The Society of Petroleum Evaluation Engineers

SPEE Denver Chapter announces its October Meeting
It will be a Virtual Chapter Meeting

(Members and Guests are cordially invited to attend)

Wednesday, October 12, 2022

Richard Hares, M.Sc, P.Eng.

Principal Carbon Management, Sproule

Will be speaking on:
"The Application of Storage Resource Management System (SRMS) Guidelines"

Abstract: Richard will discuss:

- Key concepts and principles in CO_2 storage.
- Storage Resource Management System (SRMS) Introduction and Purpose
- Comparison to Petroleum Resource Management System (PRMS)
- Methods for estimating storable quantities of CO_2
- Case Studies (Sproule and others)

Speaker Bio.: **Richard Hares** is Principal, Carbon Management for a global energy advisory firm called Sproule. Sproule is a leading global energy consulting and advisory firm based in Calgary, Canada, with offices in Denver, Mexico City, and The Hague. Sproule has expertise in Reservoir Characterization, Reserves Certification, Transaction Advisory, and Carbon Management. Richard leads the development of a global consulting and advisory practice in Carbon Management, identifies commercial Carbon Management and Carbon Capture, Utilization and Storage (CCUS) opportunities for new and existing clients and advises clients on Carbon Management and CCUS market positioning, providing tools and solutions to help navigate the Energy Transition. Richard has MSc. in Sustainable Energy Development and is a registered Professional Engineer (P.Eng) in the province of Alberta, Canada.

The Application of SPE Storage Resource Management System (SRMS) Guidelines

October, 2022

Richard Hares
Principal, Carbon Management
richard.hares@sproule.com
+1 403 444 0288

Sproule

A global energy consulting firm which provides commercial and in-depth geoscience and engineering expertise and insights to help clients discover value from energy resources around the world.

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300+ Clients Served Annually	100% Independent	500+ Annual projects completed	15+ Geoscientists
	30+ Asset Management Professionals	2,000+ Professionals Trained in Last 5 years	20YR Average Experience

Agenda

- Key Concepts and Principles in CO_2 Storage
- SRMS Introduction and Purpose
- Comparison to Petroleum Resource Management System (PRMS)
- Methods for Estimating Storable Quantities of CO_2
- Case Studies

Key Concepts and Principles in CO_2 Storage

(Peck et al., 2017)

Types of CO_2 Storage and Geological Considerations

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(Peck et al., 2017)

There are many ways to store CO_2 in geological media, most notably:

- Injection into **deep saline aquifers**,
- Use in **CO_2-Enhanced Oil Recovery (CO_2-EOR)**, or
- Injection into **depleted oil and gas reservoirs**.

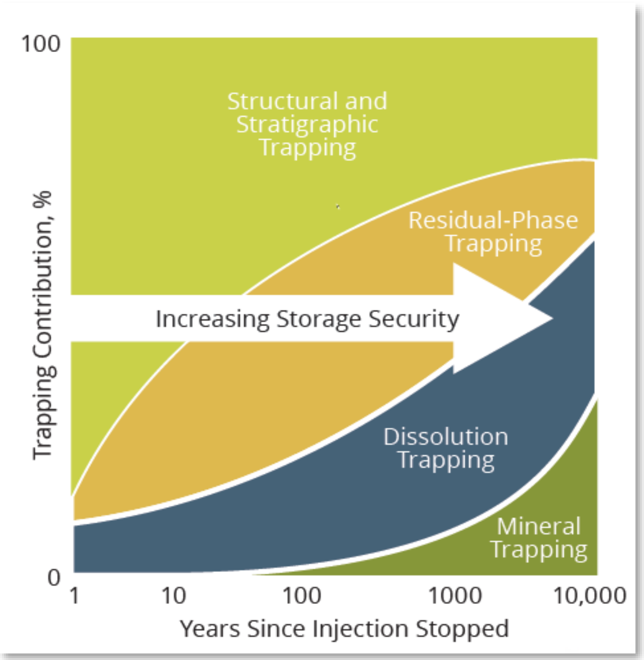
There are several important criteria to consider when analyzing the suitability of a geological media for CO_2 storage. Geology suitable for CO_2 storage must have:

1) **Capacity:** capacity to store volume of CO_2 securely;
2) **Injectivity**: the formation has sufficient injectivity to accept the CO_2 at the rate that is delivered from the source; and
3) **Containment**: the formation must be able to indefinitely confine the injected CO_2 safely underground to ensure storage and integrity

Finding the right reservoir to store CO_2 requires detailed subsurface including the identification of: reservoir pressure and temperature, porosity, permeability, seal thickness and continuity, geomechanical properties of pressurization and faulting, wellbore leakage pathways – all key factors for CO_2 sequestration suitability.

