Applying Exploration Common Process to Site Selection for Geologic Carbon Storage Complexes

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[2]BP

Abstract

The secure geological storage of carbon dioxide is widely regarded as being a necessary contribution to the global emissions reductions needed if temperature change is to be limited to the 2 degrees Celsius target set out in the Paris Agreement. While global screening studies have suggested there is ample pore space available worldwide to sequester carbon on the gigatonne scale necessary, one of the challenges with the widespread deployment of geologic carbon storage is the identification of suitable locations for storage at the project-scale. The tools and techniques for hydrocarbon exploration have been refined over the years to define a relatively universal methodology that can be followed to appropriately assess the risk and uncertainties inherent in identifying, high-grading and maturing prospects to the drill-ready stage. In contrast, the process for identifying an attractive carbon storage complex is not as well defined, although many of the tools and techniques from hydrocarbon exploration can be repurposed to evaluate whether an area is prospective for the long-term subsurface containment of carbon dioxide. We propose the elements necessary for an economic geologic carbon storage complex must include consideration of: Carbon dioxide source, proximity, long-term availability; Trap integrity, top seal continuity (natural and anthropogenic), permeability and fracture gradient, lateral sealing elements, neotectonic environment; Reservoir connected pore space volume, injectivity, pressure, salinity, temperature; Monitorability, ease of collecting baseline and future data to assess plume migration and ensure secure storage. In this presentation we will review these elements and propose a framework for the subsurface characterization necessary to develop a portfolio of attractive, drill-ready prospects.

Conclusions

- Geological Carbon Storage is needed on a large scale to meet the Paris goals at the lowest societal cost
- Sufficient storage capacity exists globally
- Work is needed to define the most feasible areas for near-term storage projects

- Exploration Process allows the hydrocarbon extraction industry to make rigorous portfolio decisions and maximize the efficient deployment of shareholder capital
- With some minor modifications, EP tools can be used to help prioritize GCS opportunities and grow the storage industry

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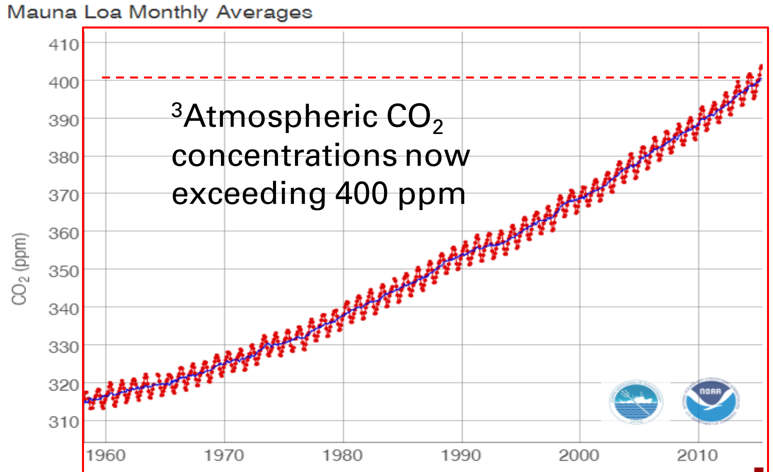
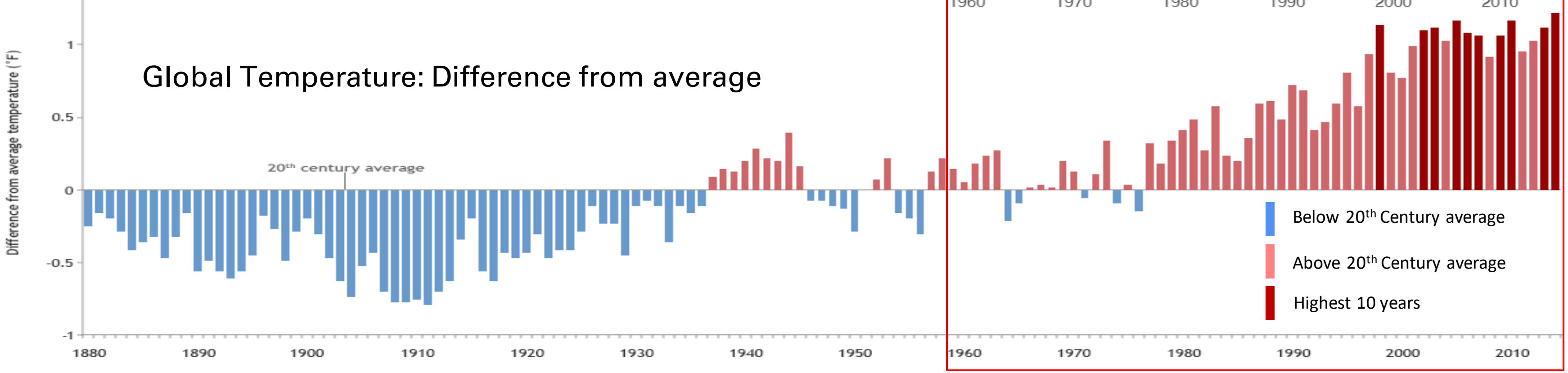
CO_2 concentrations are rising…

Global GHG emissions continue to rise - mainly due to human activities[1].

This has been linked to the global temperature rise[1] with the 10 hottest years on record all occurring since 1998[2].



