Risk Aspects Related to Pipeline Transmission of CO2

Workshop on Future Large CO2 Compression Systems
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What is this talk about?

- Intro:
  - About risk management
  - About CCS
  - About CO_2 pipeline transportation
- Risk aspects
  - Is CO_2 dangerous?
  - Concerns about CO2 transmission
  - Dispersion assessments

RISK and Rewards

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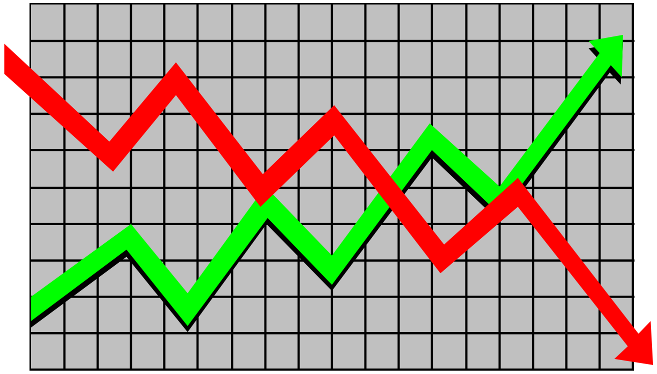
- No risk – no business

- Risk Management is to:
  - Understand and control the risks
  - Take the right risks
  - Balance risk and reward for *all* stakeholders



Risk management strategies

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- Prescriptive risk management
- Regulatory driven
- Repetitive technology

V.S.

- Analytical risk management
- Operator driven
- Evolving technology

The basic elements of risk assessment

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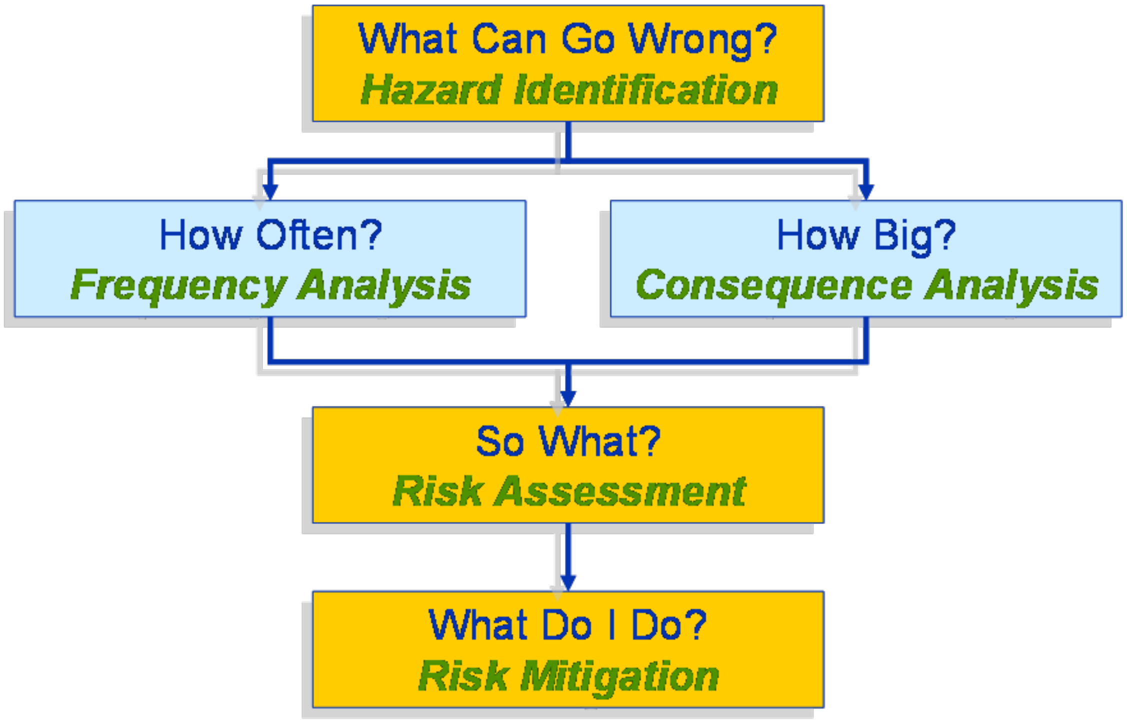

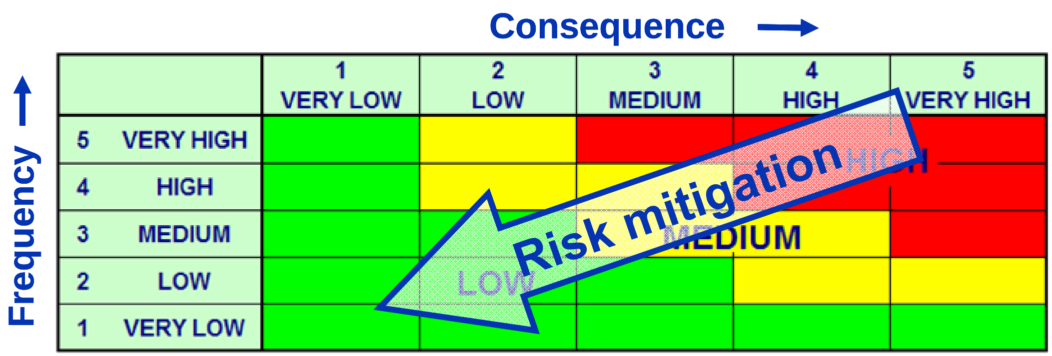

Types of risks in CCS

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- Political risks (incentives, future regulations, legal responsibilities)
- Commercial uncertainties (energy prices, value of CO_2, land rights)
- Reliability (new technologies, different medium)
- Safety risks (releases and dispersion)
- Environmental risks (releases and dispersion)

Risk acceptance

- Risk acceptance involves a subjective balancing of benefits with risks.
- Two people who may agree on the degree of risk involved may disagree on its acceptability.
- *Environmental risks* are linked to consequences of significance to the nature and the people using it.
- *Environmental* risk is thus a public concern
- The public can not always see the benefits of taking the risks

Two key challenges – for all of us

Need for energy

Climate change

Carbon Capture and Storage – The solution?

