

REX-CO₂: RE-USING EXISTING WELLS FOR CO₂ STORAGE OPERATIONS

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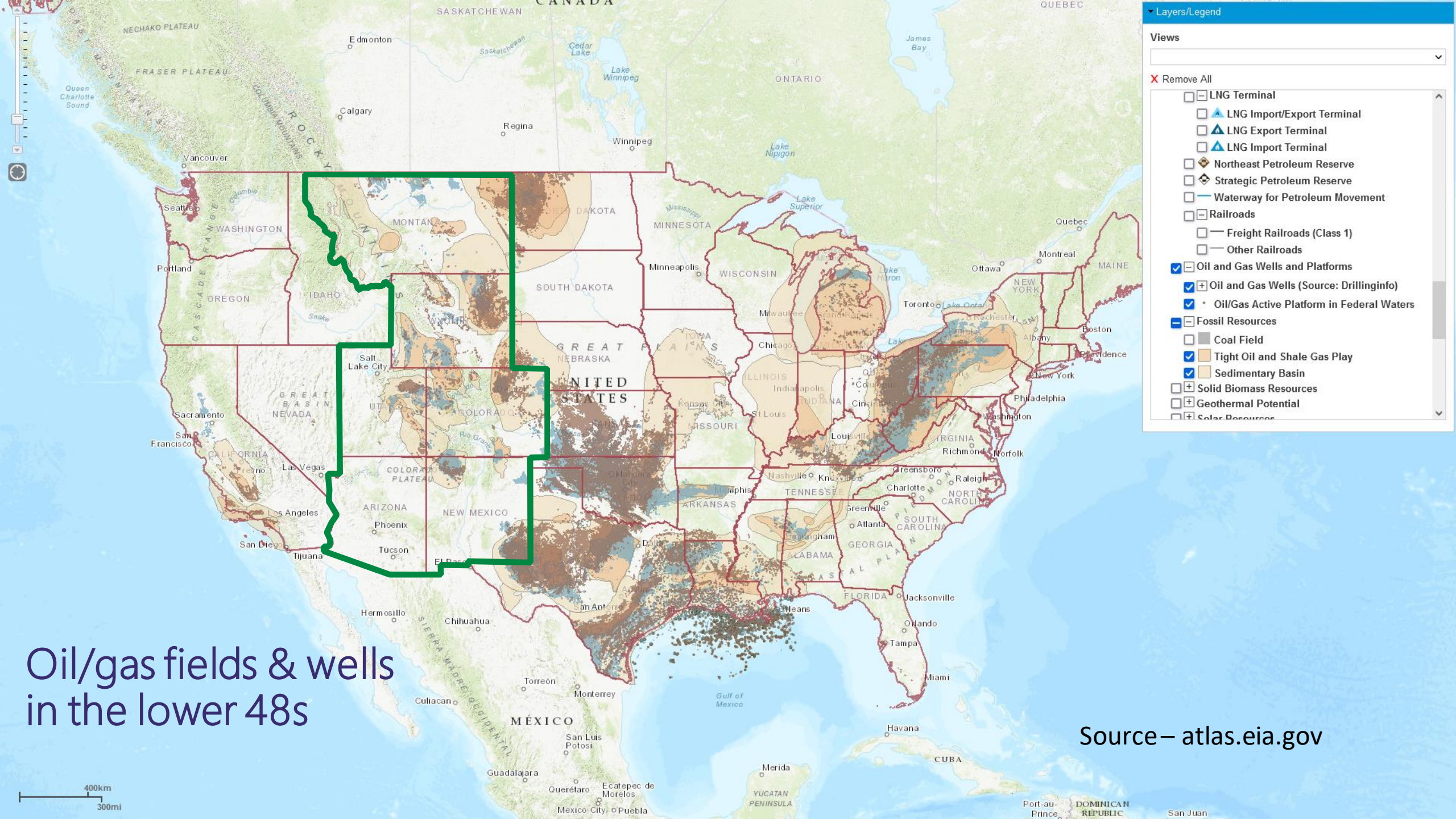
Carbon Management Project Review Meeting

August 15-19, 2022



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REX-CO₂
re-using existing wells