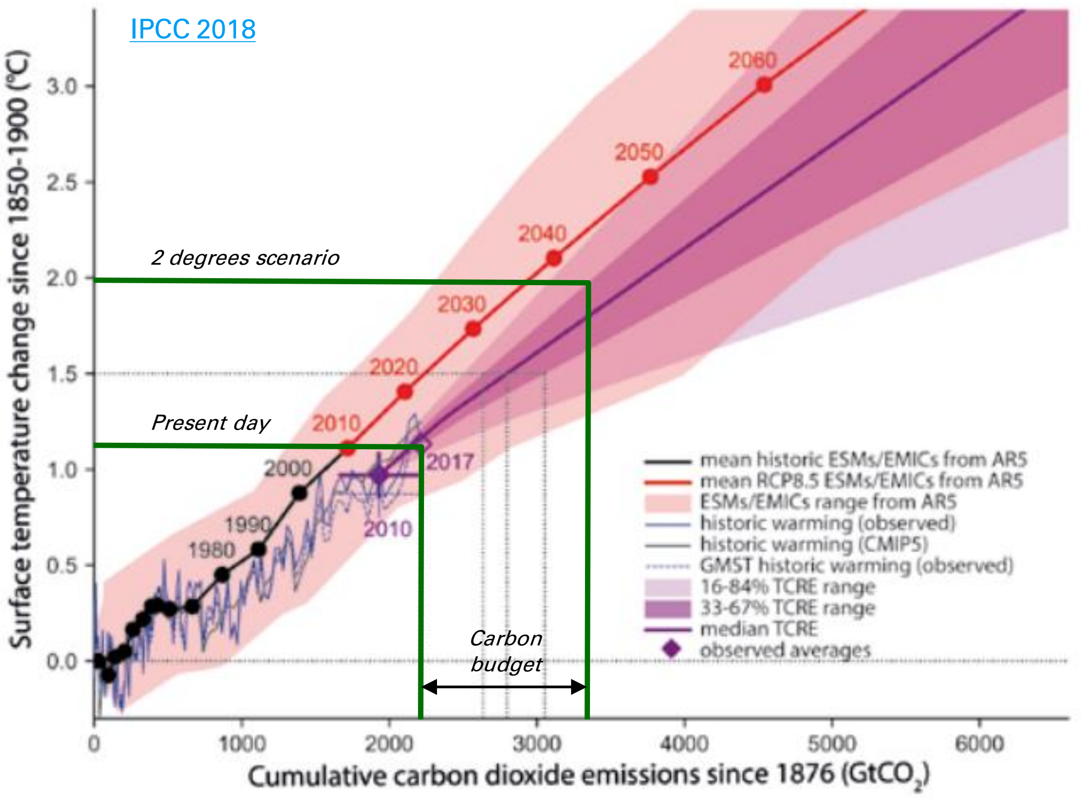
[1]IPCC 5th Assessment Report
[2]World Meteorological Organization
[3]IPCC / Princeton



… and temperatures are rising too

- ~1°: Current rise above pre-industrial values
- 2°: Threshold above which impacts are projected to rapidly increase[1]
- 3°: By 2100, delivered by Paris Nationally Determined Contributions[2]
- 6°: By 2300, projected along current trajectory[1]

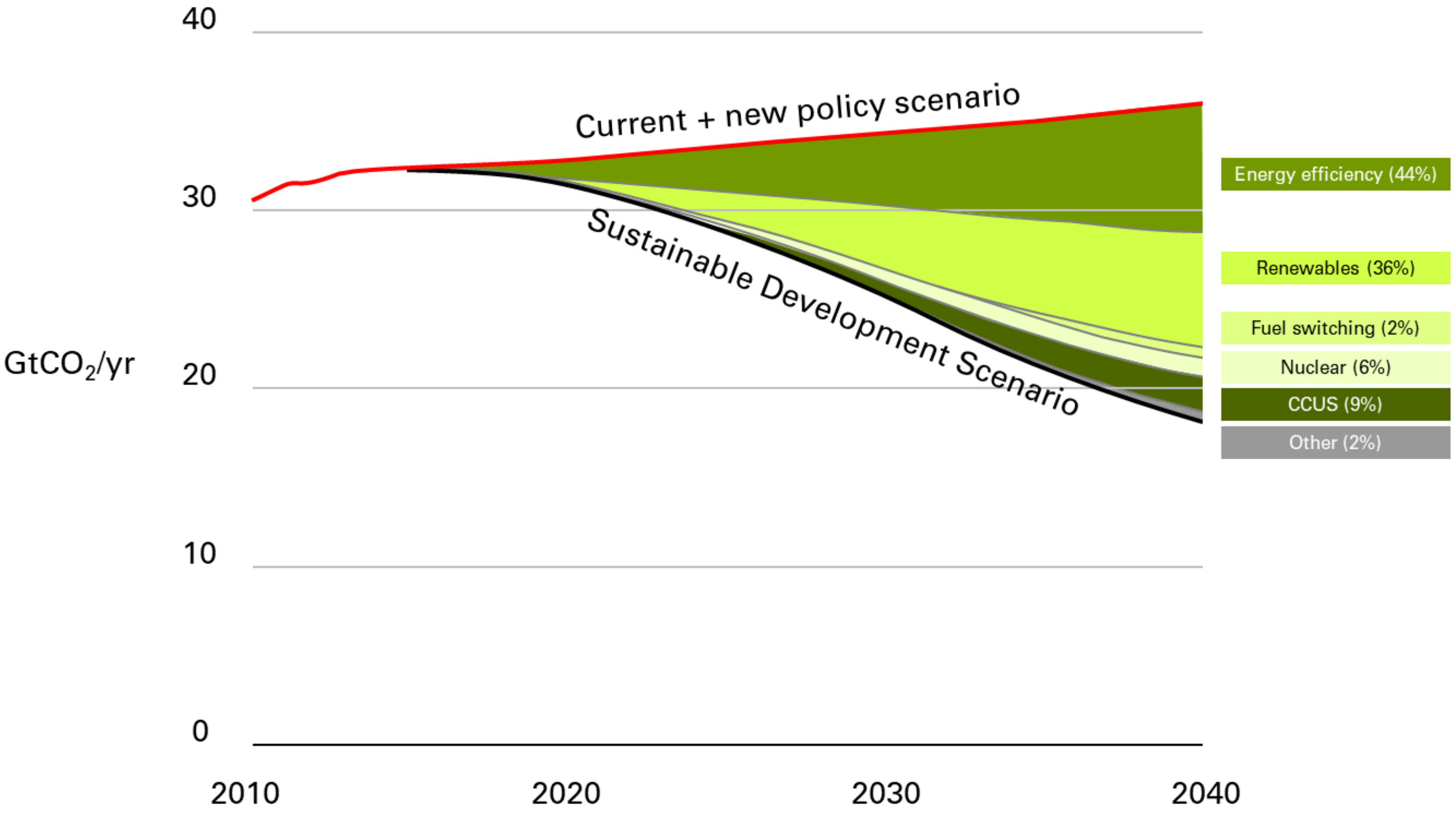
- ~2.2 trillion tonnes of CO_2 has been emitted since 1867, only ~1 trillion more can be emitted if global temperatures are not to exceed 2° above pre-industrial levels. This is the remaining "carbon budget" [3]
- To meet the Paris goals of staying "well below" 2°, even less can be emitted[3]