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Capture

- Fossil power plants
- Natural Gas CO_2 reduction
- Other industrial processes

Transport

- Pipelines
- Ships

Storage

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

Transportation of Super Critical CO2

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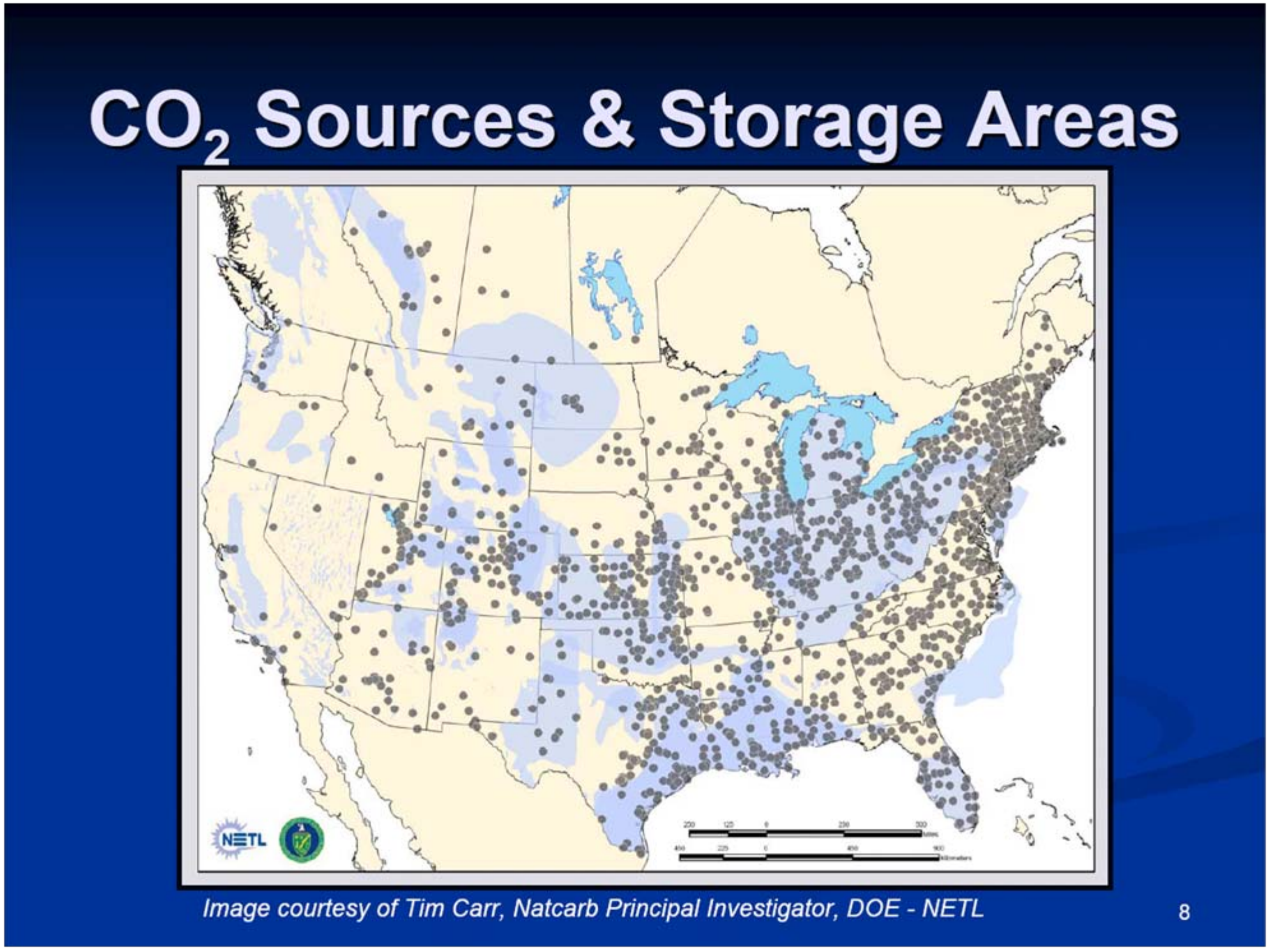
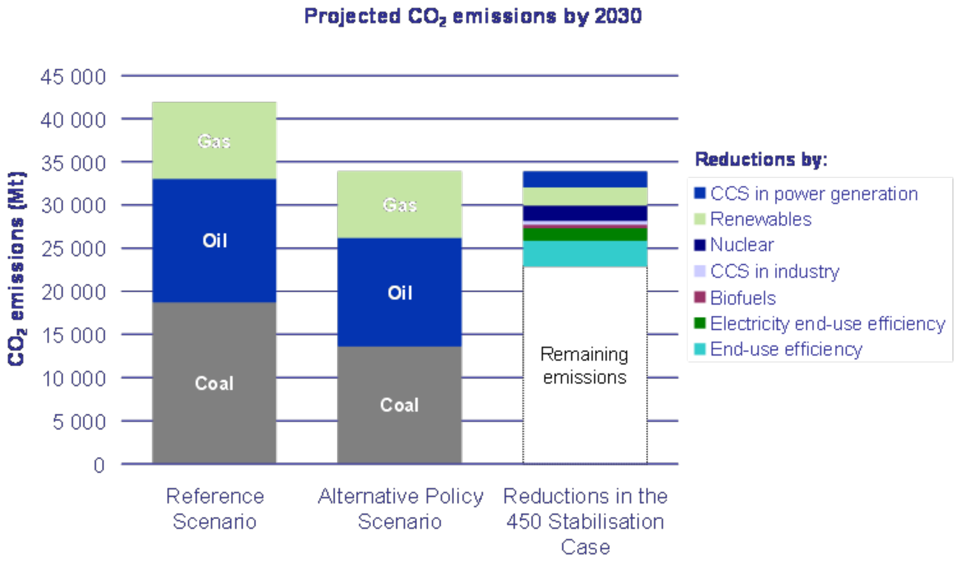
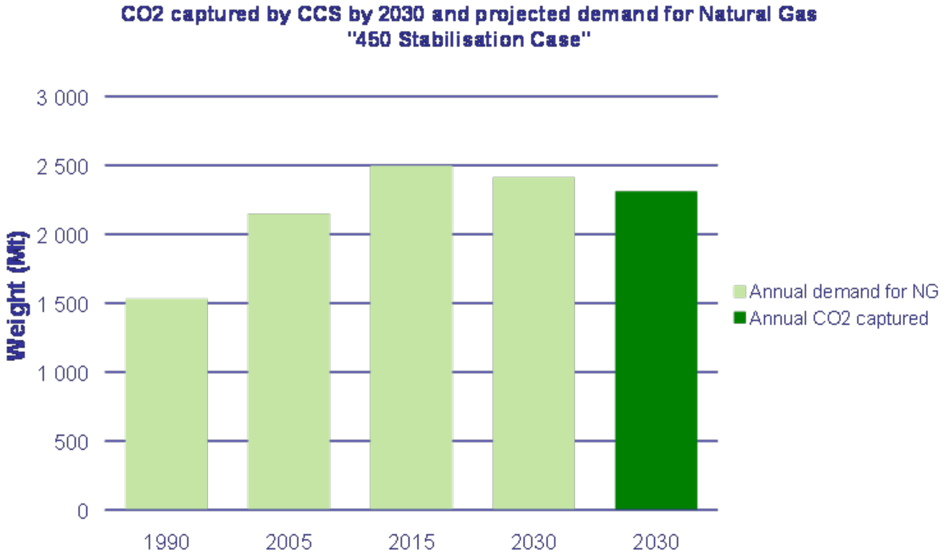


