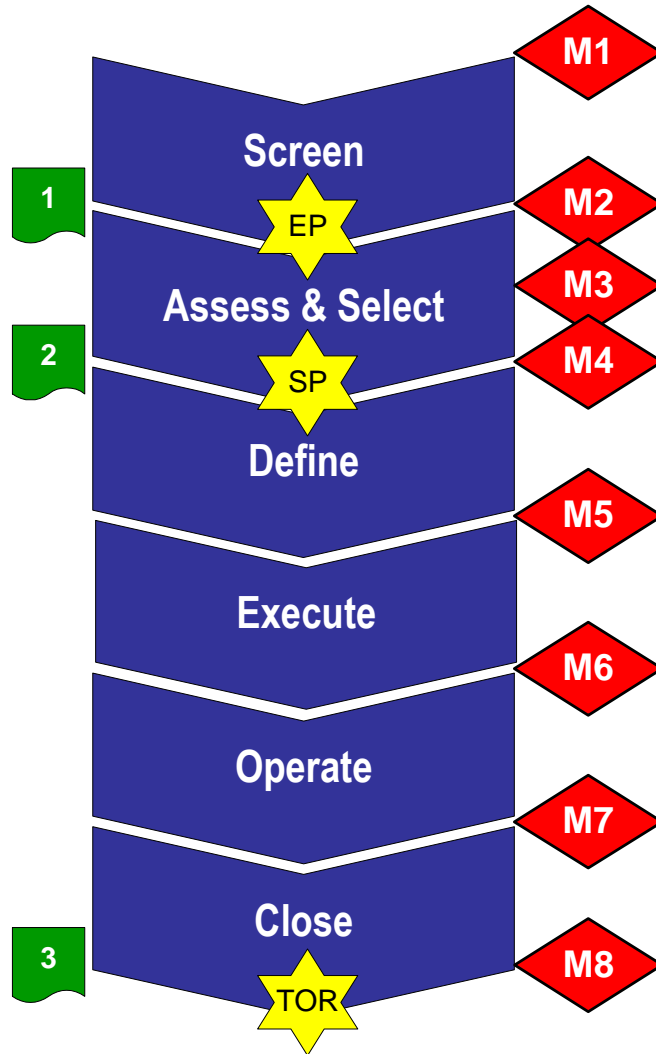
ARUP

Basic Principles for the Guideline

- **Risk based approach** that aims to provide an appropriate level of assurance with respect to the amount of information available
- **Site-specific approach** – every storage site is unique
- **Qualification** allows flexibility to adapt selection and verification approaches to site-specific conditions.
- Principles of **Technology Qualification (DNV RP-A203)** applied to selection and qualification of geological storages: ***“Systematic process of providing evidence that a technology will function reliably within specific limits.”***



Qualification Stages



Milestones

- 1) Begin site screening
- 2) Shortlist storage sites
- 3) Select site & engineering concept
- 4) Storage permit application
- 5) Initiate construction
- 6) Initiate CO₂ injection
- 7) Qualify for site closure
- 8) Initiate decommissioning

Qualification Statements

- 1) Statement of storage feasibility
- 2) Certificate of fitness for storage
- 3) Certificate of fitness for closure