[1]IPCC 5th Assessment Report (2013), [2]Climate Action Tracker (2018), [3]IPCC (2018)

CCUS can provide >9% of CO_2 reductions

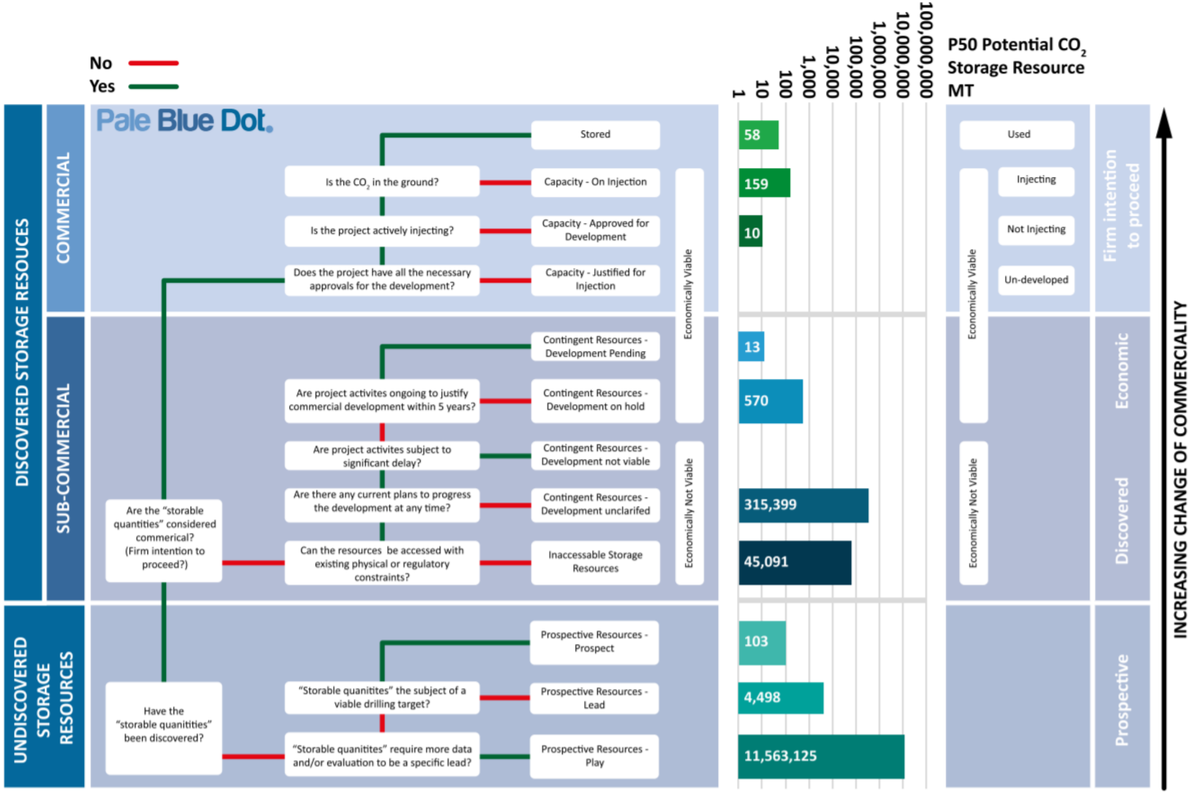
according to the IEA Sustainable Development Scenario



IEA World Energy Outlook 2017

Global scale

- ~12,000 Gt storage available worldwide[1]
- 94 Gt needed by 2050 to stay below 2°C [2]
- How do we high-grade and progress storage resources?

