



CO₂-EOR Status, Experiences and as a Storage Resource

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Using CO₂-EOR in the Gulf States to Reduce CO₂ Emissions

20-21 January 2015, Abu Dhabi, UAE

Global Status of CO₂-EOR



- Principally North America (USA + Canada)
 - USA
 - 136 projects injecting 3.5Mt CO₂
 - **Many projects Operating since mid 1980's**
 - 3600km pipeline network – mostly non anthropogenic CO₂
 - Regulatory process developed – EPA Class II Wells
 - Drivers
 - » Tax incentives for increased oil production
 - » **Readily accessible “cheap” CO₂**
 - » Large numbers of small fields with high ROIP levels
 - » High exploration capacity

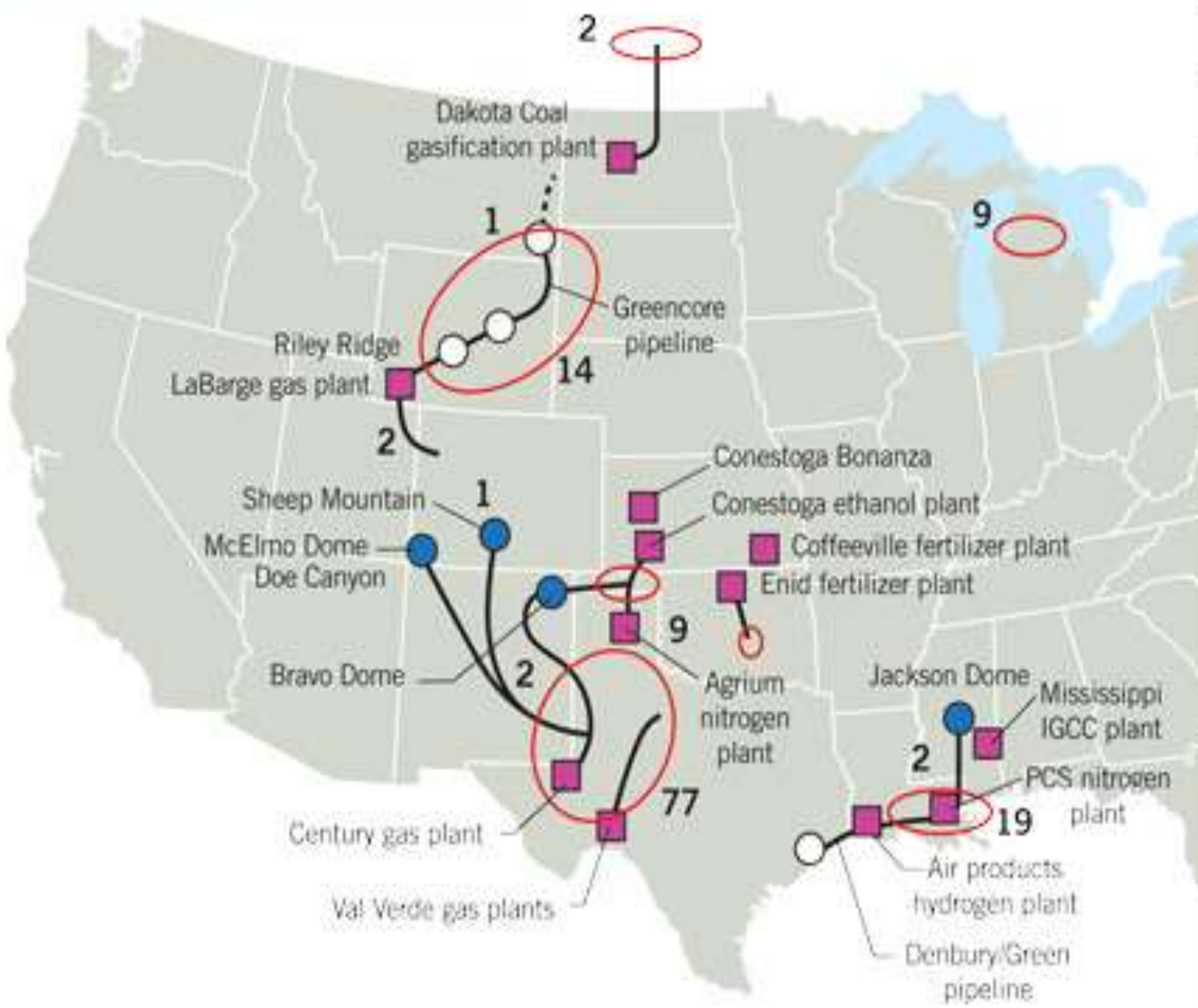
USA CO₂-EOR Experiences



- Commercial technology proven to recover cost effectively additional oil
- Robust regulatory process tested for over 20 years
 - Potential problems with new EPA Class VI wells for CO₂ Storage
 - Limited monitoring under Class II well program
- Safety record industry good
 - US DOT records on pipeline safety
 - Good track record over 20+ years
 - No associated issues – like CBM or unconventional oil and gas
- Not originally as well researched as storage
 - IEAGHG Weyburn-Midale CO₂-EOR monitoring and stage project (2000-2012)

CO₂-EOR OPERATIONS, CO₂ SOURCES: 2014

FIG. 1



| Oil production, 2014 | |
|-------------------------------|-----|
| CO ₂ -EOR projects | 136 |
| Oil production, 1,000 b/d | 300 |

| CO ₂ supplies, 2014 | |
|--------------------------------|-----|
| Number of sources | 17 |
| • Natural | 5 |
| • Industrial | 12 |
| CO ₂ supply, MMcfd | 3.5 |
| • Natural | 2.8 |
| • Industrial | 0.7 |