Permits issued by Regulator

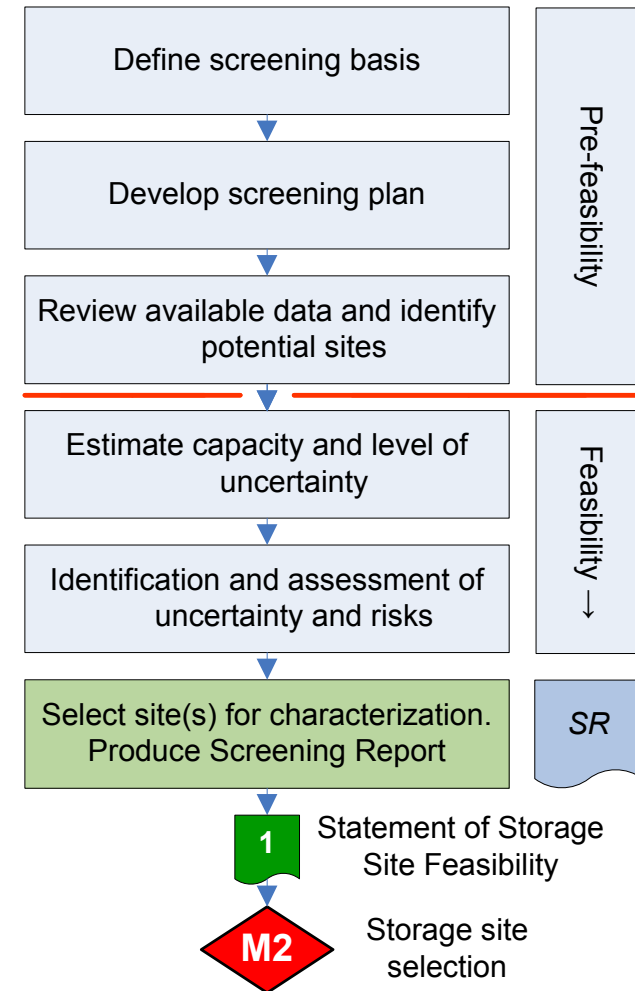
EP – Exploration Permit
 SP – CO₂ Storage Permit
 TOR – Transfer of Responsibility

Screening Stage

- Pre-feasibility largely based on existing data
- Early stage risk and uncertainty assessment
- Build common understanding of opportunities and risks
- Statement of storage site feasibility (SR) – regulator, entity acting on behalf of regulator or third party verifier