- The CO_2 sources and sinks are not all in geographical proximity.
- The need for pipelines for CCS may therefore be considerable

CO_2 pipelines – a booming industry?



- IEA's proposed mix of means to stabilize the CO_2 concentration in the atmosphere to 450 ppm by 2030 includes 2.3 Gt/year by CCS



- This would imply that the future amount of captured CO_2 will be in the same order of magnitude as today's natural gas production

CO_2 – A different risk exposure

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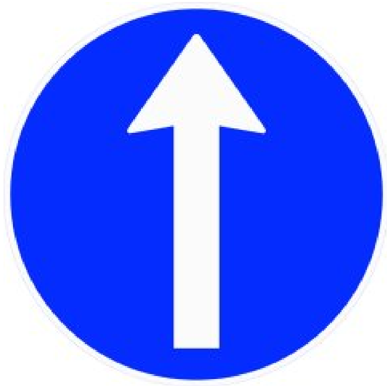

- ☺ CO_2 is inflammable
- ☺ CO_2 is not toxic in normal concentration
- ☺ A single CO_2 release has insignificant environmental impact

- ☹ Other chemical constituents (as H_2S) carried in the CO_2 may harm people and the environment
- ☹ Concentrated CO_2 can displace oxygen and cause asphyxia
- ☹ Elevated CO_2 levels causes neurological effects ranging from flushed skin, muscle twitches and raised blood pressure to disorientation, convulsions, unconsciousness and death (IDLH[1)] level is set to 4%)
- ☹ CO_2 is heavier than air and may fill up sunken areas and confined spaces. Safety zones for NG can therefore not be adopted directly.