Trapping CO_2 in Rocks

- **Geologic (structural and stratigraphic)**
  - Trapping causes CO_2, as a buoyant fluid (in the presence of brine), to accumulate below a caprock
  - Large potential if suitable structures can be found
- **Residual trapping**
  - Occurs when CO_2 migrates over long distances, displacing brine
  - The brine imbibes into the CO_2 plume until the free-phase CO_2 is immobile at its residual saturation
  - Low risk in terms of caprock integrity
- **Solubility trapping**
  - Occurs when CO_2 progressively dissolves in brine
  - CO_2 dissolves best at low formation salinity
  - Occurs on time scales that are longer than the life of a project so convection may be deemed negligible in ·most resource assessments
- **Mineral trapping**
  - CO_2 dissolves in brine, altering the chemistry of the brine, leading to dissolution of some minerals and precipitation of new minerals
  - CO_2 will contribute to the formation of carbonate minerals and will be trapped as mineral, a solid phase
  - Very slow and may be negligible for most resource assessments, but very secure



(Peck et al., 2017)

What is a Storage Resource?

- "A CO_2 storage resource is defined as the quantity (mass or volume) of CO_2 that **can be stored** in a geologic formation" (SRMS, 2017)
- **"can be stored"** implies a future action, quantification, and containment
- Demonstrating that injected CO_2 can be contained in a geologic formation is key difference exploring for CO_2 storage resource and exploring for petroleum accumulations

Rationale for SPE Storage Resource Management System (SRMS)

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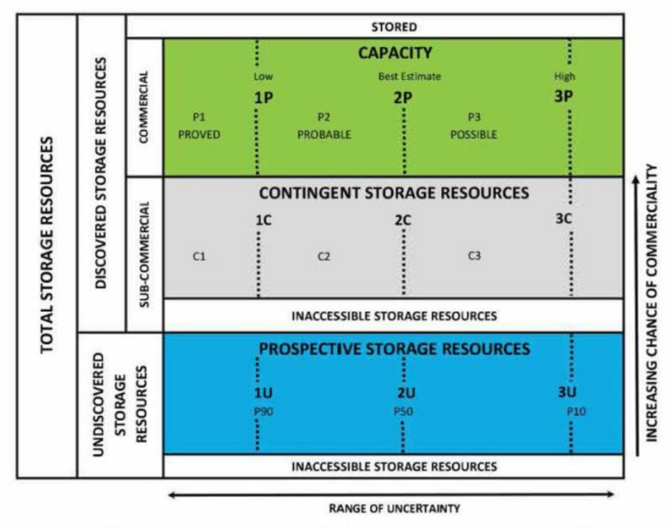
- Need for universal framework to assess carbon storage projects
- Provides common terminology and clear definitions needed to classify storage quantities - the commodity for storage
- Quantifying storage is an essential part of all projects
  - SRMS provides context for investment and tracking the performance of the investment
- Modelled on PRMS – well known and understood process of maturing petroleum resources
- Independent of implementation – SRMS does not provide advice

"A CO_2 storage resources management system (SRMS) provides a consistent approach to estimate storable quantities, evaluate development projects, and present results within a comprehensive classification framework" (SRMS, 2017)