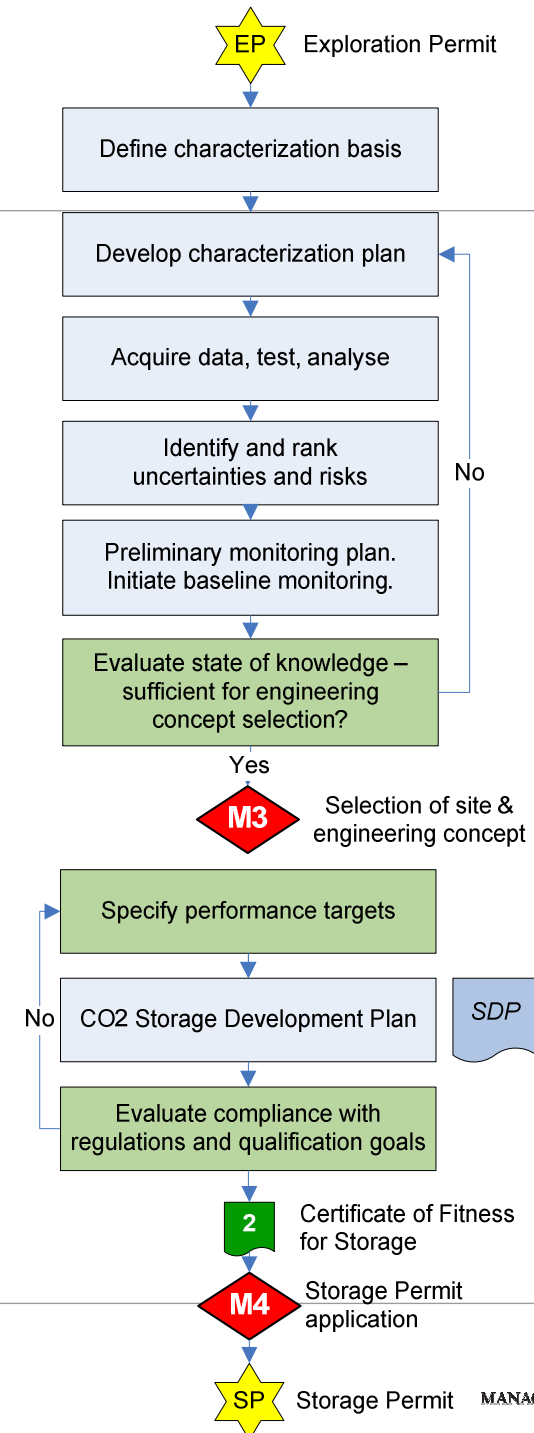


Guideline recommends involvement of regulator



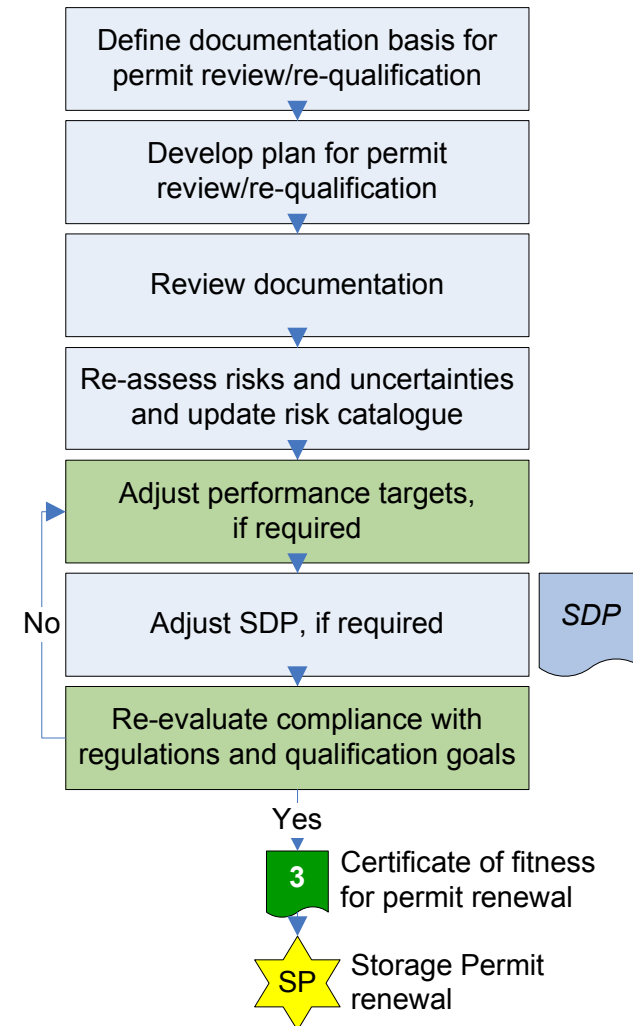
Characterization Stage

- Collect and assess data – define criteria for demonstrating “fitness for storage”.
- Risk assessment:
 - **Identify and assess risks and uncertainties.**
 - **Identify and assess of safeguards**
 - **Rank risks: insignificant, contingent acceptable and unacceptable**
- State of knowledge - present alternatives prior to final site & concept selection
- **Select site and engineering concept**
- Specify performance targets – agree with regulator on acceptable level of risk
- Define site development plan
- Evaluate if site meets criteria for storage
- **Submit storage permit application**



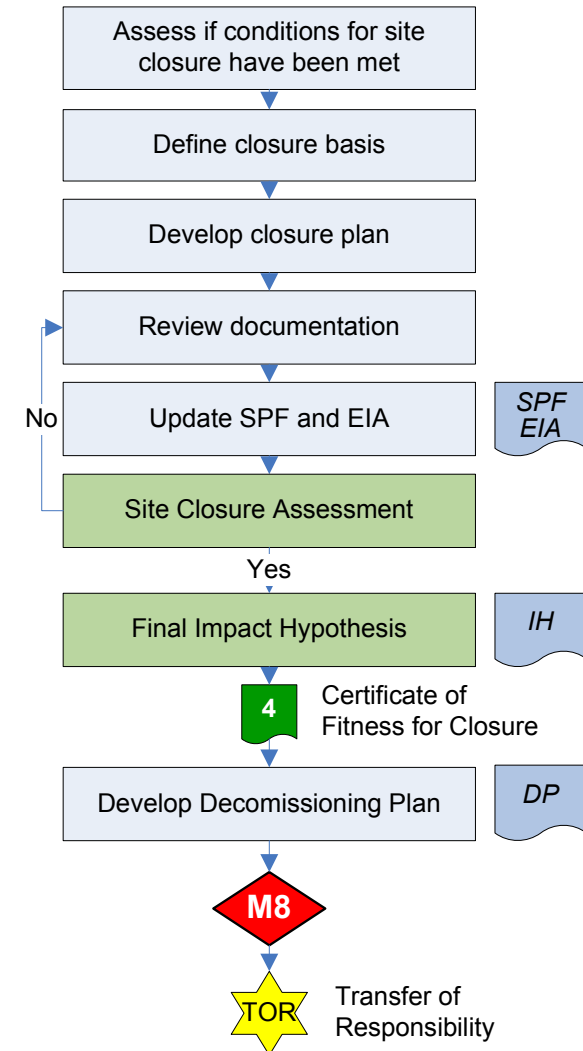
Operation / Permit Review

- Operation = injection + post-injection
- The Storage Permit is reviewed and updated throughout the lifecycle of the project.
 - Re-qualification – initiated by events or new information
 - Routine permit review to assess compliance with storage permit
- By end of injection the performance targets for closure have to be agreed with regulator