[1)] *IDLH: "Immediately Dangerous to Life and Health"*

UK HSE Exposure Criteria

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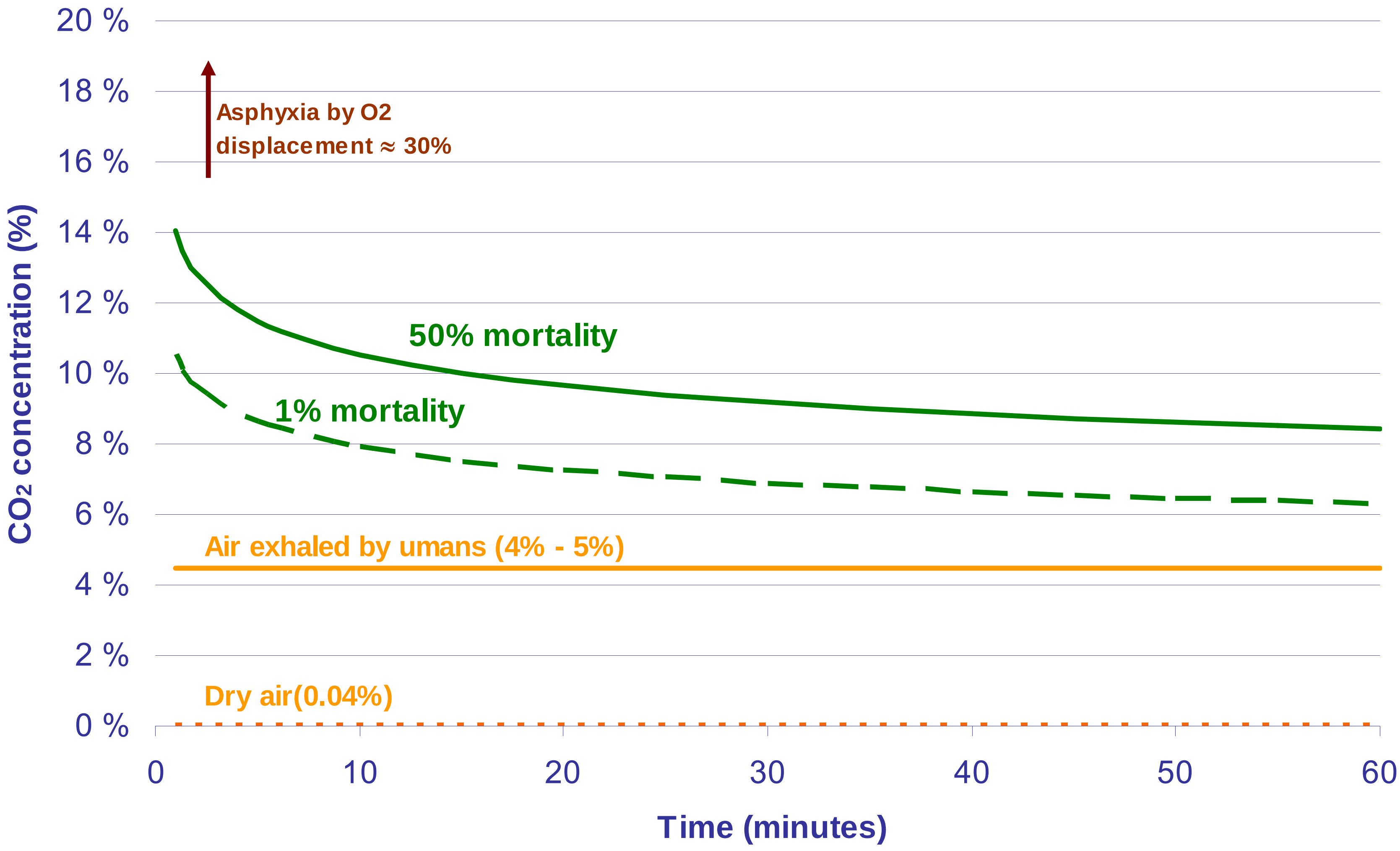

CO_2 – An enhanced risk exposure

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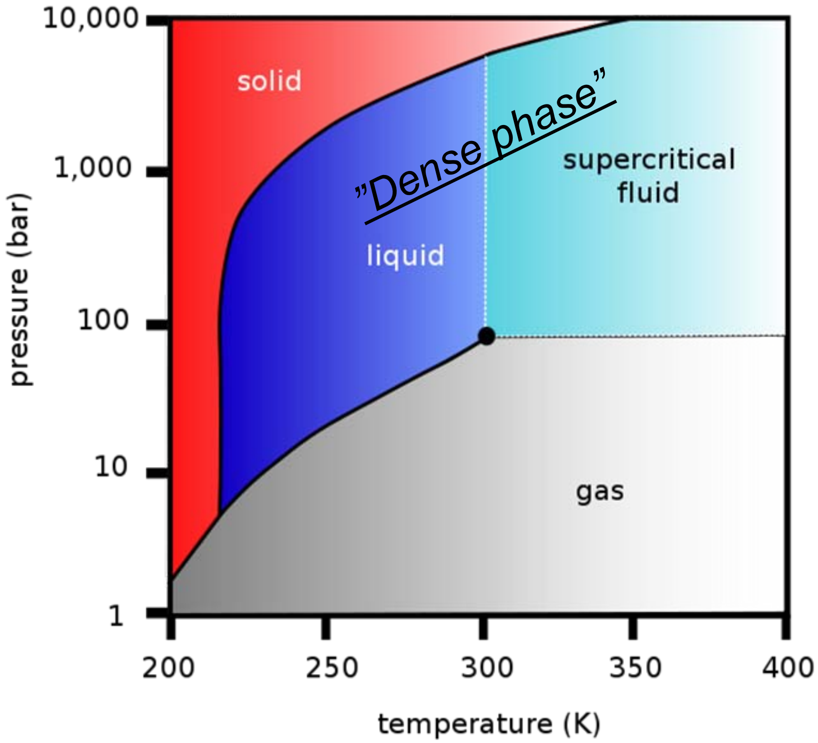
- The future CO_2 pipeline infrastructure may become several hundreds times larger than today.
- The CO_2 will be transported in highly concentrated form at high pressure (dense phase)



- The need to locate CHP coal power plants near consumers implies that CO_2 pipelines will pass through more densely populated areas
- Thus, large populations will be exposed to a risk, which for them will be perceived as *new*

Concerns related to CO_2 transmission

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Root causes:

- Emergency blowdown of large dense phase inventories
- Accidental denting
- CO_2 corrosion leaks in case of accidental intake of water
- Material compatibility (elastomers, polymers)
- Ductile fracture_ (“un-zipping”)

Consequences:

- Dispersion of concentrated CO_2
- Dispersion of toxic impurities
- Pipeline damage/downtime

Frequency Analysis

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- The incident rate for onshore natural gas pipelines is ≈ 0.00008 km^{-1} yr^{-1} due to:
  - Corrosion (30%)
  - Third party (42%)
  - Design (7%)
  - Incorrect operation (13%)
  - Natural hazards (8%)
- The incident rate (from only 10 incidents) for CO_2 pipelines is ≈ 0.00032 km^{-1} yr^{-1} due to:
  - Corrosion (20%)
  - Third party(10%)
  - Relief valve failure (40%)
  - Weld/gasket/valve packing failure (30%)

CO_2 corrosion

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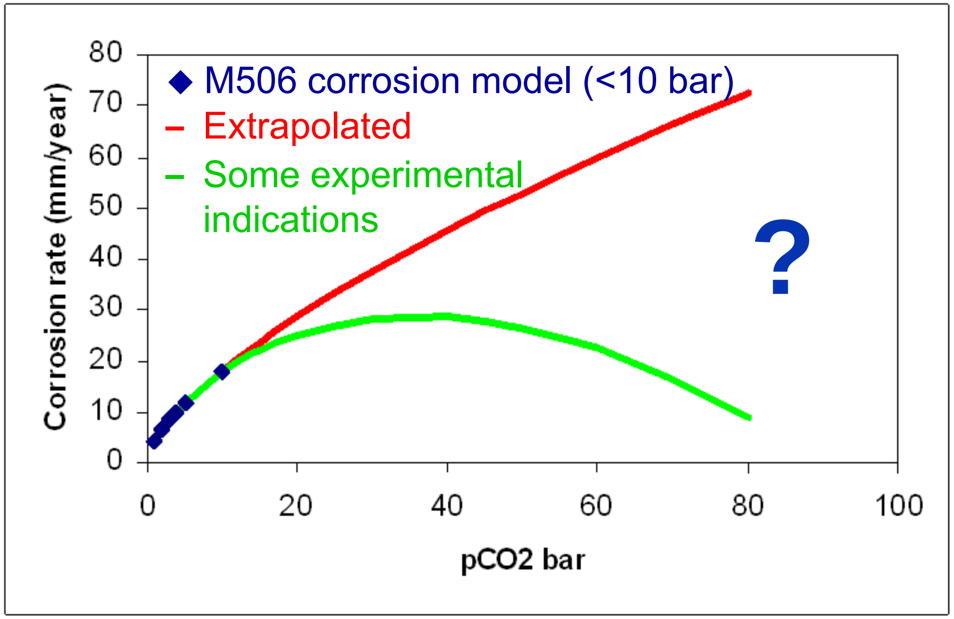
- CO_2 in free water phase creates carbonic acid ($CO_2 + H_2O \rightleftharpoons H_2CO_3$) which is highly corrosive to C-Mn steels
- At high partial pressures of CO_2 the corrosion rates are expected to be dramatically higher than experienced for O&G pipelines
- We do not have models for predicting CO_2 corrosion rates which are valid for P>10 bar and T<20°C
- Experimental data for high pressure CO_2 are few
- We have little insight in the effect of impurities
  Mixtures of CO_2 streams from different sources makes the picture complex.



CO2PIPETRANS / IFE

CO_2 corrosion

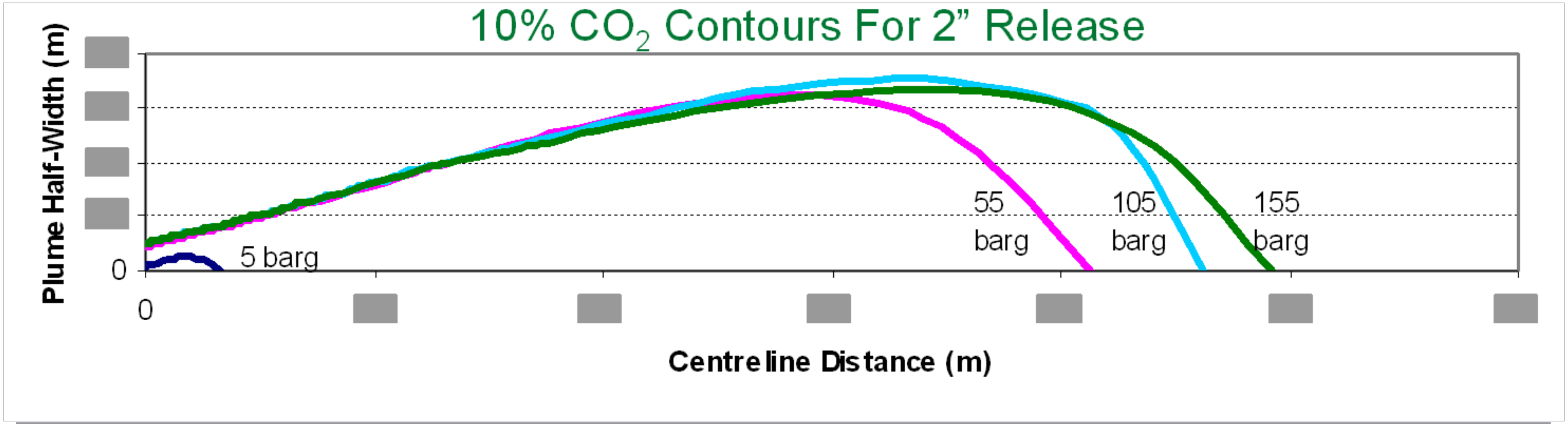
- Design basis:
  Dehydration to ensure no formation of free water under any operational condition. (No corrosion allowance needed.)
- What if an accidental intake of humidity?
  - Can the pipeline be considered undamaged if the situation is quickly restored to normal?
  - Should/can the pipeline be inspected for corrosion damage?
  - What kind of monitoring is required?