SRMS Structure

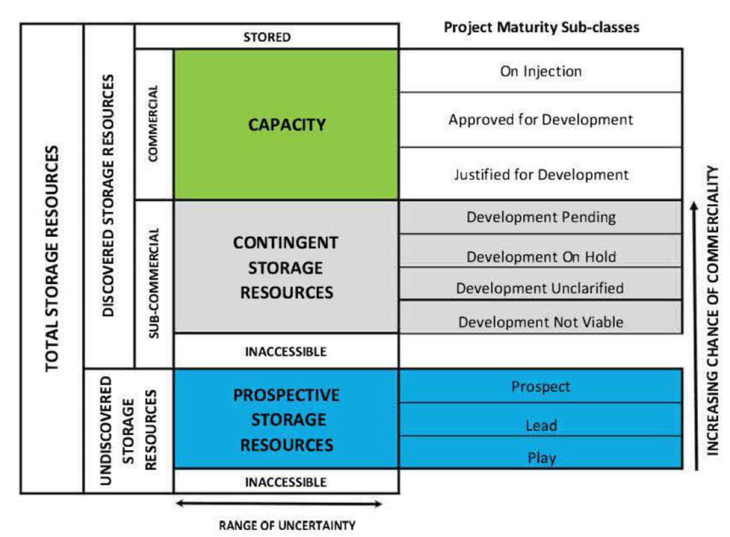
Classification



Resources Classification Framework

- Based on maturation of a project
- Major classifications
  - Low
  - Most-likely (Best)
  - High

Categorization



Storage Resources Classes and Subclasses based on Project Maturity

- Based on certainty in an estimate
- Major classifications
  - Discovered vs. Undiscovered
  - Commercial vs. Sub-commercial

Prospective Storage Resources (*Undiscovered*)

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Prospective Storage Resources have both an associated chance of discovery and a chance of development

Play

- A project associated with a **prospective trend of potential prospects**, but that requires more data acquisition and/or evaluation to define specific leads or prospects.

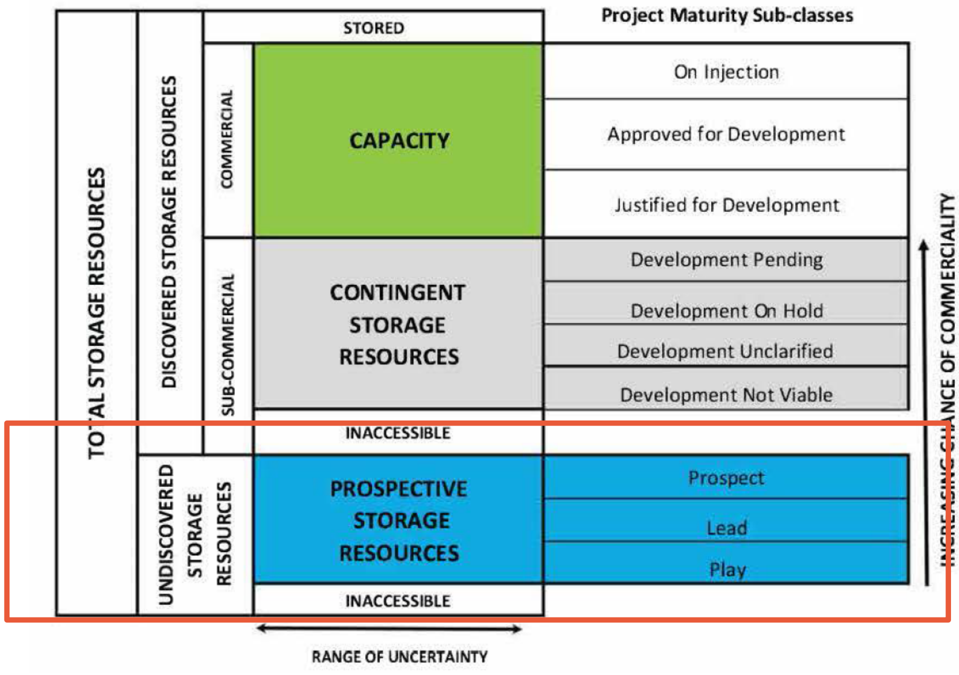
Lead

- A project associated with undiscovered storable quantities that is currently **poorly defined and requires more data acquisition** and/or evaluation to be classified as a prospect.