Oil/gas fields & wells
in the lower 48s

Source – atlas.eia.gov

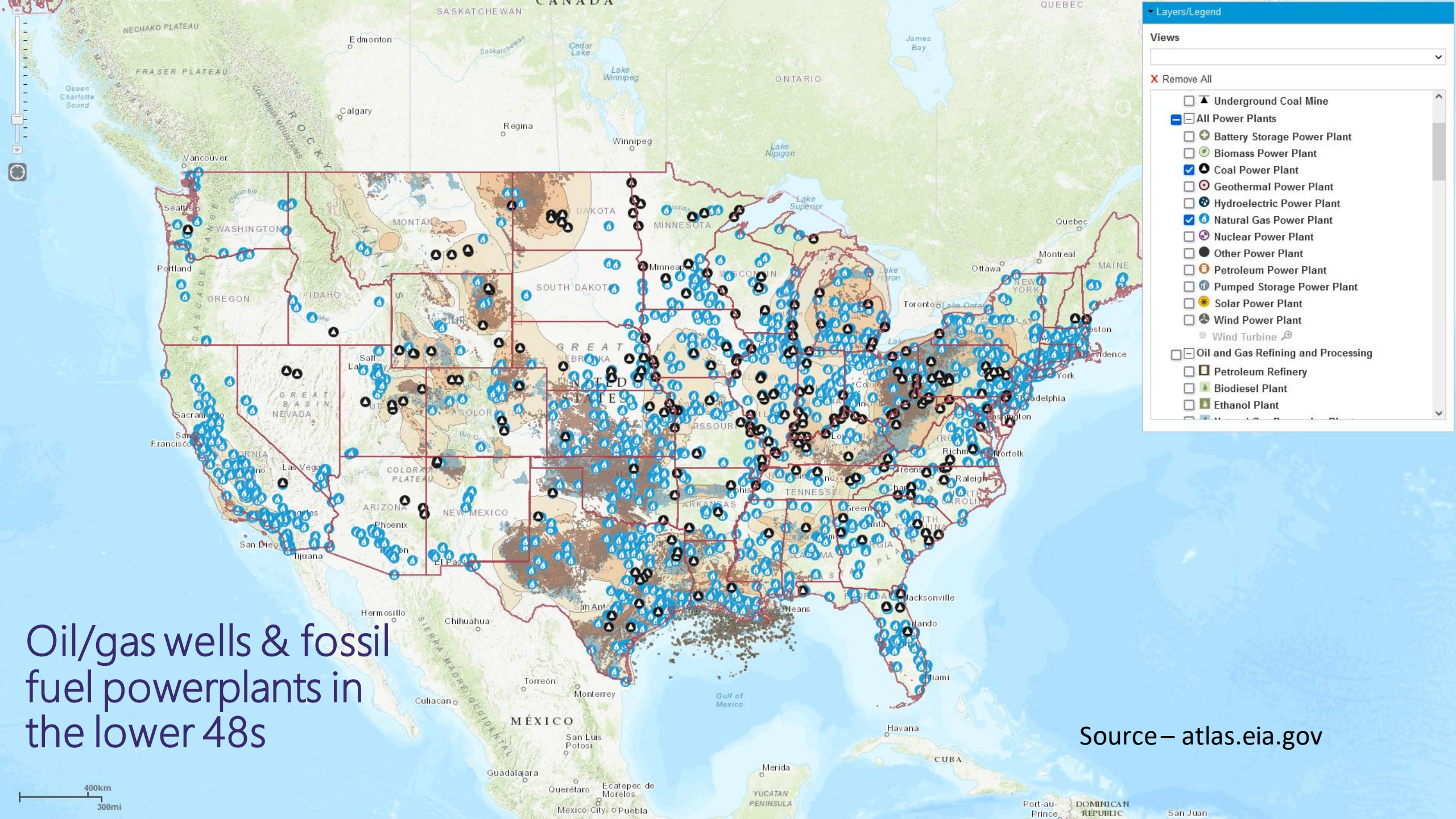
Layers/Legend

Views

X Remove All

- LNG Terminal
- ▲ LNG Import/Export Terminal
- ▲ LNG Export Terminal
- ▲ LNG Import Terminal
- ⬠ Northeast Petroleum Reserve
- ⬠ Strategic Petroleum Reserve
- Waterway for Petroleum Movement
- Railroads
 - Freight Railroads (Class 1)
 - Other Railroads
- Oil and Gas Wells and Platforms
 - + Oil and Gas Wells (Source: Drillinginfo)
 - * Oil/Gas Active Platform in Federal Waters
- Fossil Resources
 - Coal Field
 - Tight Oil and Shale Gas Play
 - Sedimentary Basin
 - + Solid Biomass Resources
 - + Geothermal Potential
 - + Solar Resources

400km
300mi



Oil/gas wells & fossil fuel powerplants in the lower 48s

Source – atlas.eia.gov

Layers/Legend

Views

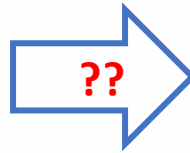
X Remove All

- ▲ Underground Coal Mine
- All Power Plants
- + Battery Storage Power Plant
- Biomass Power Plant
- ▲ Coal Power Plant
- Geothermal Power Plant
- Hydroelectric Power Plant
- Natural Gas Power Plant
- Nuclear Power Plant
- Other Power Plant
- Petroleum Power Plant
- Pumped Storage Power Plant
- Solar Power Plant
- Wind Power Plant
- Wind Turbine
- Oil and Gas Refining and Processing
- Petroleum Refinery
- Biodiesel Plant
- Ethanol Plant



CO₂ storage in depleted oil and gas reservoirs

- ~205 billion tons storage capacity
 - Source: Carbon Storage Atlas, 2015
- Potential for cost saving through re-purposing of existing infrastructure – especially, offshore
 - ~900,000 active wells in US (Source: EIA)



- How do we assess whether oil/gas wells will meet CO₂ storage related requirements?
- Multiple wells will have to be assessed → time consuming and subject to inconsistency/incompleteness
- A structured & independent well screening process is required to help decision-making and stakeholder buy-in

Re-purposing oil and gas infrastructure is one of DOE FECM's strategic priorities to expand reliable CO₂ storage infrastructure

(Source - DOE FECM's Strategic Vision)