⇒***There is a need to understand more about corrosion rates in case of accidental intake of humidity***

Consequence analyses: Dispersion modeling

- Today's software for release and dispersion analyses are incomplete with respect to CO2
  - Phase transformations directly between gas and solid (deposition/sublimation)
- The calculations models have not been sufficiently validated by large scale experiments
- Proper understanding of CO_2 dispersion is essential to setting safety zones (land sequestration) and determine insurance liability

BP tests at Spadeadam in UK (DF1)



Dispersion Modelling Examples (1)

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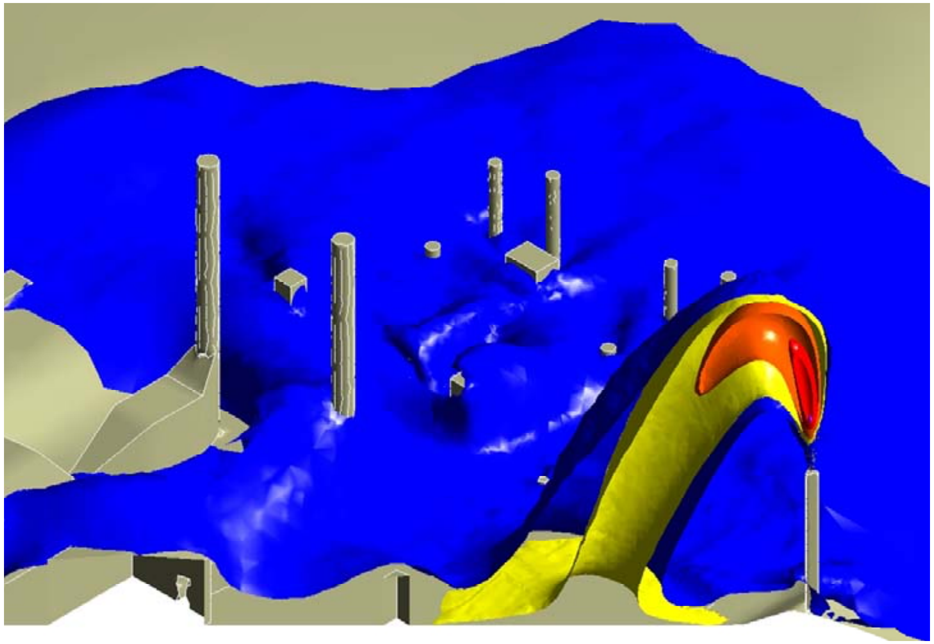

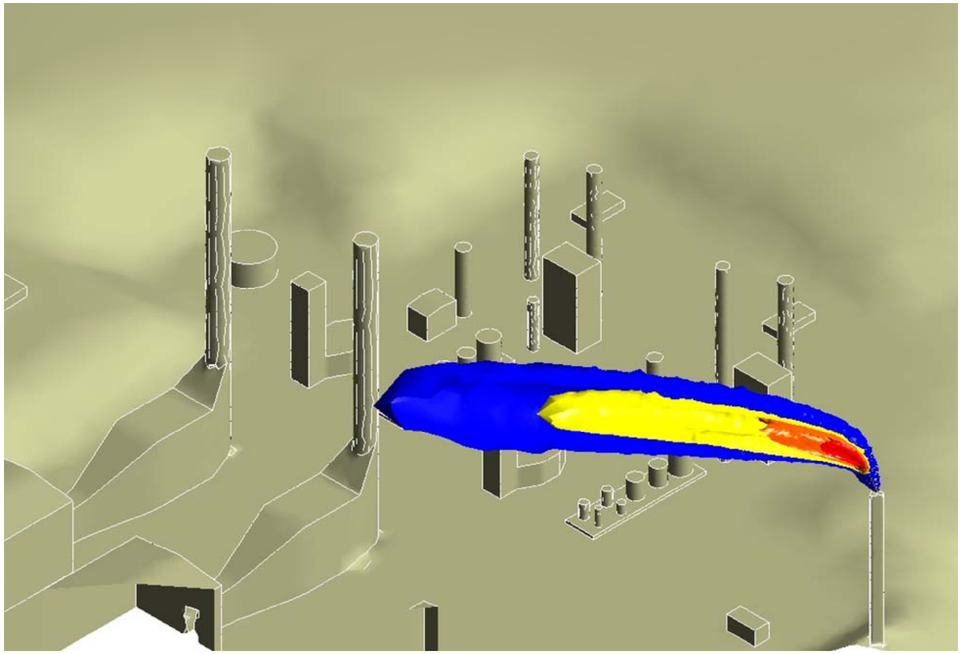

Dispersion Modelling Examples (2)