Prospect

- A project associated w/ undiscovered storable quantities sufficiently **defined to represent a viable drilling target**

Prospective Storage Resource matures with the availability of a well with adequate data for estimating storable quantities



Contingent Storage Resources (*Discovered – Sub-Commercial*)

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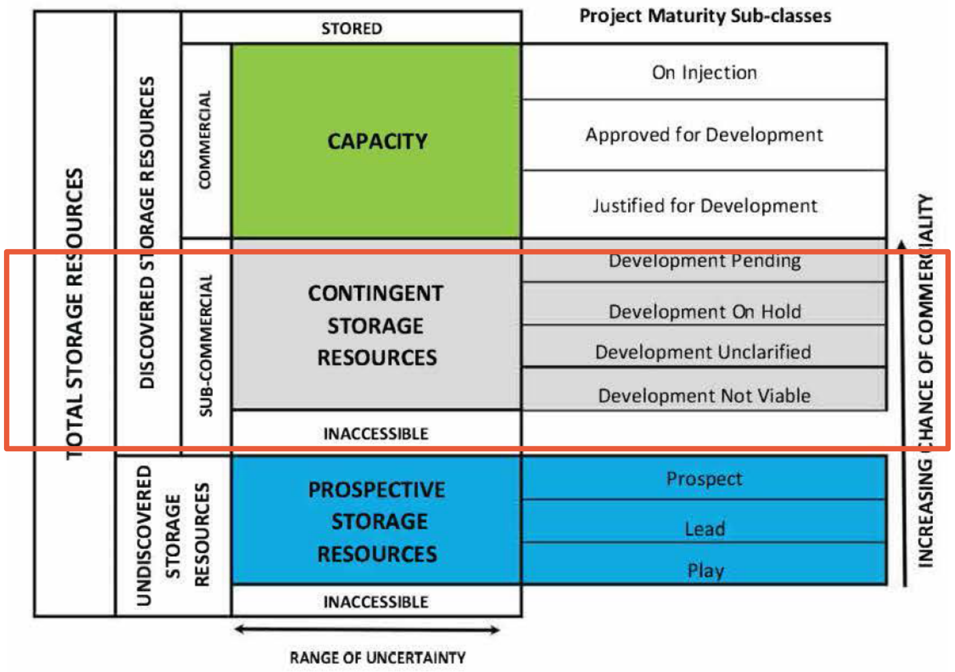
Discovery is a geologic formation(s) where one or more wells have established the presence of a significant quantity of potential CO2 storage for the proposed project

Examples of contingencies that may preclude a commercial project:

- There are currently no viable CO_2 sources
- Project value is insufficient to support development
- Permitting is still incomplete
- Commercial storage is dependent on technology under development
- Evaluation of the geologic formation is insufficient to clearly assess commerciality
- Insufficient capacity / capability to carry out the project
- Insufficient funds
- Project is not economic in current price/cost environment



Contingencies may preclude Contingent Storage Resource from maturing to Capacity

Capacity (*Discovered – Commercial*)

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On Injection

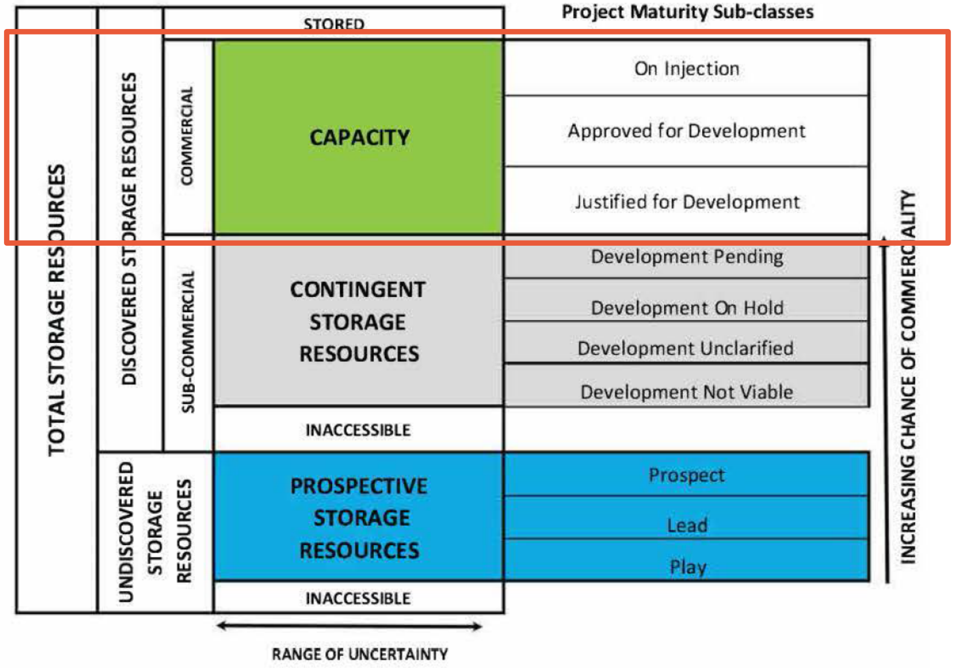
- Development project is **currently injecting** and storing CO_2