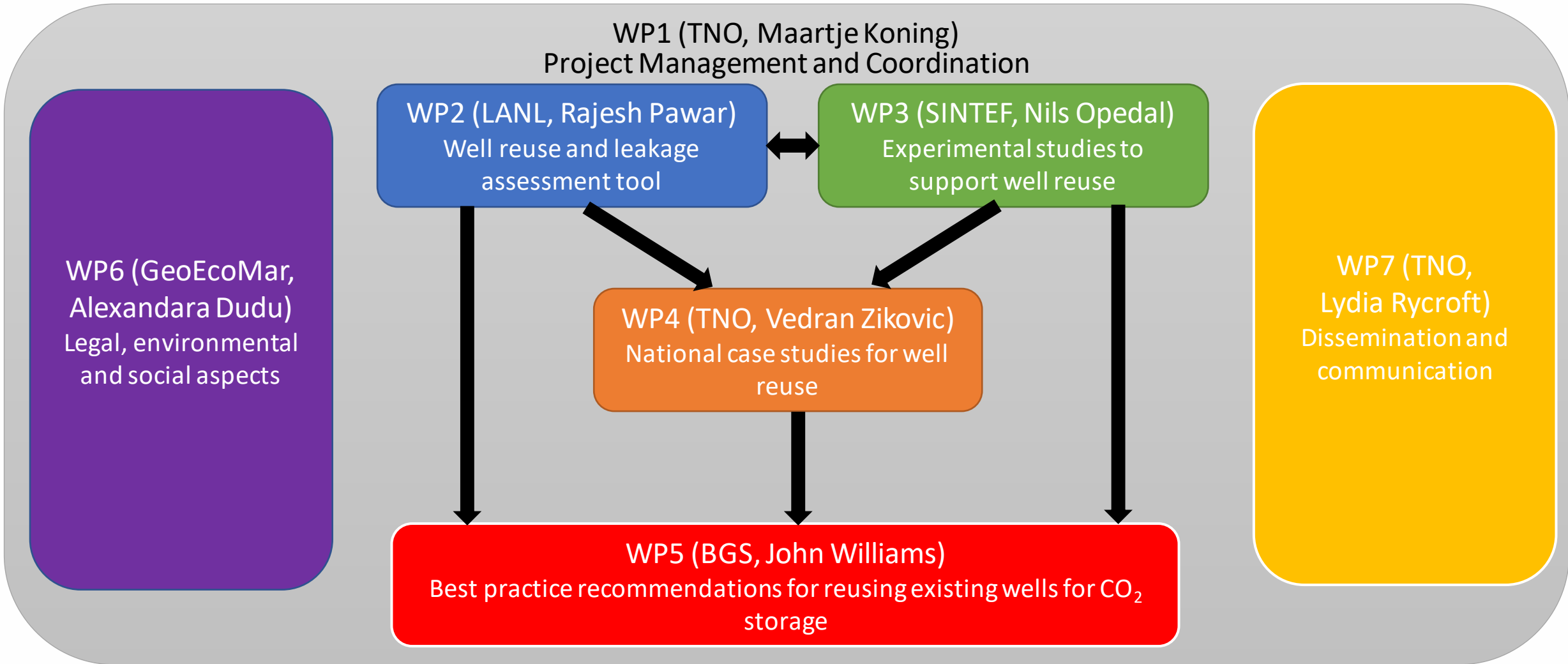
REX-CO₂

Re-using Existing wells for CO₂ storage operations (<https://rex-co2.eu/>)

- International research project, funded through the ACT (Accelerating CCS Technologies) programme (<http://www.act-ccs.eu/>)
- Objective: Provide decision makers with mechanisms and information to evaluate re-use potential of existing oil and gas well infrastructure
- Six Countries: Netherlands, USA, France, UK, Norway, Romania
- 13 research partners; 4 stakeholders; 6 R&D organizations
- Duration: September 2019 – August 2022



REX-CO₂ Project Organization



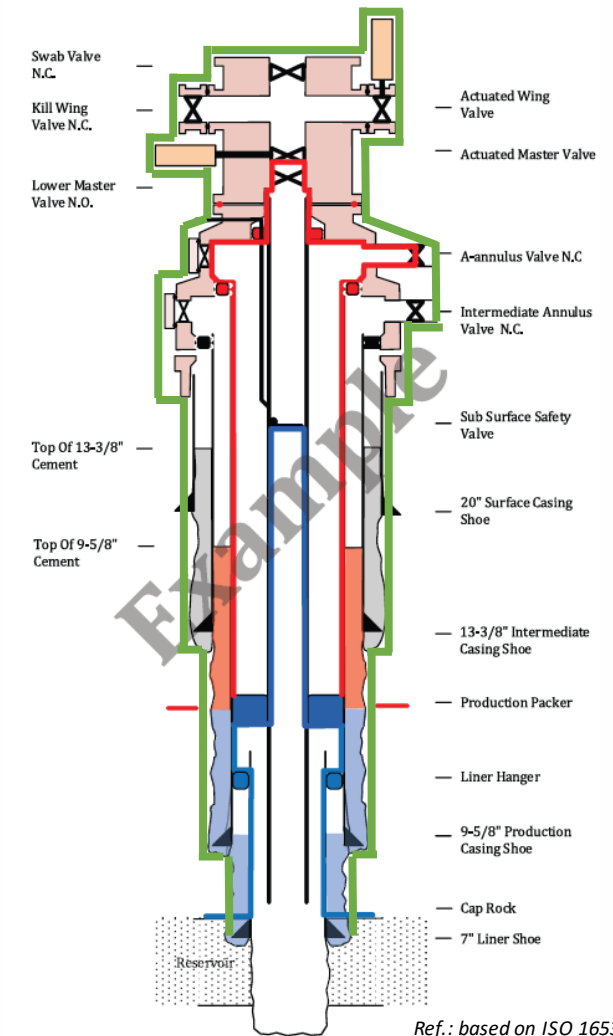
Well screening tool & workflow

Objectives:

- Develop a workflow for assessment of re-use potential of existing oil and gas wells
 - Very limited information in the public domain
- Create a publicly available tool to enable assessment:
 - Useful for a wider set of stakeholders including oil/gas industry & CCS regulators

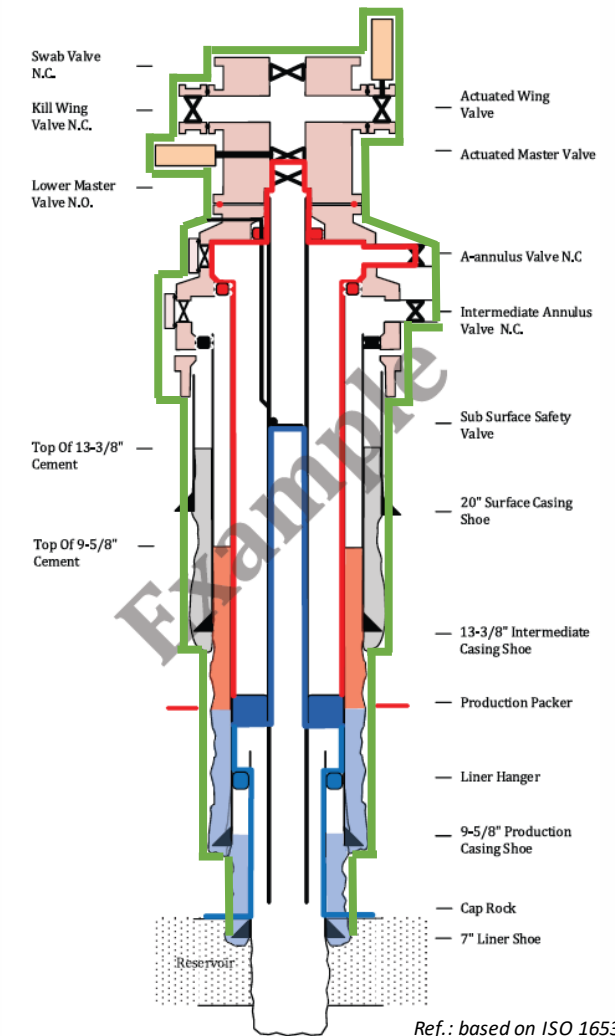
Minimum functional requirements for tool

1. Screening wells with currently available data
2. Universal and intuitive
3. Swift and consistent screening of portfolios of wells
4. Stand-alone, offline tool
5. Focus on well integrity during CO₂ injection and storage



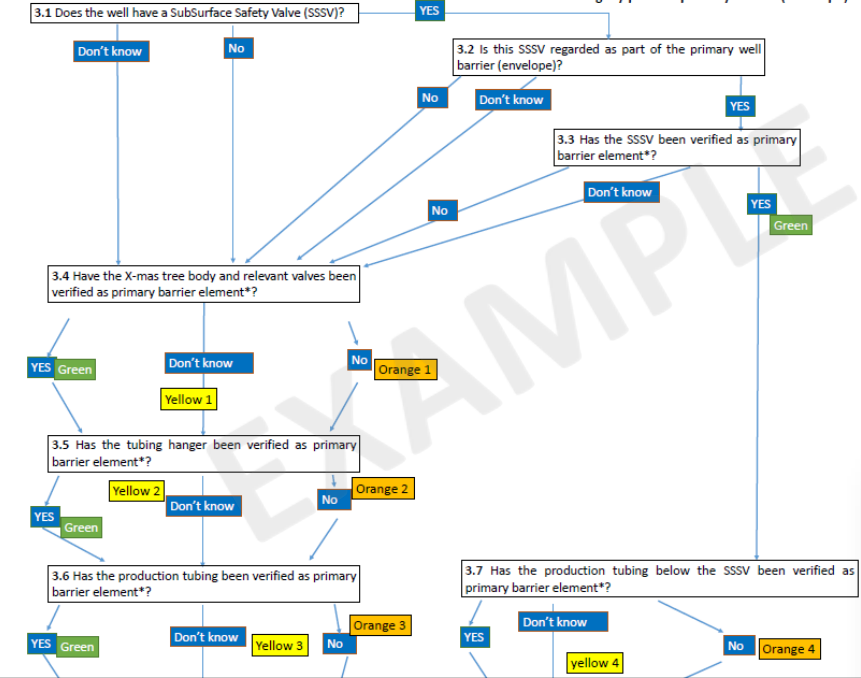
Tool development – Workflow for well screening

- Workflow based on SoA practices, well design/well integrity standards & guidelines (including CCS wells):
 - ISO Standard 27914 (CCS-specific)
 - ISO Standard 16530 & NORSOK D010 (Oil & Gas – Specific)
 - Regulatory requirements on CCS wells
 - Reference projects - Peterhead/Goldeneye, Porthos P-18
- Assessment focused on five pillars:
 - Out of zone injection risk
 - Integrity of primary well barrier
 - Integrity of secondary well barrier
 - Structural integrity
 - Material compatibility



*An element is regarded as a primary barrier element if it is (inspected), tested and verified as per applicable guidelines, standards and regulations. These describe required test interval, procedures and acceptance criteria (e.g. pressure test without leakage in the last 12 months).