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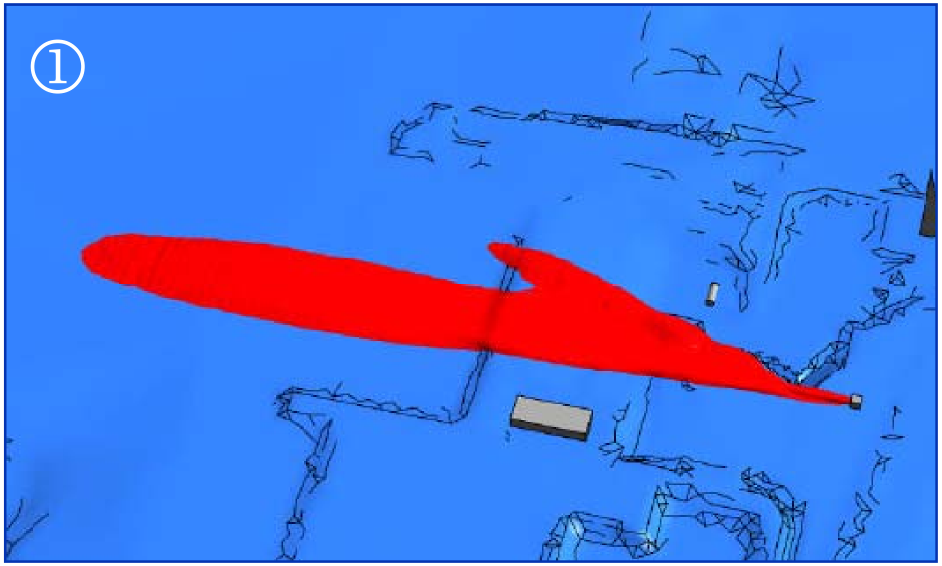

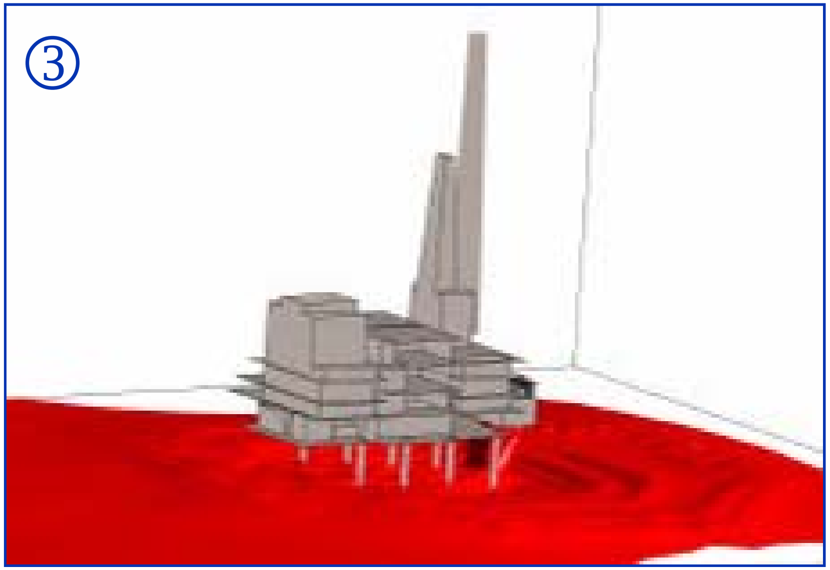

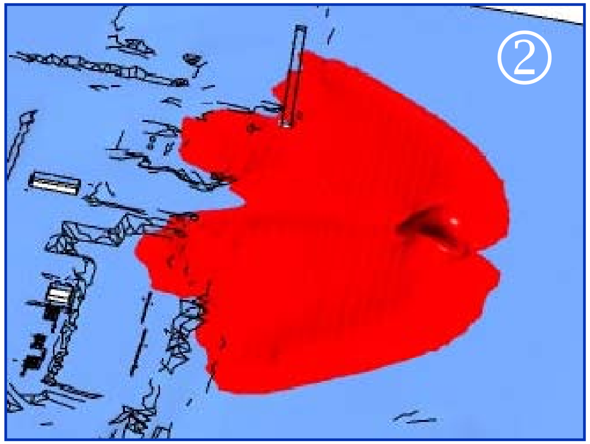

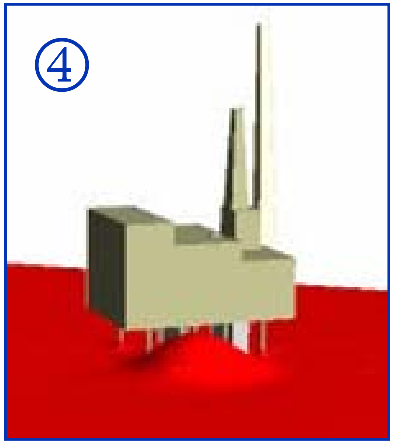

10% hazard range
100 mm diameter pipeline
150 barg pressure
① Onshore
② Underground
③ Underwater
④ Offshore platform

Dispersion Modelling Examples (3)