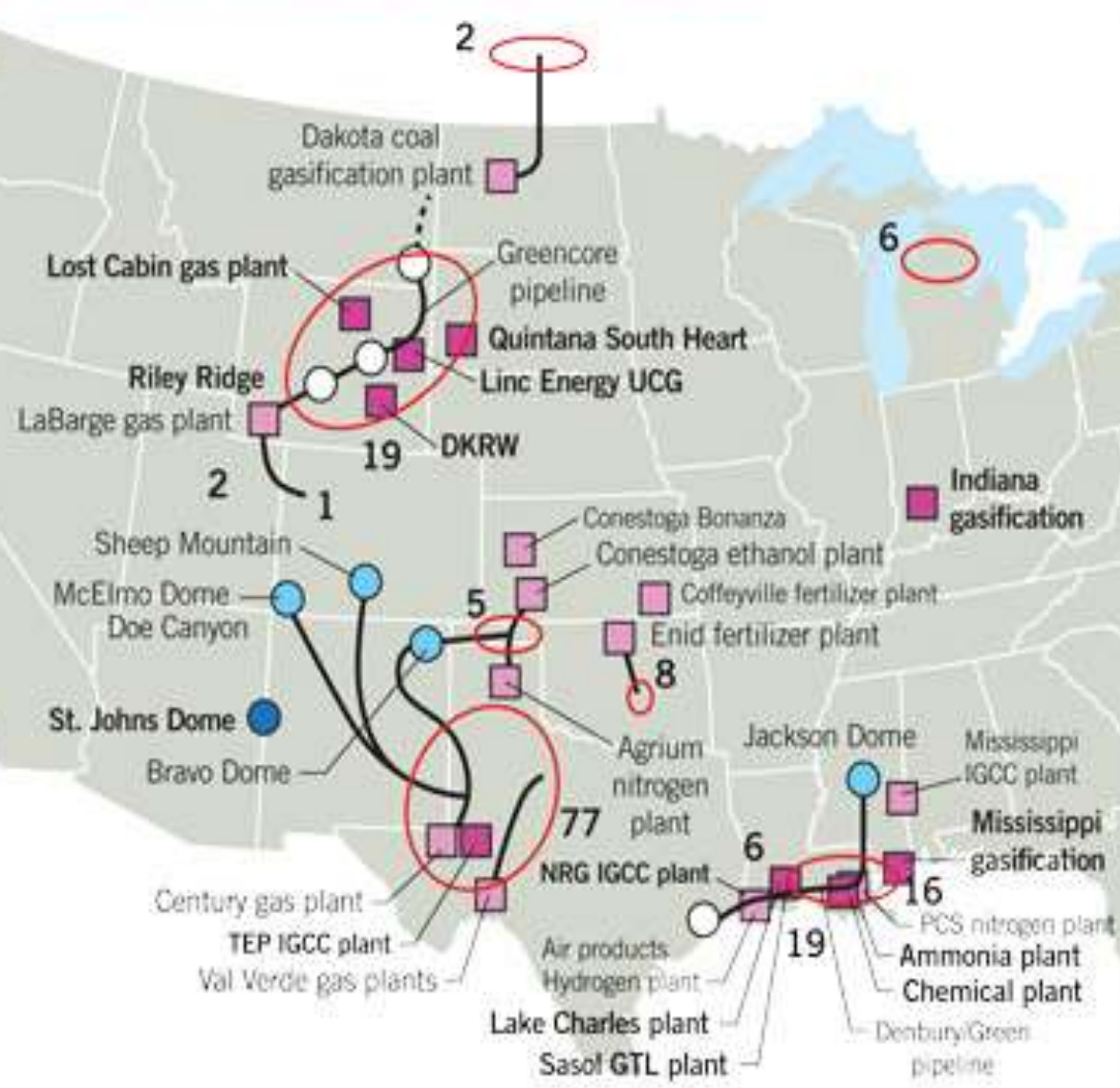
136 Number of CO₂-EOR projects

- Natural CO₂ source
- Industrial CO₂ source
- CO₂ pipeline
- CO₂ proposed pipeline

Source: Advanced Resources International Inc. based on OGI EOR/Heavy Oil Survey 2014 and other sources.

PROJECTED CO₂, EOR OPERATIONS, AND CO₂ SOURCES: 2020

FIG 4



| Oil production, 2020 | |
|--------------------------------|-----|
| CO ₂ -EOR projects | 147 |
| Oil production, 1,000 b/d | 638 |
| CO ₂ supplies, 2020 | |
| Number of sources | 30 |
| • Natural | 6 |
| • Industrial | 24 |
| CO ₂ supply, MMcfd | 6.5 |
| • Natural | 3.4 |
| • Industrial | 3.1 |

147 Number of CO₂-EOR projects

- Natural CO₂ source
- Industrial CO₂ source
- CO₂ pipeline
- CO₂ proposed pipeline

Source: Advanced Resources International Inc. based on OGI EOR/Heavy Oil Survey 2014 and other sources

CO₂-EOR outside USA



- North Sea
 - Studies by Norway and UK, Shell and BP have shown CO₂-EOR be uneconomic in North Sea
 - Large field size, low sweep efficiency
 - High recovery rates using other EOR techniques
 - Large CO₂ volumes to be transported offshore, high infrastructure costs
 - Platform modification costs considered to be high
 - Prospects for near offshore CO₂-EOR in Danish Oil Fields explored by Maersk – status unknown
 - UK Cost Reduction Task Force identified CO₂-EOR as potential cost saving element for future CCS deployment
 - Tax incentives for brown field CO₂-EOR opportunities
 - Opportunities were more limited than in USA
 - Synergies between CCS and CO₂-EOR