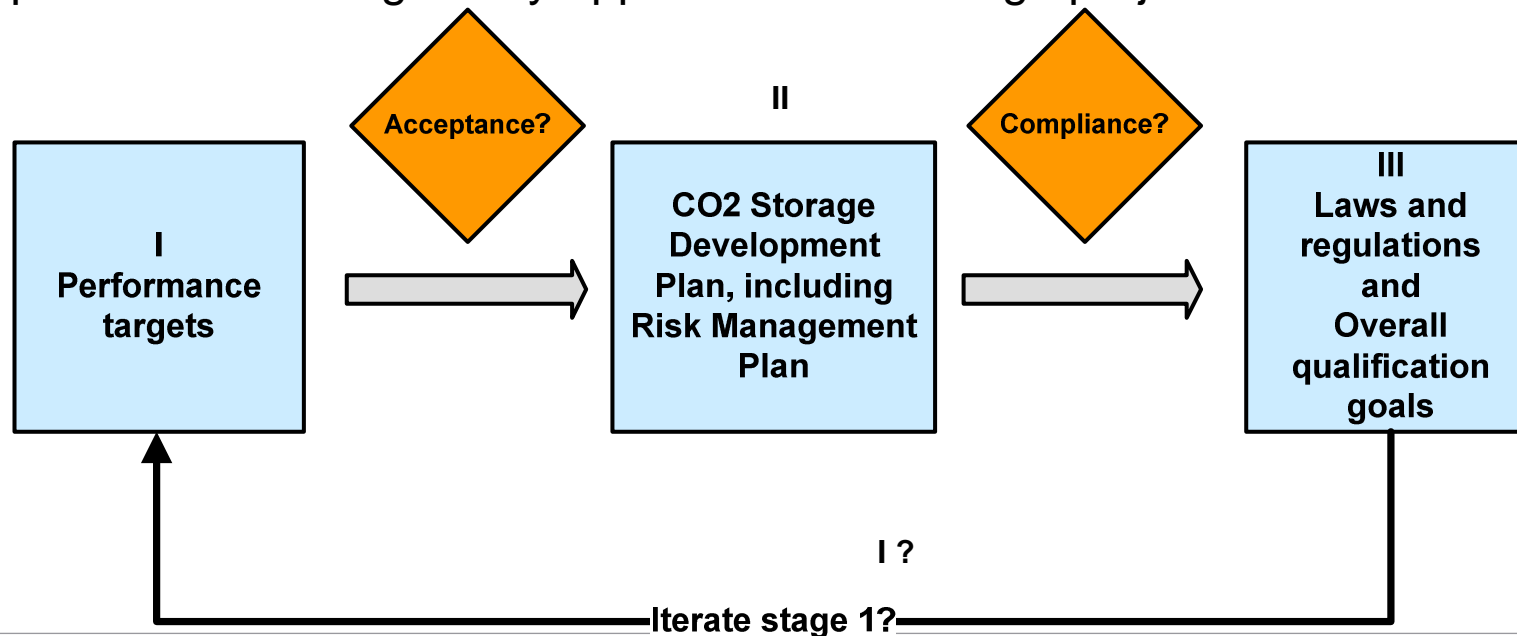
Site Closure

- Site closure stage:
 - Site closure qualification
 - Decommissioning
 - Transfer of responsibility
- Final Impact Hypothesis
 - Future negative impacts on human health and environment unlikely
 - Document reasonably degree of certainty in simulation models
 - Communicate with stakeholders
- Liability may be transferred to the authorities after decommissioning and granting of closure permit.

