Technical challenges
CO\textsubscript{2} transport experience

- Experience in CO\textsubscript{2} transport:
  - In the United States, > 6000 km of pipelines transporting 40 Mt/yr CO\textsubscript{2} for enhanced oil recovery
  - Onshore CO\textsubscript{2} transport for more than 30 years
  - Offshore CO\textsubscript{2} transport since 2007
    (Snøhvit Snøhvit CO\textsubscript{2} removal in LNG plant, Norway)
  - Extensive pipeline network required for transportation of captured CO\textsubscript{2}, but manageable
CO₂ composition

- Important: water concentration limit to prevent corrosion
  - Pipeline integrity issues (corrosion)
  - Cost (stainless steel not an option)

- Understand impact of impurities, but maintain flexible specification:
  - Thermodynamics (increase in compression requirements, impact on fracture toughness)
  - External safety (HSE exposure for some contaminants, e.g. H₂S)
  - Cost for additional treatment of CO₂ stream are significant
  - Minimize effect on storage injectivity

- (Cross) effects of impurities to be studied
Impurity concentrations

→ Technical and economic considerations

- Conditioning costs
- Economic balancing
- Operational envelope
- Technical
- Cost-efficient CCS chain
- Technical
- Impurity concentration limit
CO$_2$ release from pipeline

• Models for CO$_2$ releases require refinement
  • Validation of existing models required
  • Experiments ongoing, more are being planned

• Validated CO$_2$ release models **essential** for planning of major CO$_2$ transmission network, as required for CCS in Europe!
Other issues

• Leak detection
  • Sensitivity of leak detection should be increased (challenging)

• Many elastomers and other soft materials deteriorate in contact with high-pressure CO₂
  • Standards for CO₂-resistant materials should be developed

• Excessive noise generation during blow-down requires mitigation
  • Extensive safety zone, slow blow-down or silencer

• Offshore transmission lines do not have block valves, therefore the blow-down of an offshore pipeline could take weeks

• Mechanisms and risk related to propagating fractures need to be better understood

• Internal pipeline inspection tool to be confirmed suitable for long-distance CO₂ pipelines
Reuse of existing infrastructure?

- In principle, reuse of existing pipelines and installations is possible, but:
  - Most (natural gas) pipelines will remain in use and unavailable for CO$_2$ transport for decades to come
  - Onshore pipelines (and some offshore pipelines) not designed for pressure regime used in large-scale CO$_2$ transport

- Conclusion: in general, new pipelines have to be built
Shipping

• CO₂ shipping is an existing business

• Transported volumes are typically small
  • Example: 3 Mton/yr for 200 km transport distance, cost of shipping is equal to pipeline transport.

• Injection of CO₂ from a vessel into the reservoir: promising option, robust solutions to be developed

• Reuse of (LPG or ethylene) tankers for shipping CO₂ possible
  • Number of suitable CO₂ vessels (± 30 tankers currently) insufficient

• Dedicated CO₂ vessels will have to be built
Conclusion

• CO₂ transport technically feasible

• Reuse of existing pipelines or ships probably limited

• Research needed on specific topics (especially CO₂ release), but no real barriers to large-scale CO₂ transport

• Demo projects and R&D will help solve remaining operational issues:
  • Safety zones for CO₂ transport operations
  • Injection from ships into reservoir
  • Injection in depleted gas fields
  • Management of multi-user networks
  • Mixing rules and quality guidelines (new FP7 project planned)