3. Well integrity part 1 – primary barrier (envelope)



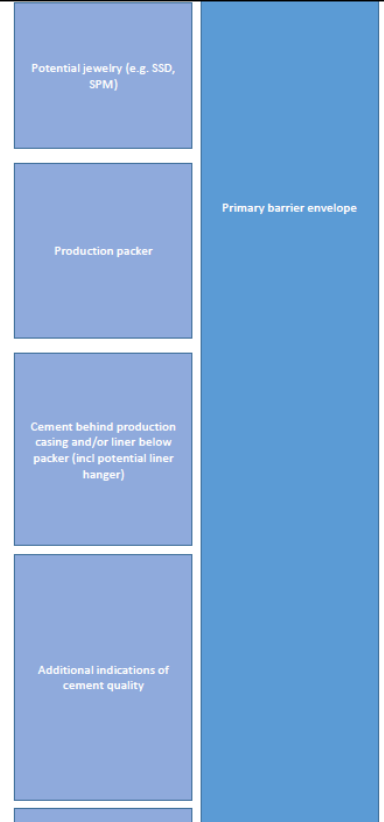
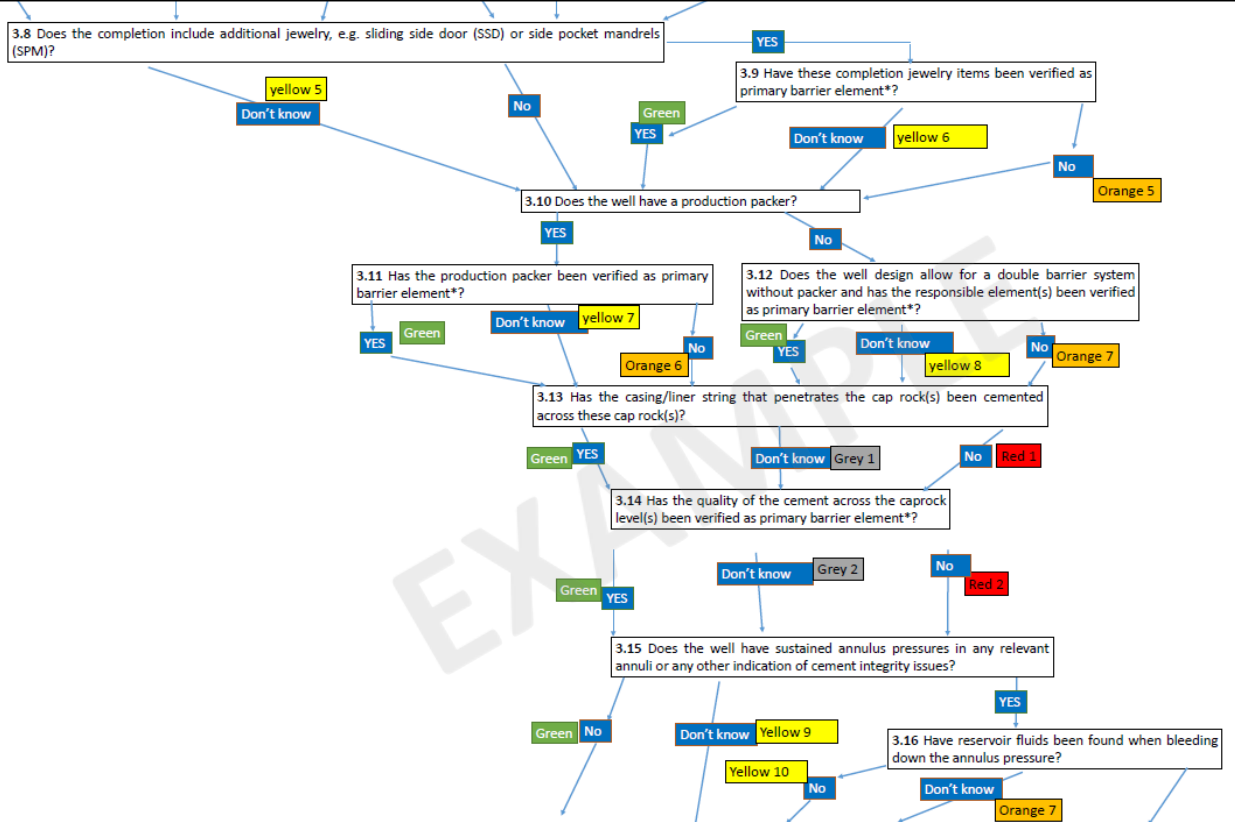
Legend

- X.X.XYZ? Decision tree question
- User answer to DT question
- Evaluation of user answer and well



Well screening – Decision Trees

- Designed to take users through step-by-step assessment using queries
- Iterated through feedback from the industry partners



REX-CO₂ tool - designed to be interactive

The screenshot shows the main interface of the REX-CO₂ Tool. At the top, it says "REX-CO₂ Tool" and "re-using existing wells". Below this is a "Well Screening" section with a description: "The well screening tool consists of a tool initialization and a well screening aspect. The first asks the user for inputs regarding the user's field and wells, while the second has the user complete a series of decision trees for each well and then provides the results of the assessment." There are two buttons: "Load Input" and "Export to File". Below these are two large buttons: "Tool Initialization" and "Well Screening".