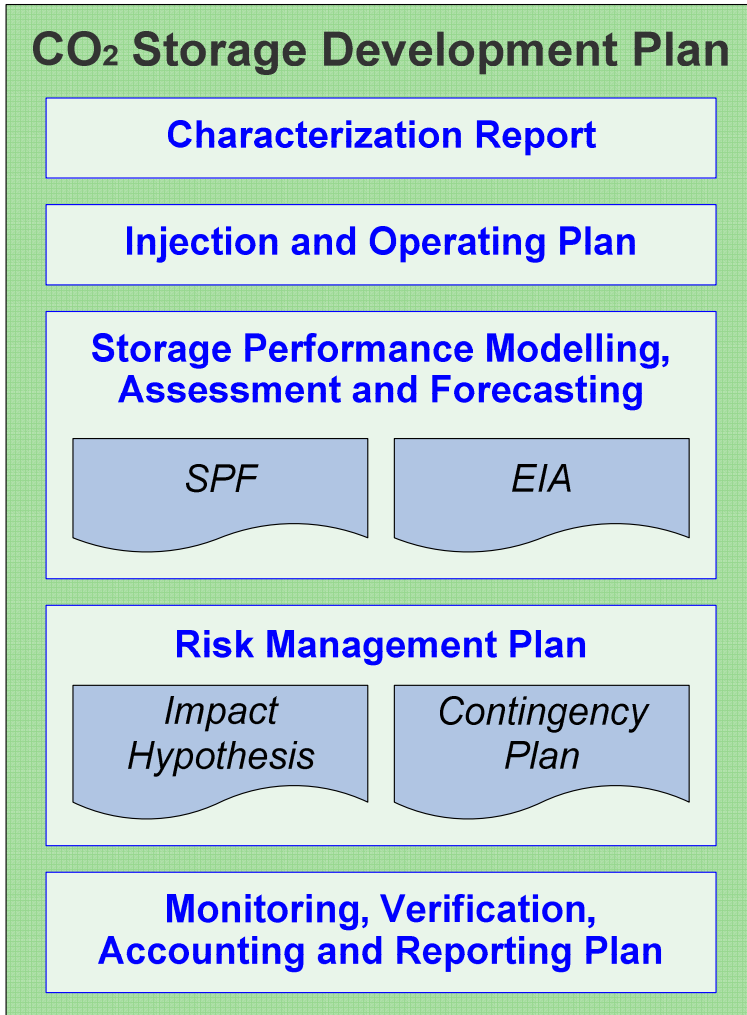
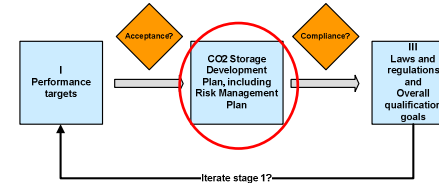


Three-stage approach to risk acceptance

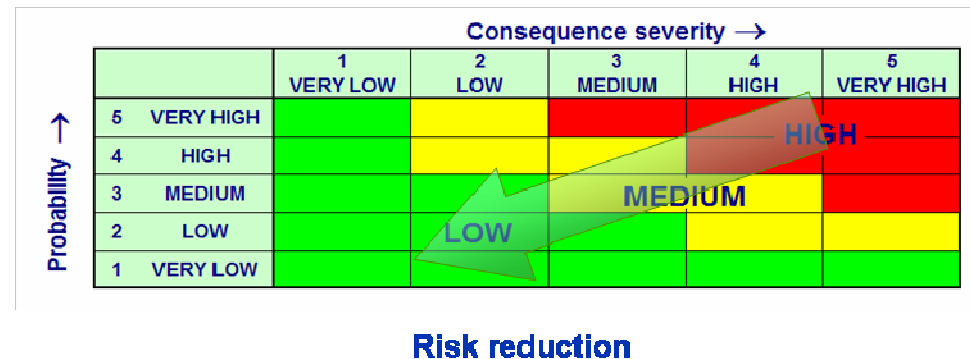
- Guideline proposes a three-stage approach to **guide dialogue** between a project developer and the relevant CGS regulator concerning acceptable levels of risk for a CGS project.
- In particular on how to specify and evaluate project specific **performance targets for risks and uncertainties** that relate to the storage leg of the CCS value chain.
- Basis for defining monitoring, verification, accounting and reporting (MVAR) requirements and regulatory approval of the storage project.