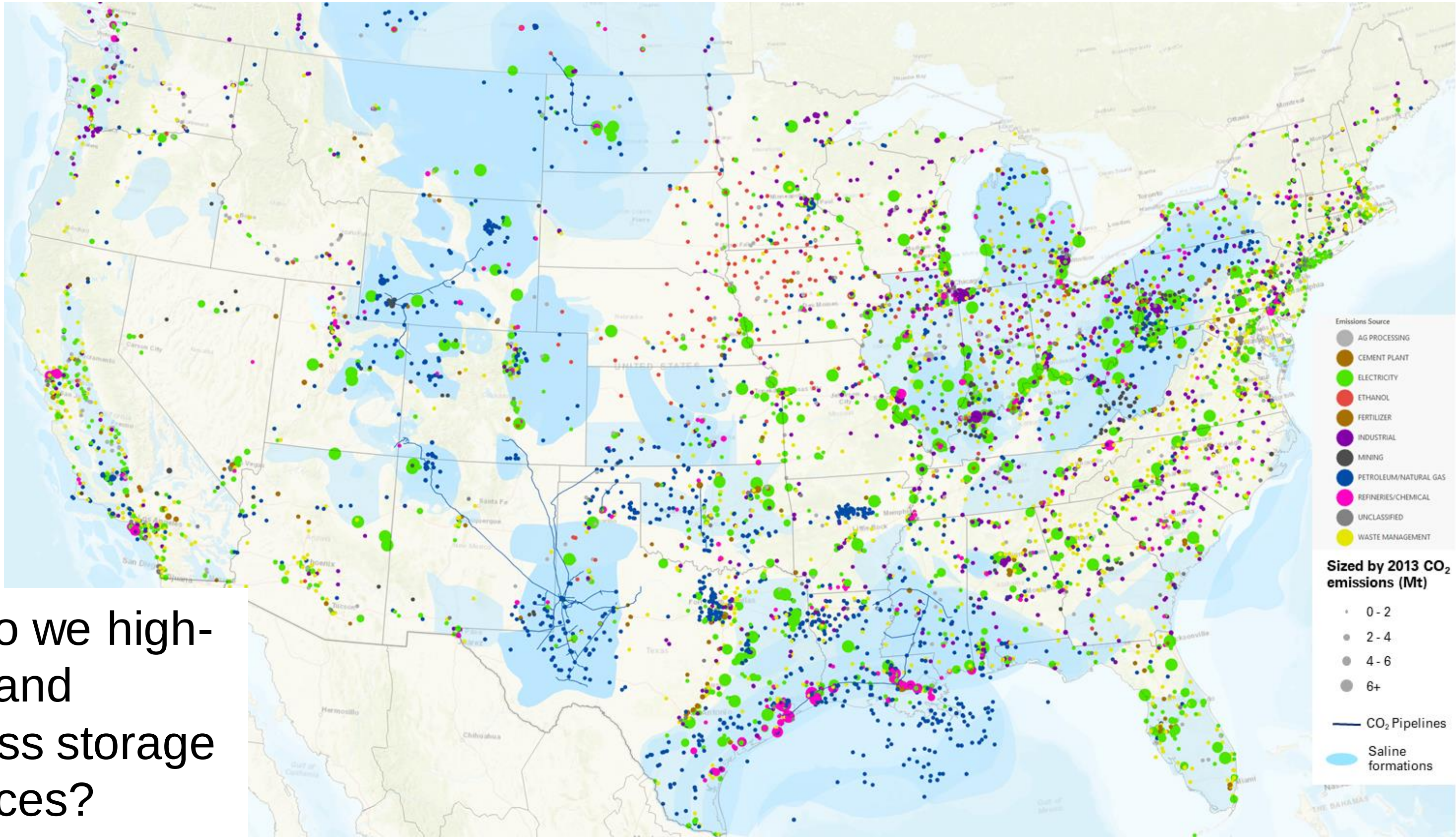


[1]OGCI Multinational CO2 Storage Resource Assessment
[2]IEA World Energy Outlook 2017

OGCI 2017

6,358 stationary sources of CO_2 emitting ~3Gt/yr

…but over 3,000 Gt of storage possible, enough for 500+ years of current emissions



- How do we high-grade and progress storage resources?

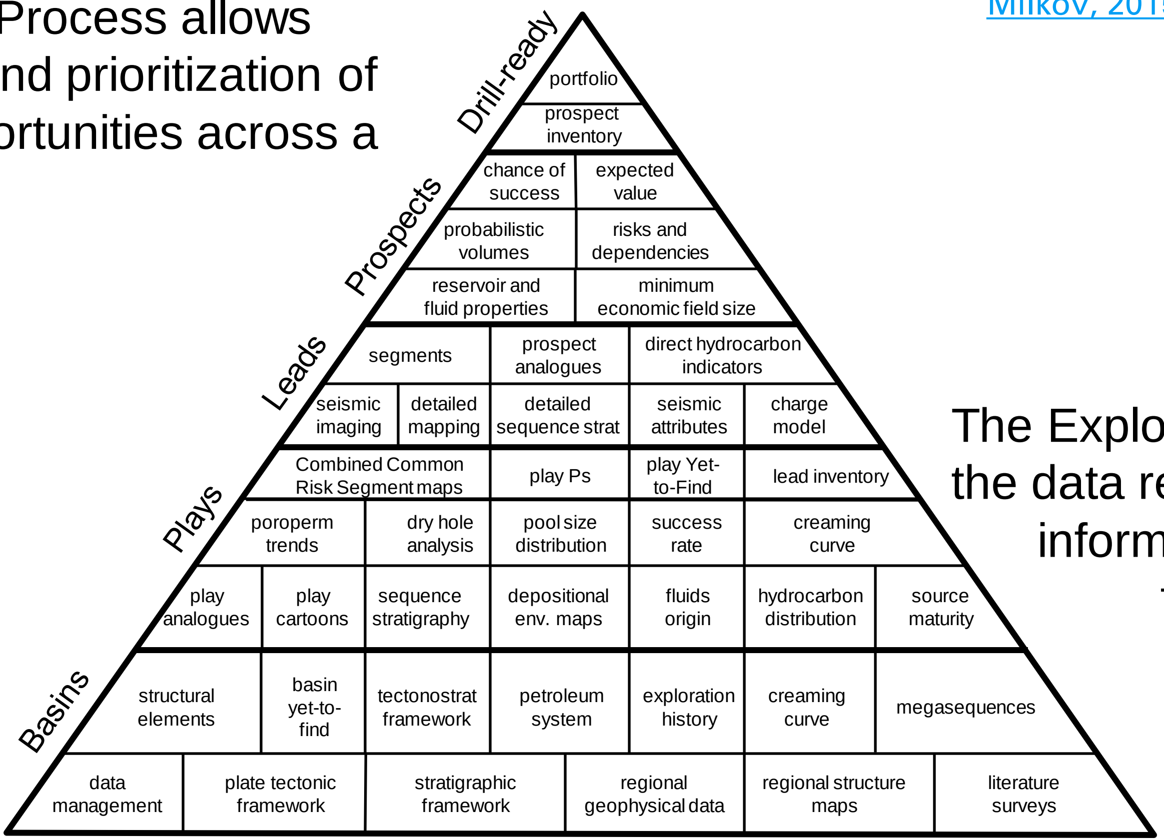
US DOE Carbon Atlas V (2013)

Exploration Process Examples

Exploration Triangle

Milkov, 2015, Earth Science Reviews

- Exploration Process allows evaluation and prioritization of diverse opportunities across a portfolio



The Exploration Triangle lists the data required to make an informed drilling decision from basin-scale to shotpoint-scale

Exploration Process Examples

Probability of Success

e.g.