CO₂-EOR outside USA

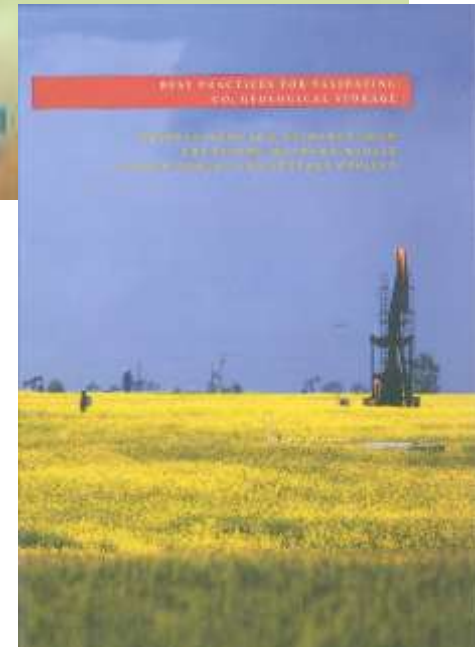


- China
 - Desire to reduce oil imports
 - Large importer – small producer
 - CO₂-EOR attractive proposition to expand internal production
 - 12 CO₂-EOR pilots currently underway
 - Likely expansion of CO₂-EOR in Northern China
 - » Linked to high concentration CO₂ production from CTL, Fertiliser and Methanol production
 - China lacks technical capacity to develop CO₂-EOR
 - Drilling rigs, oil industry expertise etc.,
 - US-China Co-operation agreement to share technical knowledge from CCS demonstrations
 - Trade - turbine experience and CO₂-Eor experience

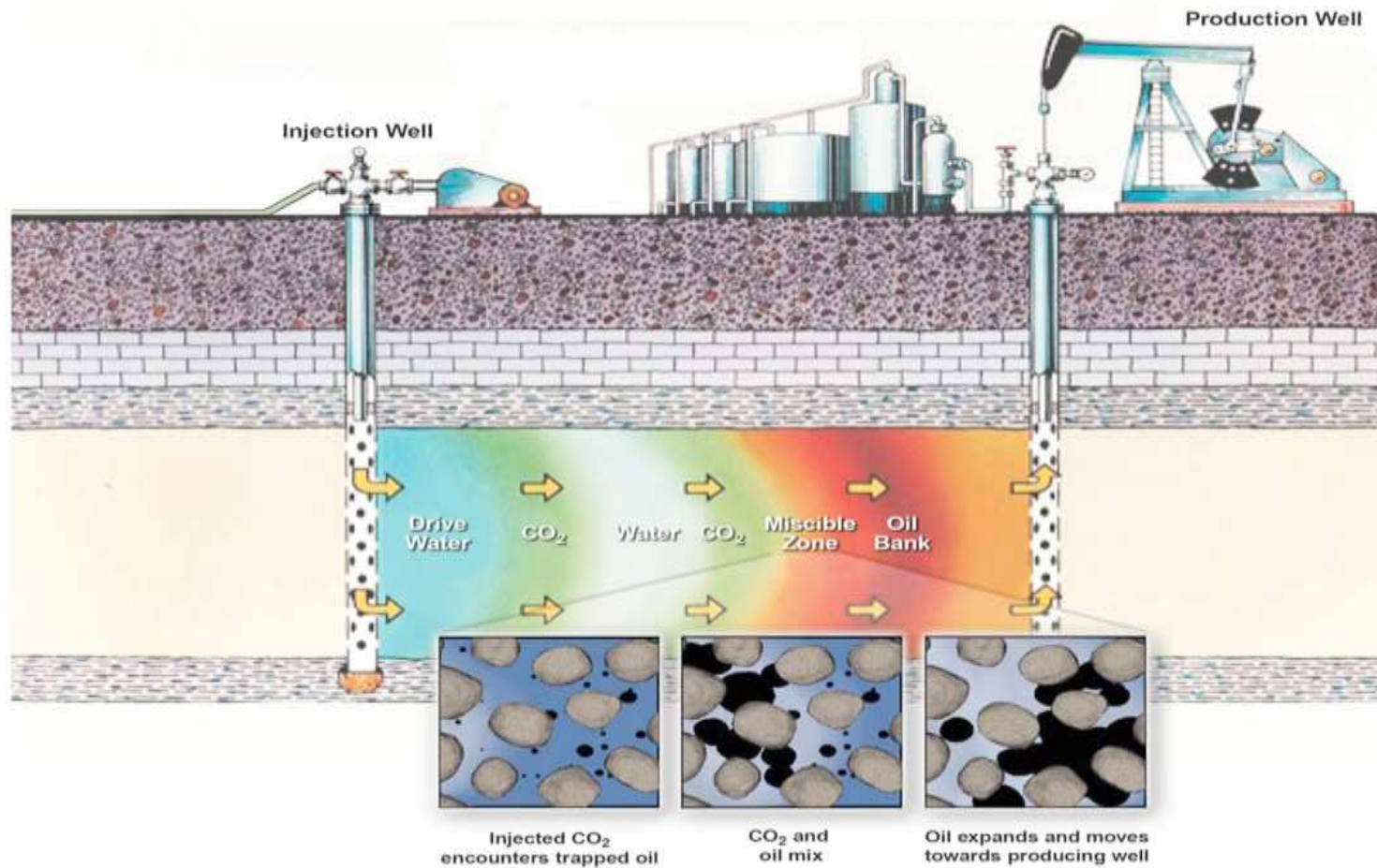
IEAGHG – Weyburn Midale CO₂ Storage and Monitoring Project