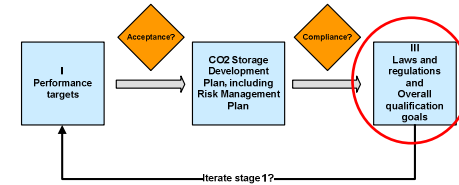
CO₂ Storage Development Plan



- **Impact Hypothesis (IH)** is based on recommendations from OSPAR guideline.
- The IH shall present an overall project risk evaluation for base case scenario based on the performance targets agreed between the regulator and the project developer.
- **Contingency Plan (CP)** provides a risk management plan for alternative scenarios.
 - Document that conceivable but unexpected features, events or processes can be controlled



Regulations and High-Level Goals



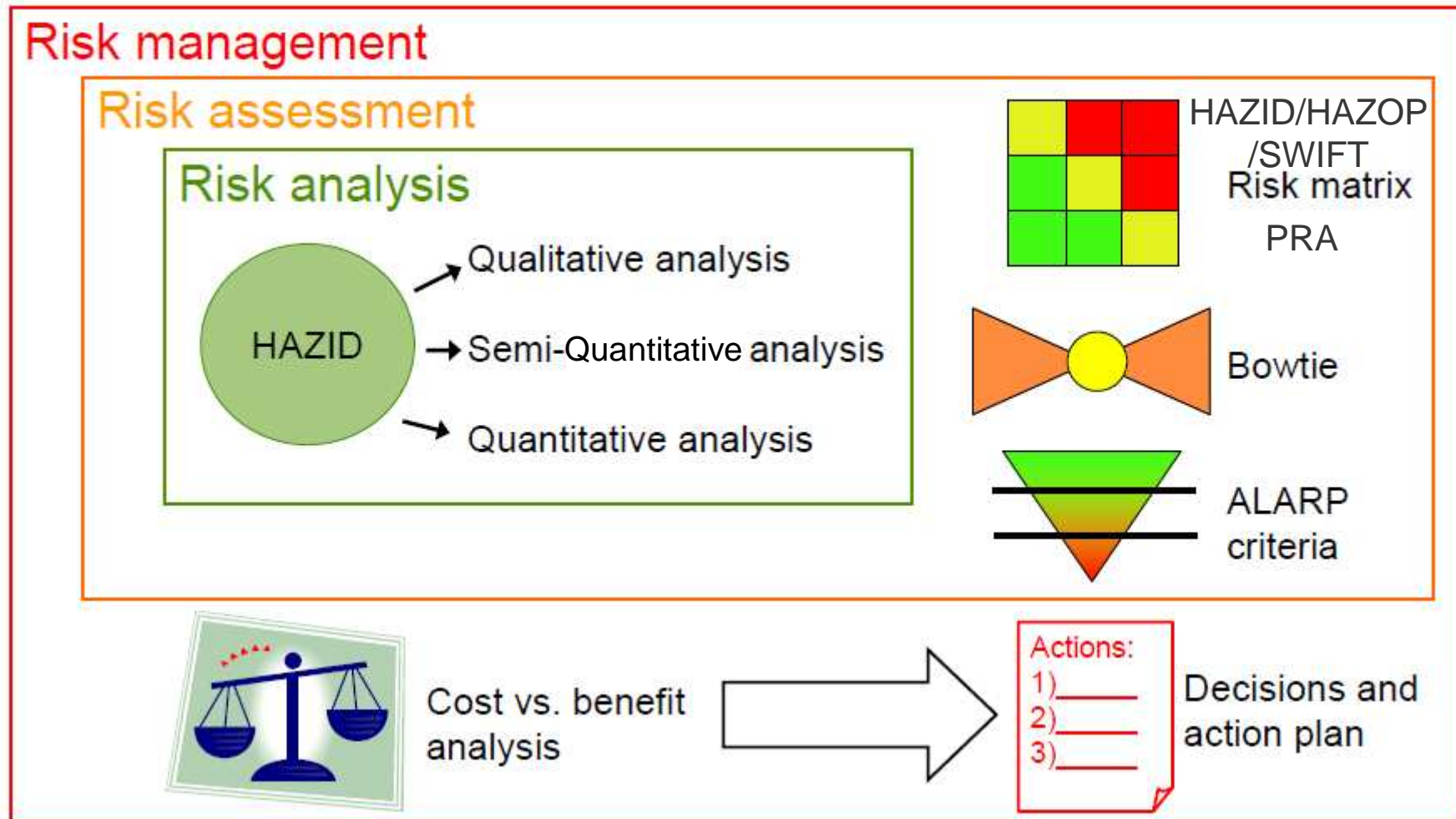
Qualification goals:

1. **Compliance with prevailing laws and regulations**
2. The project shall have a **climate benefit**, i.e., it shall store CO₂ in subsurface geological formations that would otherwise be emitted to the atmosphere.
3. The project shall **not have significant adverse consequences** for the environment, human health, and should preferably not negatively impact economic resources or potential for other legitimate uses of the surface area or subsurface volume.
4. High level of **confidence among the key stakeholders that the above objectives will be met with a reasonable degree of certainty.**

Risk Management for CCS

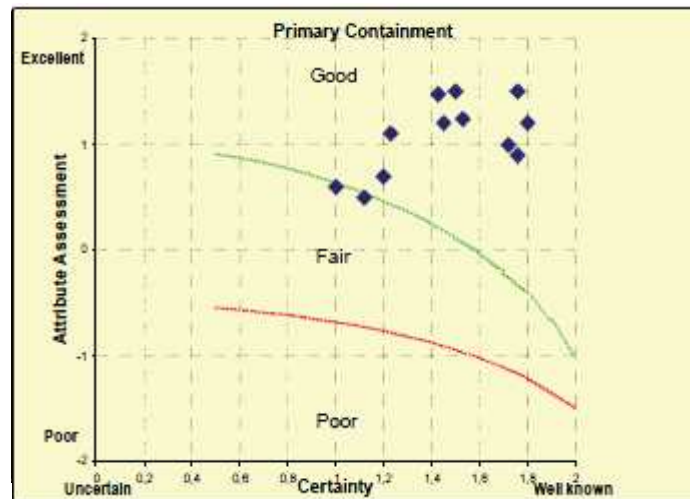
- To implement Carbon Capture and Storage (CCS) in a safe and sustainable way, there is a **need to apply risk management best-practices and actively pursue constructive engagement between industry, regulators and the general public.**
- Furthermore, to build confidence in CCS as a trustworthy option to mitigate global warming, it is important that **CCS projects are implemented in a clear and transparent way that stakeholders can accept, where opportunities and risks are balanced and well**

DNV uses a structured approach to Risk Management



Method for assessing the quality of, and uncertainty in, geological barriers

- The method for assessing the quality of, and uncertainty in, geological barriers focuses on primary and additional containment and is conducted on an individual basis by the experts after completion of the risk workshop.
- This **barrier analysis** is a semi-quantitative method that has been adapted from the Screening and Ranking Framework (SRF) for CO2 storage sites that was developed at the Lawrence Berkeley National Laboratory.
- The method relies on expert opinion to generate numerical input in response to a spreadsheet questionnaire





DNV CCS Project examples

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Technical novelties in the CCS value chain

Capture



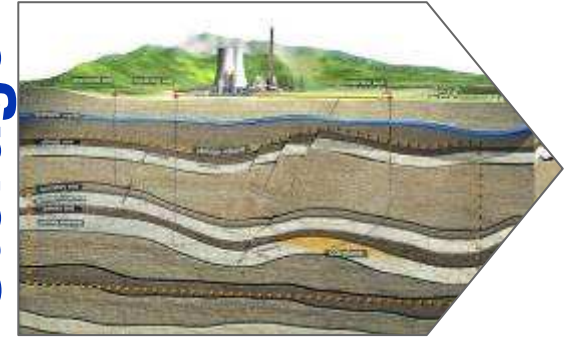
- Fossil power plants
- Natural Gas CO₂ reduction
- Other industrial processes

Transport



- Pipelines
- Ships

Storage



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

CTS

- Introduction of new technologies
- Up-scaling
- Accidental discharge and dispersion

- Corrosion
- Material selection and structural integrity
- Flow assurance and operational issues

- Qualification of sites
- Permanence of storage
- Monitoring and verification



CO₂ Storage Denmark

- **Project**
 - Client: Vattenfall AB
 - Retro-fit capture plant to Nordjyllandsværket coal-fired power station close Aalborg, Denmark.
 - CO₂ to be stored in the Vedsted geological structure.
 - 30 km long pipeline
- **Solution**
 - Expert workshop for an early Risk Assessment (RA) of the Vedsted geological structure.
 - The work followed draft procedures from the DNV JIP on qualification of CO₂ storage sites.
 - RA process to be refined as project develops.
- **Value delivered**
 - Assess the current knowledge about the Vedsted formation and it's suitability for CO₂ storage.
 - Identify and assess hazards, safeguards, major uncertainties and gaps in knowledge.
 - Document the RA process as input to the documents to be produced for Danish authorities.