Cement Integrity Predictions (beta feature)
The cement integrity predictions tool asks the user for a few inputs and then performs an analysis by running reduced order models for the specified parameters, producing a prediction of the caprock cement integrity. This component is still in development and is thus considered a beta feature.

Version: 1.0.1
E-mail: info@rex-co2.eu

Buttons: User Guide, Acknowledgements, References

This screenshot shows the "Well Data" tab in the REX-CO₂ Tool. It contains a table of well information:

Well name	Current status	Intended use	Sidetracked	Max deviation [°]
Well 1	Producing	Brine producer	No	2
Well 2	Injecting	Injector	No	1
Well 3	Monitoring	No reuse		
Well 4	Monitoring	Monitoring		

Each row has a "Delete well" button. The interface also includes tabs for "General", "Well Data", "Data Availability", and "Reservoir".

This screenshot shows the "Out of Zone Injection" decision tree in the REX-CO₂ Tool. It contains several questions with radio button options for "yes", "no", or "unknown":






- 1.7: Can the maximum anticipated pressure be lowered to ensure that it is lower than the shoe strength? (yes selected)
- 1.8: Does the well structure include a liner? (yes selected)
- 1.9: Has the cement in the liner lap been verified as permanent Well Barrier Element (WBE)? (no selected)
- 1.10: Is there a valid reason (based on well operational history) to believe that the liner lap could be regarded as verified primary WBE? (yes selected)
- 1.11: Is the production packer installed at a depth with a required minimum formation strength to avoid out of zone injection (e.g. as per ISO 16530-1)? (yes selected)
- 1.13: Is there evidence suggesting that the casings are free from significant corrosion? (unknown selected)

A "Recommendation: red" is shown at the bottom, with a text box explaining: "The information gives reason to assume the well may not be a good candidate to be reused for CCS due to risk of out of zone injection. Excessive remediation work is foreseen. An engineering and techno-economic assessment would be required to confirm."

REX-CO₂ tool will be publicly available – for info email to info@rex-co2.eu

Well screening results

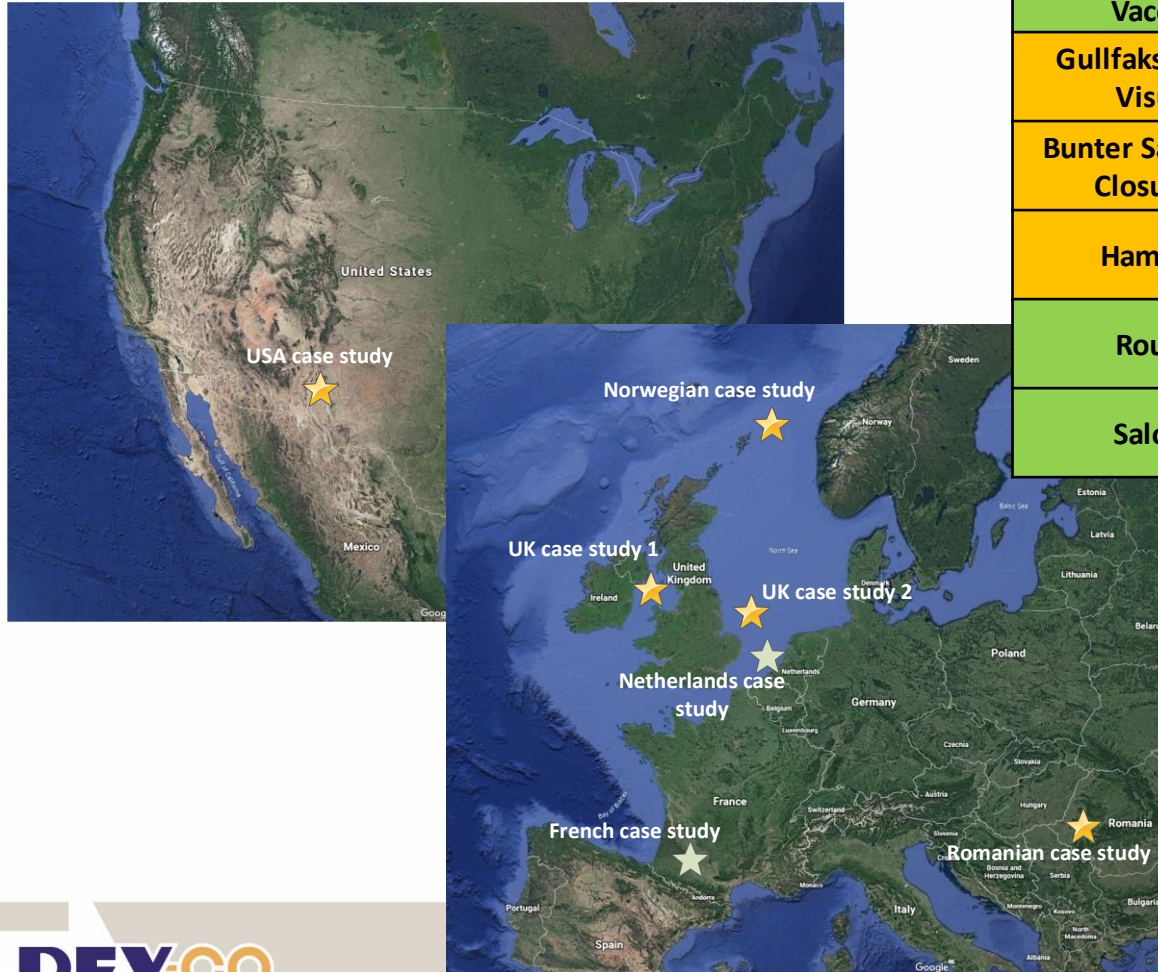
Results of well screening are qualitative and are provided in the form of traffic light recommendations