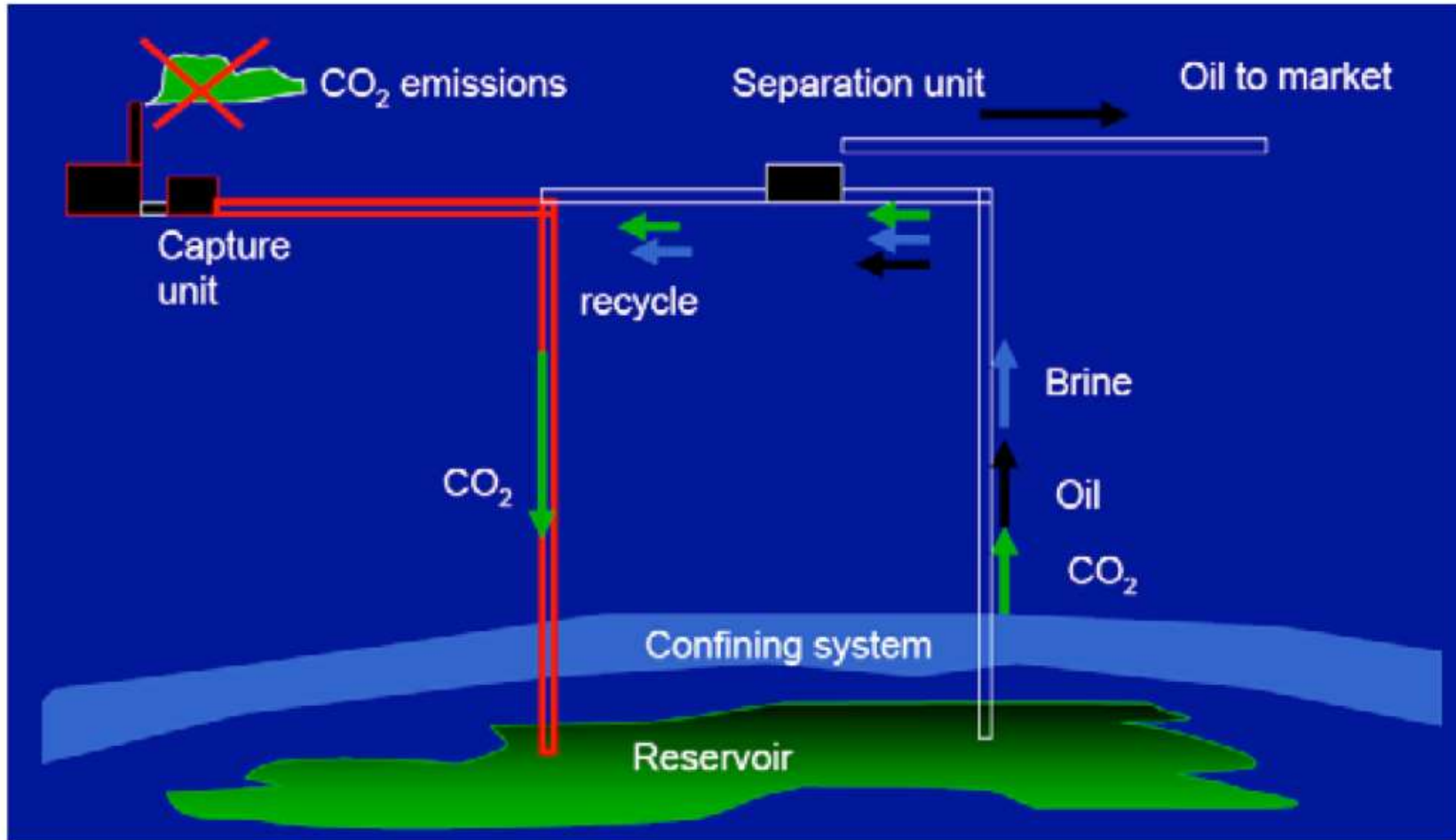
- 10 year R&D Project ended in 2012
- Detailed documented research outputs
- Key reference documents for any CO₂-EOR operation
 - Best practise document
 - Special Issue of IJGGC