Reservoir Presence	1.0	**Lowest risk**
Reservoir Quality	1.0	
Trap Quality	1.0	
Seal Adequacy	0.8	
Source Quality	0.7	
Source Maturation	0.7	
HC Migration	0.6	
Not Low Gas Saturation	0.6	
Biodegradation	0.5	**Highest risk**
Chance of Success	**7%**	

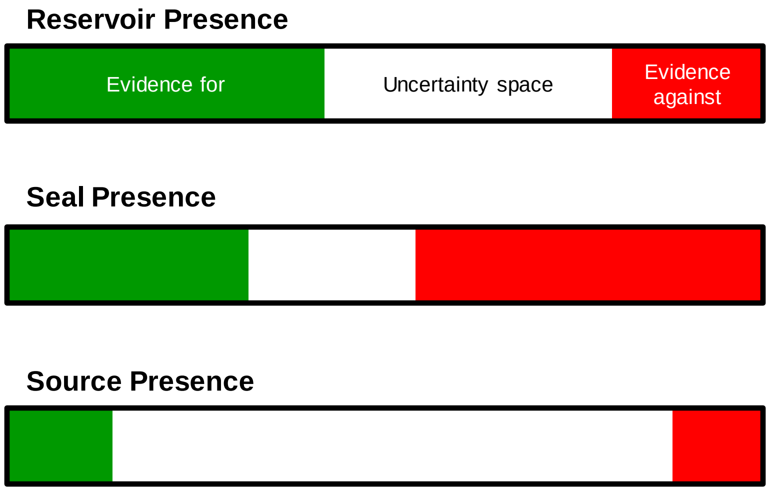
- Identify key risk factors
- Assign risk weighting
- Multiply to determine chance of finding developable amounts of hydrocarbon

Modified from Schroeder, 2004, AAPG Short Course

Exploration Process Examples

Estimation of uncertainty, e.g. Italian Flag

Blockley and Godfrey, 2007



- Visual representation of uncertainty
- Highlight the value of appraisal to reduce uncertainty in key parameters

Application of Exploration Process to GCS

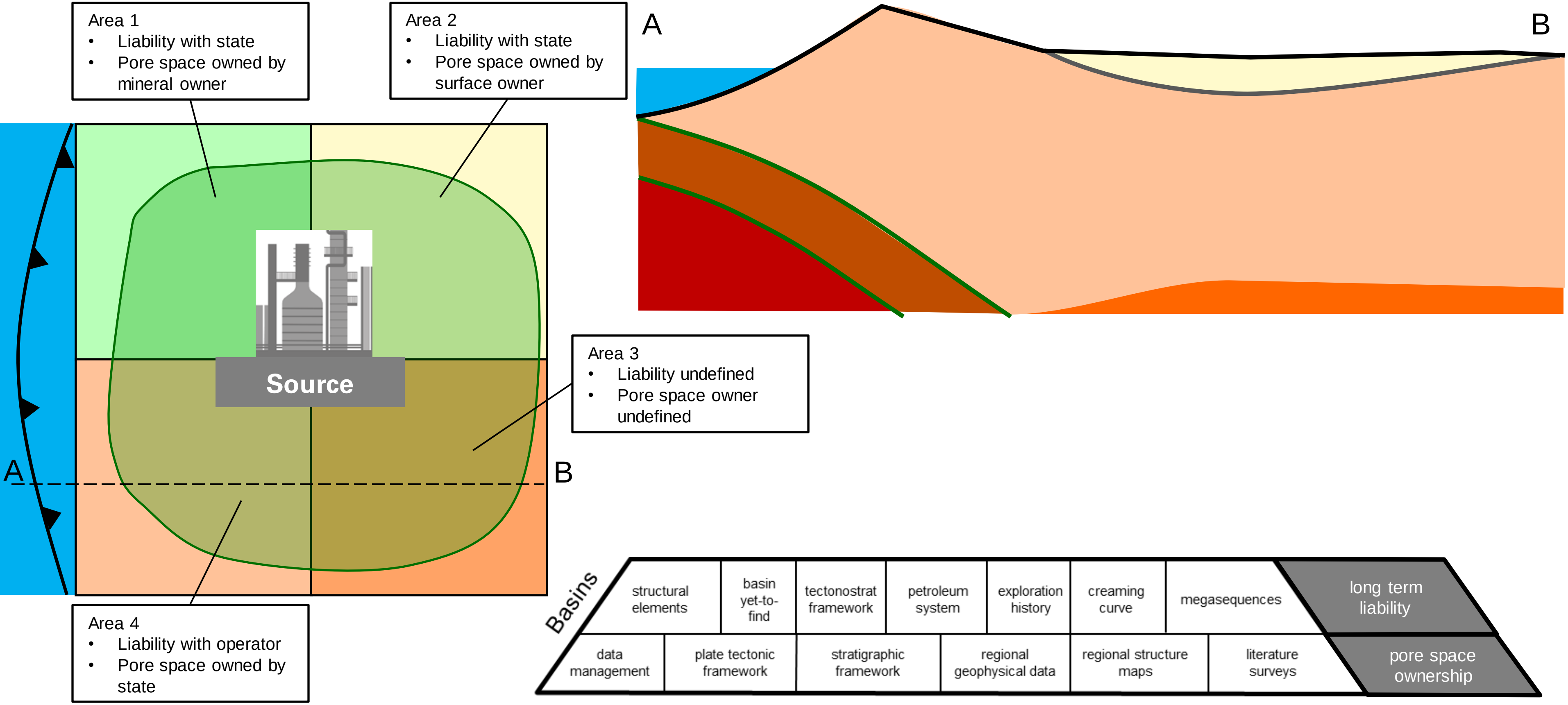
Site-specific challenges for GCS project siting

The elements necessary for an economic geologic carbon storage complex must include consideration of:

- Carbon Dioxide source; proximity, long-term availability
- Trap integrity; top seal continuity (natural and anthropogenic), permeability and fracture gradient, lateral sealing elements, neotectonic environment
- Storativity; connected pore space volume, injectivity, pressure, salinity, temperature, depth to crest;
- Monitorability, ease of collecting baseline and future data to assess plume migration and ensure secure storage
- Regulatory framework; pore space ownership, unitization, long-term liability

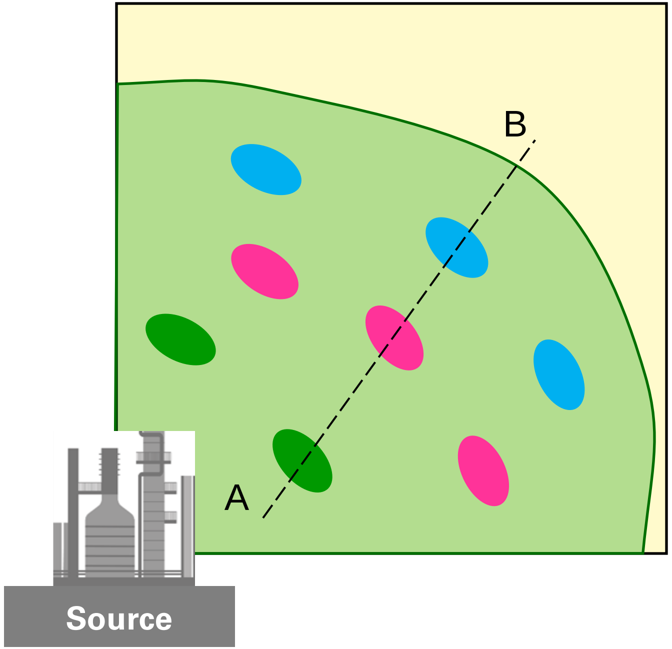
… making decisions on reservoir development with only access-level information

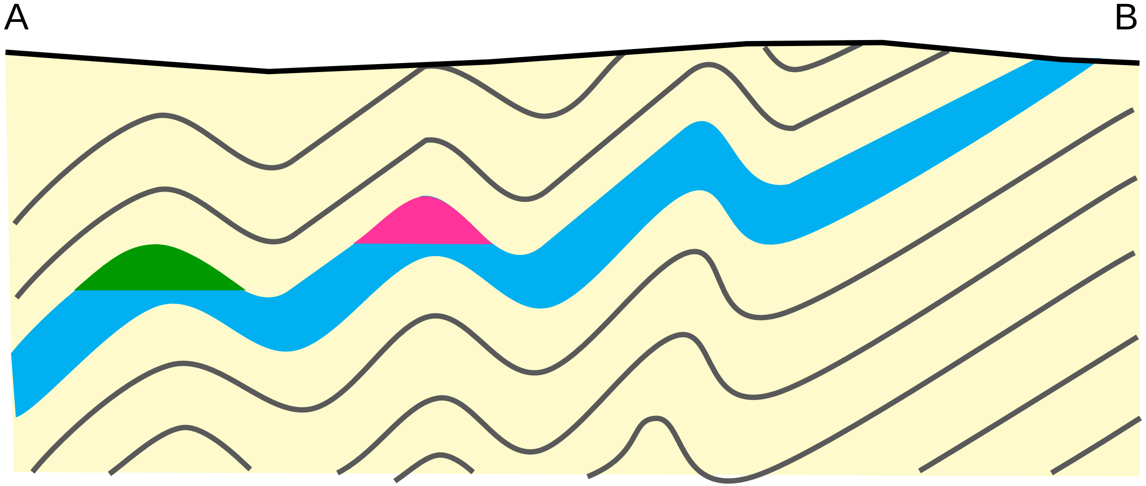
Basin scale

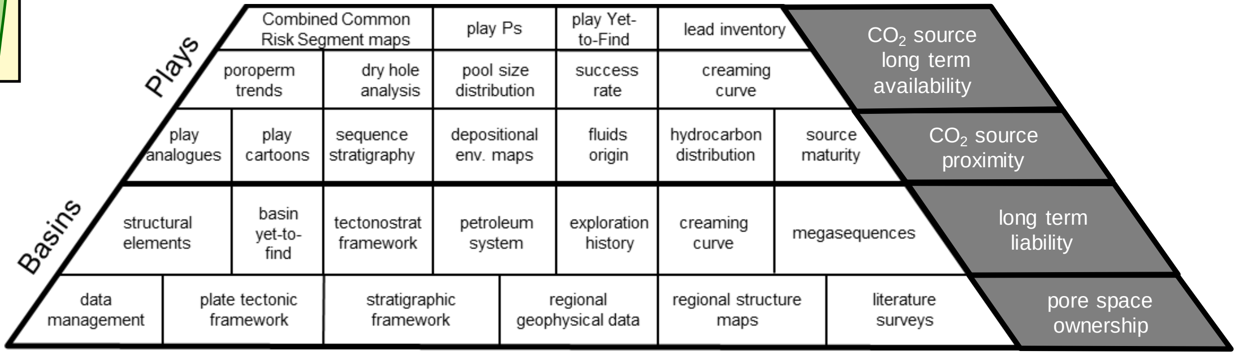


Area 1
• Liability with state
• Pore space owned by mineral owner
Area 2
• Liability with state
• Pore space owned by surface owner
A
B
Source
Area 3
• Liability undefined
• Pore space owner undefined
A
B
Area 4
• Liability with operator
• Pore space owned by state
Basins
structural elements
basin yet-to-find
tectonostrat framework
petroleum system
exploration history
creaming curve
megasequences
long term liability
data management
plate tectonic framework
stratigraphic framework
regional geophysical data
regional structure maps
literature surveys
pore space ownership