Recommendation	Explanation
	Only minor or no remediation could be expected
	Moderate remediation or additional verification efforts could be expected
	Severe remediation or a comprehensive risk management strategy on retrievable/replaceable items could be expected.
	Severe remediation or a comprehensive risk management strategy on non retrievable/replaceable items could be expected.
	Critical information is missing for the tool.

REX-CO₂ screening results are meant to inform the first steps in the decision-making process which will subsequently involve detailed techno-economic assessment

Tool application: International case studies

Tool validated using previous assessments for P18-2 and Rouse



Case study name	Country	Onshore/offshore	Type	Reference
P18-2 (Porthos)	Netherlands	Offshore	Depleted gas field	Zikovic and van der Valk (2021)
Vaccum	USA	Onshore	CO ₂ -EOR field	Chen (2021)
Gullfaks Sør and Visund	Norway	Offshore	Oil fields	Grimstad et al., (2022)
Bunter Sandstone Closure 36	UK	Offshore	Saline aquifer	Williams and Hoskin (2021)
Hamilton	UK	Offshore	Depleted gas field	Williams and Hoskin (2022)
Rouse	France	Onshore	Depleted gas field and pilot CO ₂ storage site	Guy and Cangemi (2022)
Salonta	Romania	Onshore	Depleted gas field (abandoned)	Dudu et al., (2022)

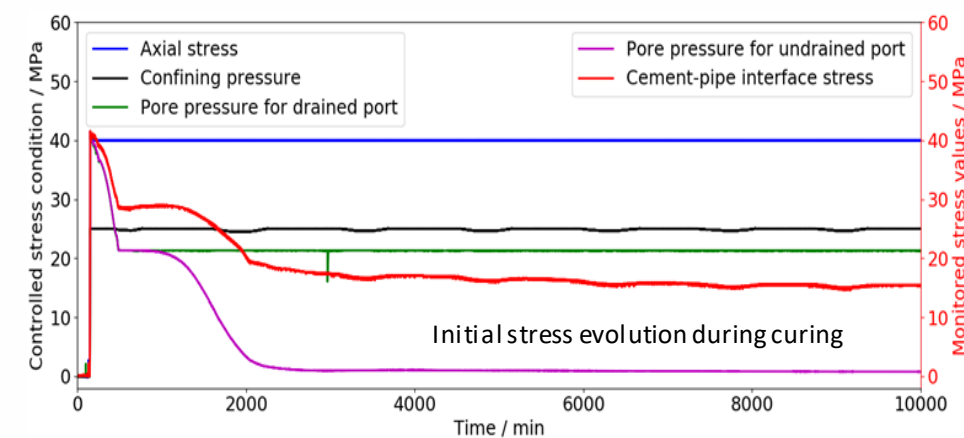
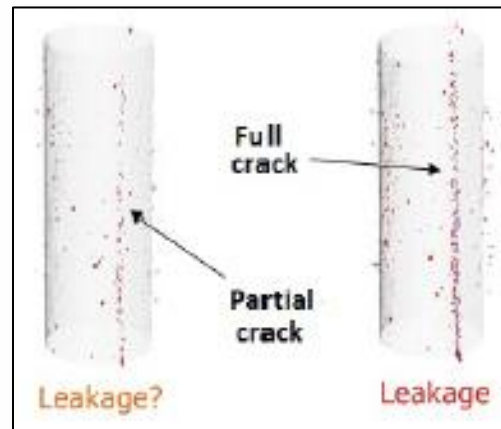
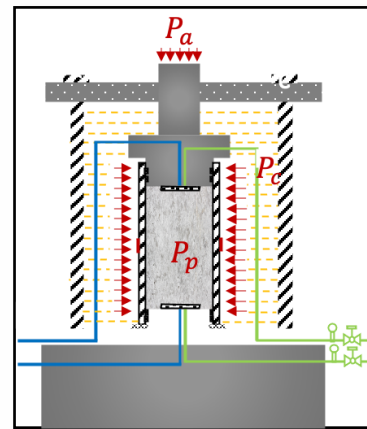
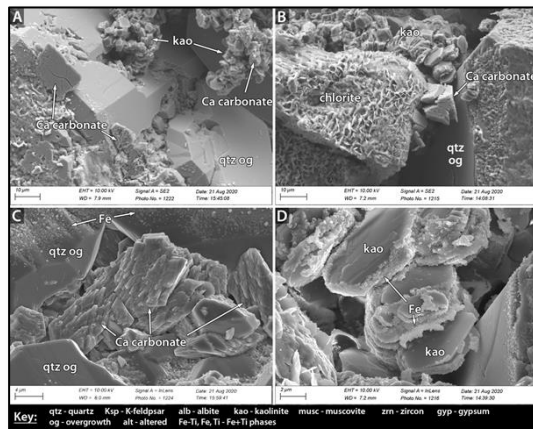
- Location: on-shore and off-shore
- Applications: Saline, depleted gas and CO₂-EOR
- Depths: 1400-5000 m
- Reservoir rock: sandstone and carbonate
- Reservoir type: gas field, oil field, saline aquifer
- Reservoir capacity: 37 – 280 Mt CO₂
- Number of available wells >100