CO₂-EOR principles



CO₂-EOR Processes



CO₂ Storage in CO₂-EOR



- Numerical history match undertaken at Weyburn for 2010
 - 51% of injected CO₂ (2Mt) was recovered by end of 2010.
 - Recovered CO₂ was in produced oil, water and gas
 - The remainder was considered to be stored
 - 12% in oil phase
 - 18% in brine
 - 70% in gaseous phase
 - Mineral carbonation <1% of that stored.
- Projection to end of CO₂-EOR flood that 25 Mt CO₂ would be stored.

Source: Volume 16, Supplement 1, June 2013, Pages S35–S49 Effects of mechanical dispersion on CO₂ storage in Weyburn CO₂-EOR field—Numerical history match and prediction' Mafiz Uddin, , Alireza Jafari, Ernie Perkins

Global estimate for storage



- 2009 IEAGHG study gave a global capacity of 140 GtCO₂ storage in depleted oil fields
 - in worlds 10 most prospective basins
- Implications:
 - CO₂-EOR will play a role in meeting global CO₂ storage needs
 - Depleted gas and deep saline reservoirs provide the primary storage resource in the longer term
 - The key role it is currently playing is de-risking CCS demonstration projects

CO₂-EOR studies/activities



- Quantifying and monitoring emissions reductions from CO₂-EOR,
 - report due mid 2015
- Cost components for Storage of CO₂ in association with enhanced oil recovery
 - report due mid 2015
- Criteria for Depleted Oil and Gas Fields to be Considered for CO₂ Storage
 - report due late 2015
- On-going International research networks on monitoring and risk management cover CO₂-EOR related issues

Conversion of CO₂-EOR Projects to CO₂ Storage Projects (CSLF).



- There are no technological barriers
- The main differences are; legal, regulatory and economic.
- CO₂ storage operations will likely require more monitoring and reporting of
 - a wider range of parameters and on a wider area, and for a longer period of time than oil production.
- A big issue will be the lack of baseline data for monitoring,
 - wellhead and production monitoring data excluded
- Sent up to Policy Group



Thank you

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