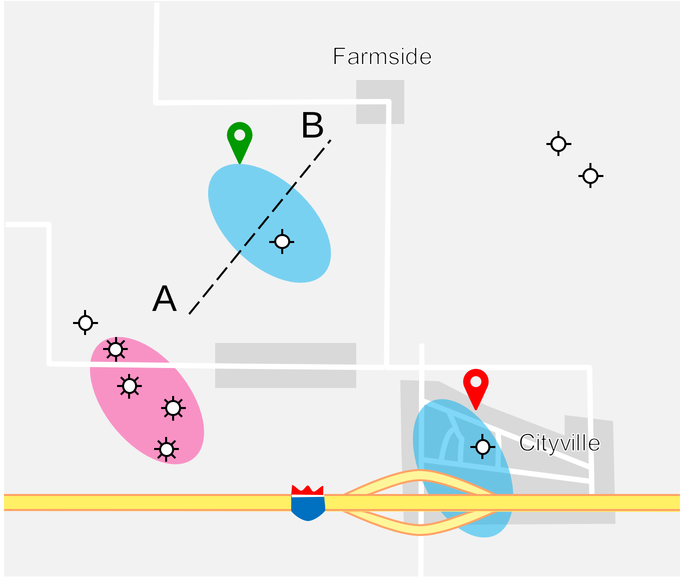
Play scale

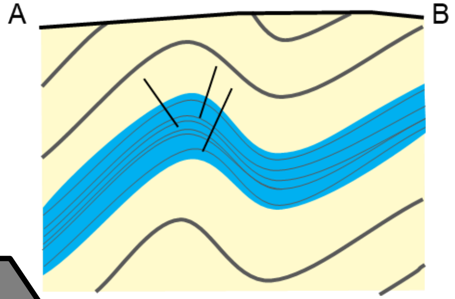

B
A
Source

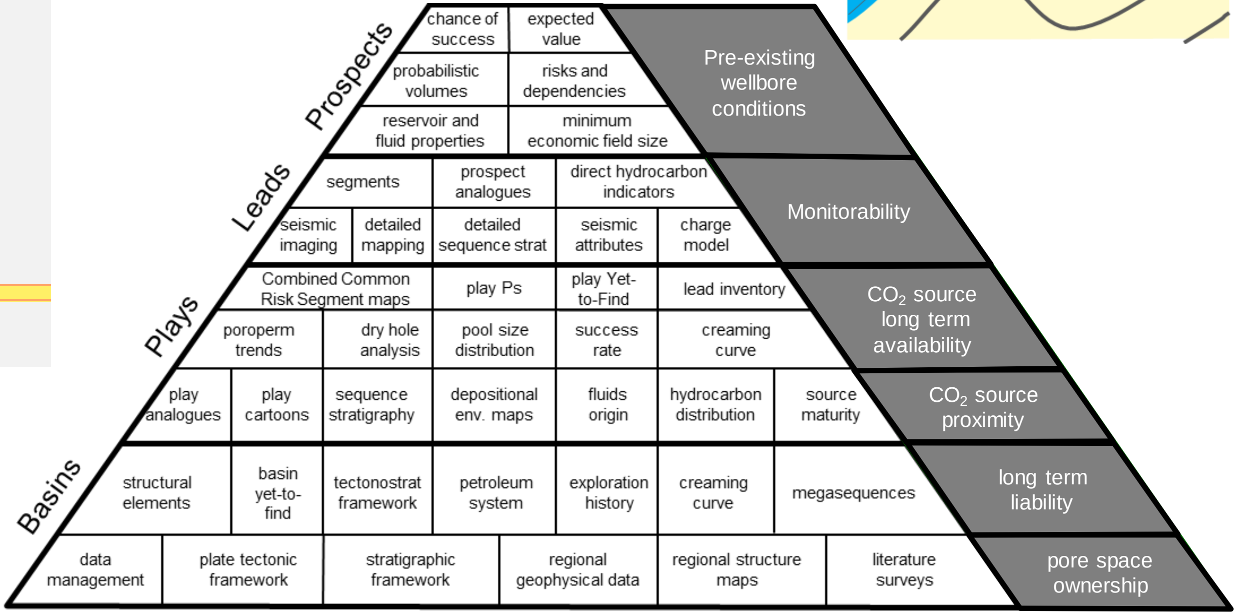

A
B


Plays
Basins
Combined Common Risk Segment maps
play Ps
play Yet-to-Find
lead inventory
CO_2 source long term availability
poroperm trends
dry hole analysis
pool size distribution
success rate
creaming curve
play analogues
play cartoons
sequence stratigraphy
depositional env. maps
fluids origin
hydrocarbon distribution
source maturity
CO_2 source proximity
structural elements
basin yet-to-find
tectonostrat framework
petroleum system
exploration history
creaming curve
megasequences
long term liability
data management
plate tectonic framework
stratigraphic framework
regional geophysical data
regional structure maps
literature surveys
pore space ownership