Approved for Development

- **All necessary approvals have been obtained**, capital funds have been committed, and implementation of the development project is underway

Justified for Development

- Implementation of the development project is **justified based on reasonable forecast commercial conditions** at the time of reporting, and there are reasonable expectations that all necessary approvals/contracts will be obtained



Capacity classification requires a development plan (reasonable timeframe) and no known contingencies to pass the commerciality threshold

Flowchart for the classification of storage resource

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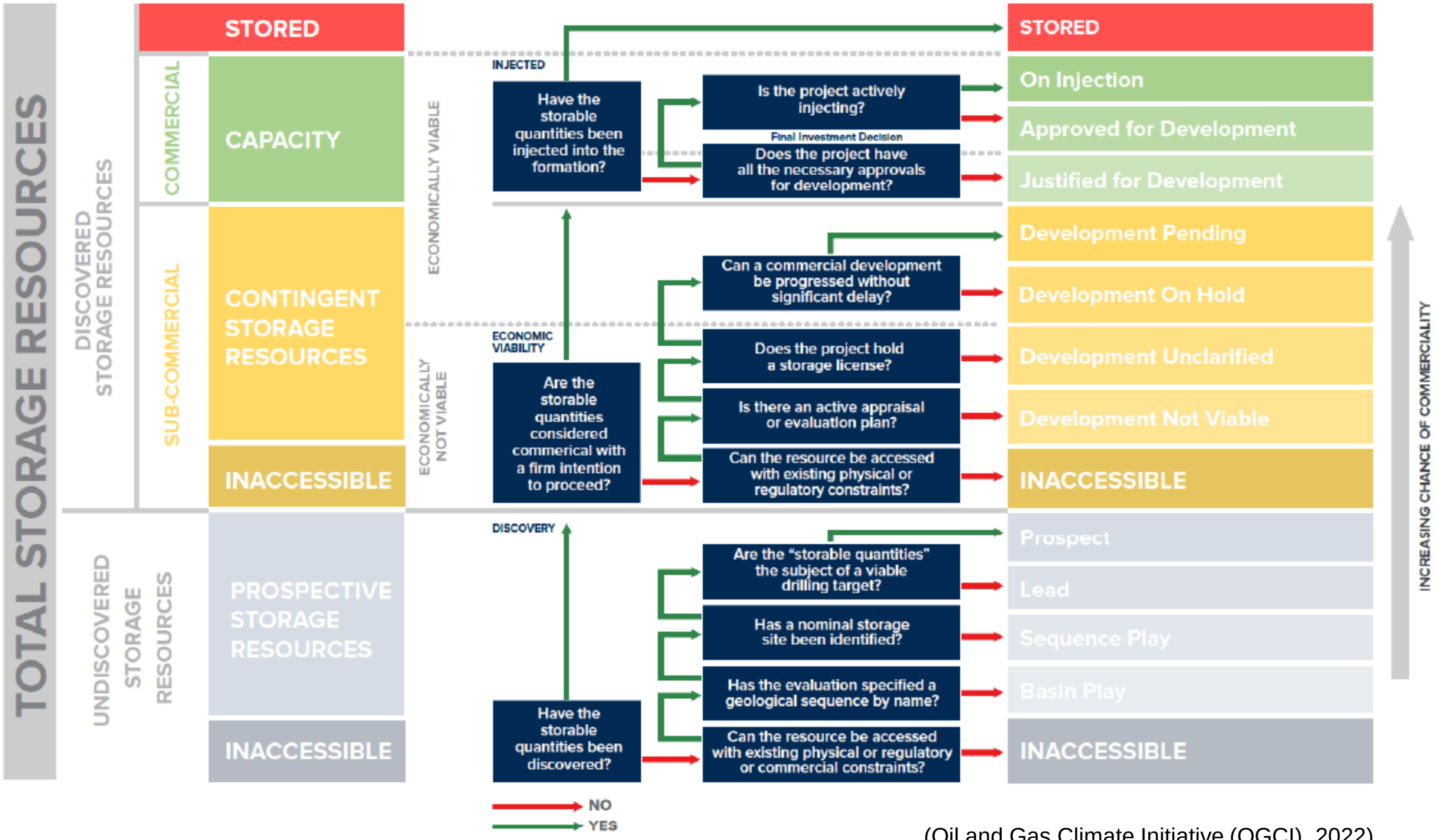