Key findings from case studies

- Data/information needed for assessment can be limited
- Intervention required to re-purpose all wells
 - A rig or workover is usually required to repurpose wells
 - Remediation can be achieved via coiled tubing interventions
- Primary barrier components and completions may be subject to cooling and may not be fit for re-use
- Structural integrity may be costly and technologically challenging to assess
- Quality of cement sheath and casing corrosion uncertainty
 - New logs may be necessary
 - Dual-cased sections may be difficult due to logging challenges

Experimental investigations for re-using wells for CO₂ storage

- Provide experimental data that describe how well degradation and well design influence potential re-use as CO₂ injectors
 - Bond strength between cement & steel
 - Mechanical behaviour & integrity of cement-rock systems & interfaces
 - Downhole cement state of stress
 - Self-healing of leakage pathways
 - Microbial remediation
- To define boundary conditions at which well integrity could fail and/or be remediated



Highlights of experimental investigations

- State-of-stress experiments and simulation studies indicate that well integrity is more robust to thermal and mechanical stresses than previously understood (Agofack *et al.*, 2021; Meng *et al.*, 2021).
- Cycling tests on downscaled wellbore samples illustrate that the ratio between the stiffness of cement and of rock formations is important.
- Higher pressure conditions during cement curing increases the mechanical strength of cemented interfaces (Rossillon *et al.*, 2022).
- Determining leakage rates that account for the stresses and mechanical behaviour of cement in well systems should be prioritised.
- Down hole microbial-induced carbonate precipitation (MICP) technologies have potential applications in geotechnical engineering including the remediation of oil and gas wells for CO₂ storage.

Regulatory and social aspects

Objective:

- Assess non-technical aspects that influence the implementation of well re-use application, from regulatory (legal) aspects to public acceptance
 - Assessment of national legal frameworks
 - Workshops with regulators and other stakeholders
 - Guidelines for permitting process
 - Public perception and acceptance of well re-use for CCS

Possible gaps identified in national legal frameworks

LIFETIME STAGE/ MILESTONE/POLICY	POSSIBLE REGULATORY/POLICY GAP	FR	NL	NO	RO	UK	US
TRANSITION FROM PRODUCTION TO STORAGE	Procedure for postponing decommissioning of wells	o	(+)	o	o	o	+
	Simultaneous HC production and CO ₂ storage	o	+	+	o	o	+
	Arrangements during mothballing/hibernation	o	o	o	o	o	+
HIBERNATION (TEMPORARY ABANDONMENT)	Rules for mothballing and hibernation of wells	+	o	+	+	+	+
	Ownership of wells and costs	o	o	o	o	o	+
PERMITTING WELL RE-USE	Rules for permitting, monitoring and testing	o	o	o	o	o	+
POLICY FOR WELL RE-USE	Promoting re-use	o	(+)	o	o	+	o
	Incentivisation	o	o	o	o	(+)	o

+ = none, (+) = proposal/in consideration, o = possible gap

Summary & take-away points

Value of REX-CO₂:

- Fast turn-around time & systematic approach to assess large number of wells – publicly available well screening tool
- Improved decision making, optimised capacity planning & cost savings when maturing CCUS opportunity
- Facilitate safe well re-use & CCS uptake – project deliverables, results and recommendations on project public site
- **Case studies:**
 - Well Screening tool results in line with Engineering Assessments
 - Well intervention always required to re-purpose for CO₂ injection
- **Experimental:**
 - Provides insights in fundamental well integrity processes
 - A (larger) data-base with actual and historic downhole data for different well conditions is needed
- **Permitting:**
 - Major differences in permitting & lack of specific legislation for well re-use
 - Regulatory barriers expected (not in US)
 - Data sharing & early discussion between operators, regulators and future CO₂ storage operators should be encouraged
- **Recommendations for re-using existing wells – Report D5.1 (available on project web site)**



British Geological Survey

REX-CO₂

re-using existing wells

Thank you for your attention

<https://www.rex-co2.eu>



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This project has received funding from ADEME (FR), RVO (NL), RCN/CLIMIT (NO), UEFISCDI (RO), BEIS (UK), and DOE (USA), under the EU Horizon 2020 programme ACT, Project No. 299681. The contents of this publication reflect only the author's view and do not necessarily reflect ERA-NET ACT's position. ERA-NET ACT is not liable for any use that may be made of the information contained here.