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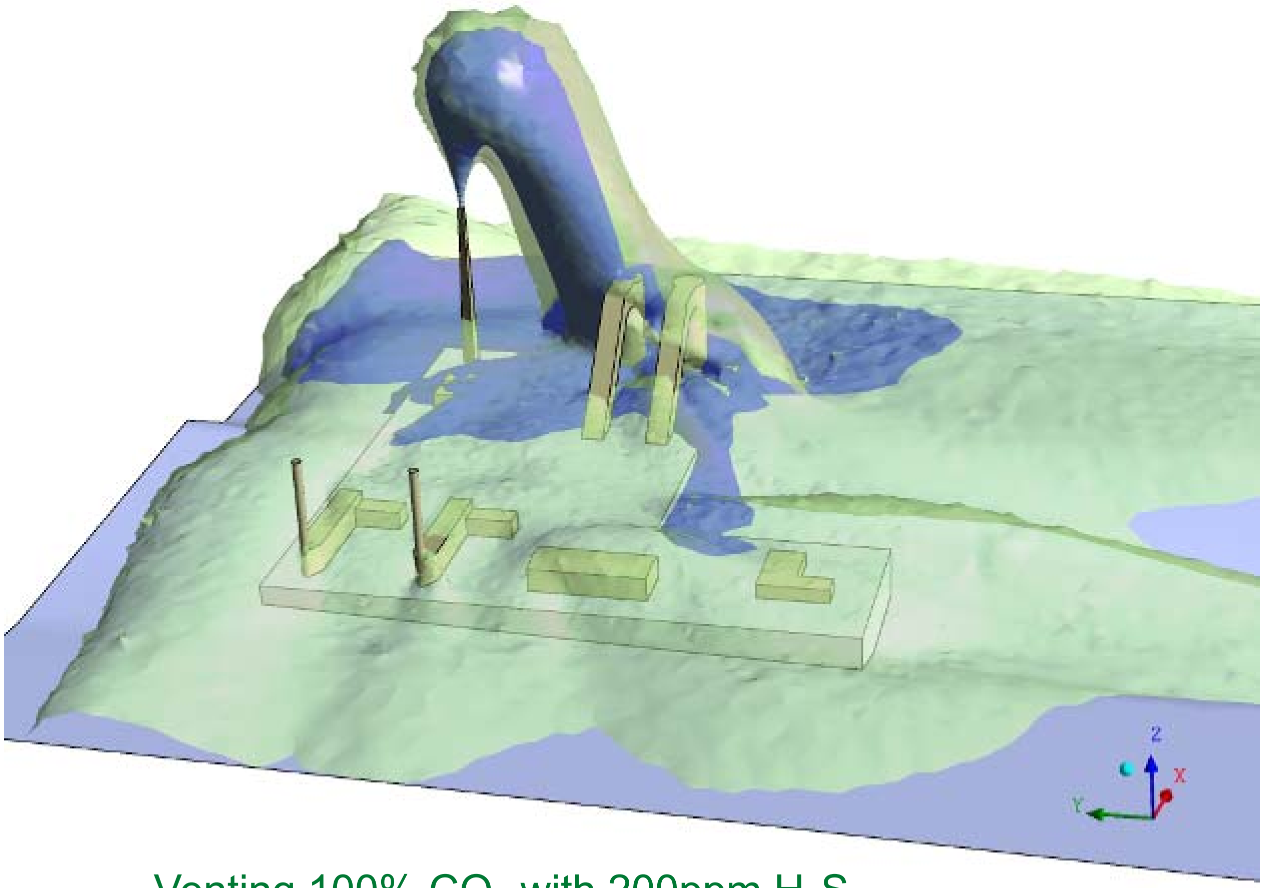

Venting 100% CO_2 with 200ppm H_2S
at 416 tonnes/hr (10,000 Tonnes/day)
through 36” vent with 0.5m/s wind.
Blue isosurface = 0.5% CO_2 (LTEL)
Green isosurface = 13ppm H_2S (odour threshold)

Approach:
Recommended Practice for design of CO_2 pipelines

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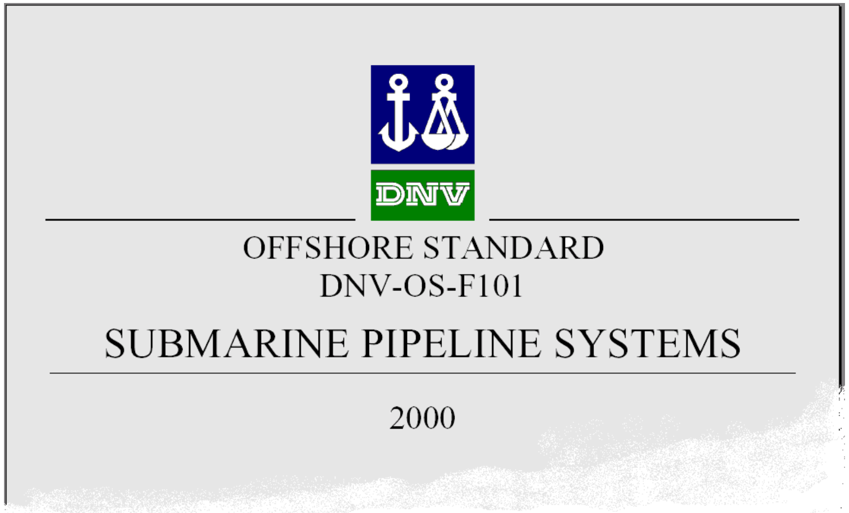
- Existing pipeline design codes do not adequately address issues which are specific to CO_2 transmission
- DNV is developing a Recommended Practice (RP) for transportation of dense phase CO_2. together with 12 industry partners


OFFSHORE STANDARD
DNV-OS-F101
SUBMARINE PIPELINE SYSTEMS
2000

- The RP will supplement current design codes
  such as ASME B31.8, ISO 13623, DNV OS-F101, API RP1111, BSI PD 8010, EN 14161, EN-1594.
- Phase 1:
  - A guideline incorporating current knowledge
  - To be issued in 2009
- Phase 2:
  - Investigations into selected knowledge gaps
  - A revised guideline within 2 – 3 years

RISK and Rewards

- No risk – no business …
- … but risks have to be managed!

Thank you !

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