Planned Timeline

- 2008 – acquisition of new seismic data
- 2009 – drilling of test wells
- 2010 – investment decision
- 2010 – apply for storage permit
- 2013 – begin CO₂ capture and storage operation



Risk assessment tools & methodology applied for CCS sites selection and qualification

- **The assessment tools are applied in a workshop environment and make use of a range of discipline experts from inside and outside the project organisation.**
- **They are well suited to the screening and assessment of storage sites, but need to be complemented with more detailed assessments, data collection and modelling for the later design and operation of CCS sites.**
- **The three main tools used are:**
 - A Structured What-IF Technique (SWIFT) for the comprehensive identification of geological risks;
 - A semi-quantitative risk ranking;
 - A spread-sheet tool for assessing the quality of, and confidence in, primary and secondary reservoirs and seals.
- **This methodology has been applied and tested on five specific sites:**
- **The Vattenfall CCS project developments in Denmark (one site for the Nordjyllandsværket power plant, ref the Vedsted case shown previously) and Germany (two sites for the Jämschwalde power plant).**
- **Two offshore sites in Norway i.e. for Sleipner and Snohvit**



Germany's Jämschwalde power plant, one of six sites to receive EU funding for CCS projects

Reference Ole K. Sollie, Christian Bernstoneb, Michael E. Carpenter, Ståle Selmer-Olsen:
"An early phase risk and uncertainty assessment method for CO₂ geological storage sites", Energy Procedia GHGT-10

IGCC + CCS Australia

- **Independent Project Review (IPR) of IGCC + CCS Project**
- **DNV developed CTS assessment protocol for the IPR based on CO2Qualstore, CO2Pipetrans**
- **DNV facilitated the CTS part of the IPR**
- **DNV assessed the Risk Management Practices based on protocol developed following the CO2Qualstore Guideline**
- **DNV co-editor for the IPR assessment report**



- **Will be a 530 megawatt (gross) power plant**
- **The technology has potential to capture and store up to 90% of CO2 for full sequestration**
- **Mitsubishi Heavy Industries will provide technology for the IGCC power plant and carbon capture**
- **The power plant location will be determined as part of a pre-feasibility study now completed**
- **CO2 will be captured at site and transported to a storage location that will be determined as part of a feasibility study.**

<http://www.zerogen.com.au/project/overview.aspx>

Final Remarks

- The guideline developed in the **CO2QUALSTORE** project represents a consensus between industry partners on how to select, assess the risk and qualify subsurface geological storage sites for CO₂.
- The guideline is designed to facilitate an overall project risk management process by providing **storage related stage gates** that may be coordinated with:
 - **CO2 capture and transport activities and approval processes by CCS authorities;**
 - **Best practice project development and operation from the CCS industry;**
 - **The selection of safe and reliable storage sites that will provide containment and the required storage capacity and injectivity rates;**
 - **The operation of the storage facility and the subsequent transfer of responsibility to a state authority.**
- The main intentions of the document are to:
 - **Provide an unified industry practice**
 - **Accelerate implementation of CCS**
 - **Build trust between stakeholders and the public in the effort to gain acceptance of CCS as a necessary vehicle to combat global warming**

Final remarks cont'd

- **A major concern in CCS is the integrity of wells** and well bores intersecting the CO2 plume; that arises from wells drilled during the site development, abandoned wells crossing the reservoir formation, or corrosion of well casings that may cause leakage paths.

In response to these concerns DNV has initiated a JIP:

- The CO2WELLS Joint Industry Project lead by DNV that began in April 2010 is **developing a specialized risk assessment protocol for wells** that penetrate CO2 storage sites.
- A guideline will be publicly available by next summer i.e. June - July 2011.

Thank you!

Safeguarding life, property and the environment

www.dnv.com



MANAGING RISK