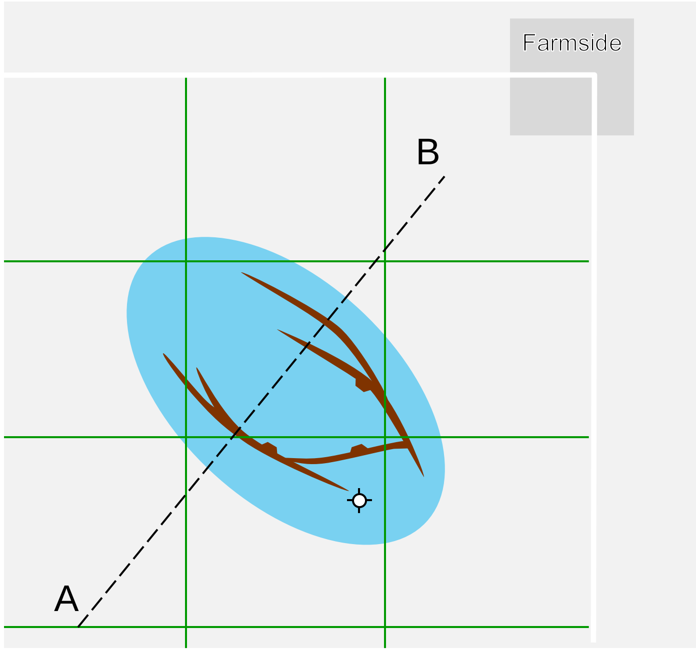
Prospect scale

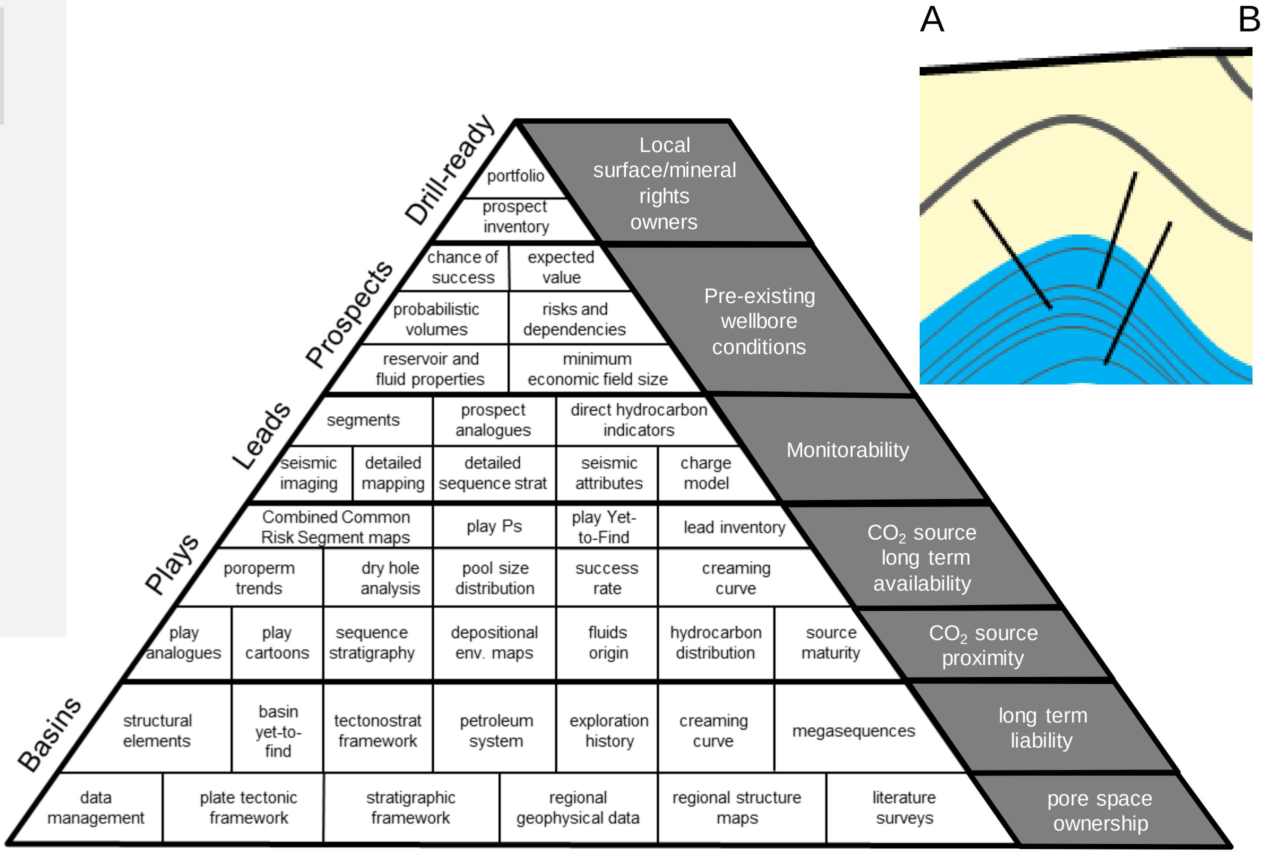






Shotpoint scale





Probability of success

e.g.		
Top Seal Strength	1.0	**Lowest risk**
Sufficient Injectivity	1.0	
Sufficient Pore volume	0.9	
Hydrocarbon absence	0.8	**Highest risk**
Chance of Success	**72%**	

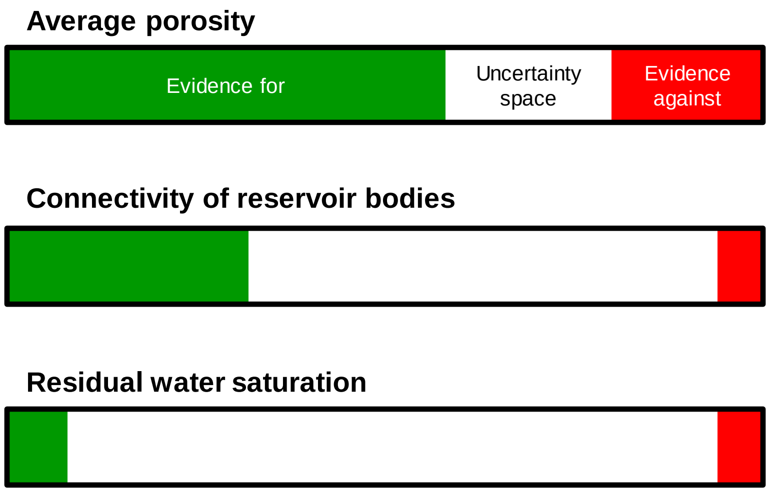
- Success defined as appraising a large enough pore space volume that can take CO_2 at a sufficient rate to meet project goals
- This is different from a leakage assessment
- Need to make sure that low "chance of success" is not perceived as chance of leaking CO_2 out of zone
- Leakage should be evaluated separately at the prospect level

Schroeder, 2004, AAPG Short Course

Exploration Process

Estimation of uncertainty, e.g. Italian Flag

E.g. What is raising the risk of finding Sufficient Pore Volume



- Very little information on residual water saturation in reservoir
- Uncertainty can be reduced by collecting whole core in appraisal well and performing injection tests

Conclusions

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