(Oil and Gas Climate Initiative (OGCI), 2022)

Global Estimate of CO_2 Storage Resource – Massive!

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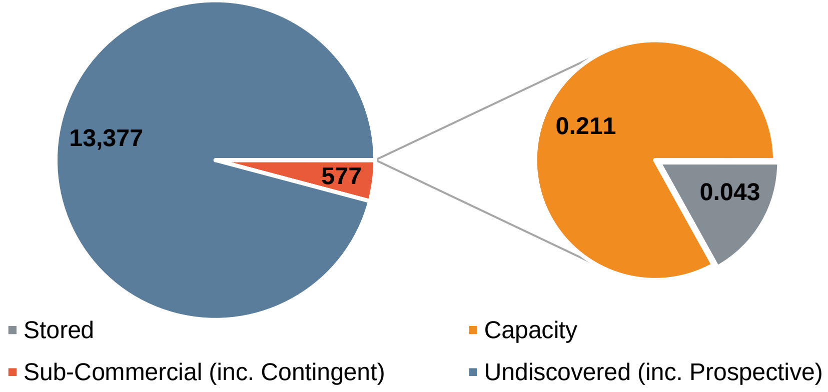
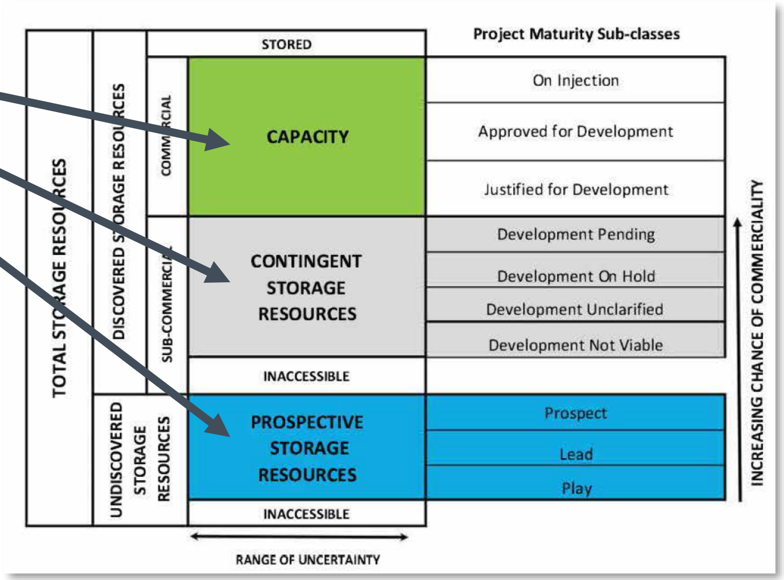
Classification	CO_2 Storage Resource (Gt) Project specified	CO_2 Storage Resource (Gt) Project and no project
Stored	0.043	0.043
Capacity	0.211	0.211
Sub-Commercial (Contingent)	66.2	577
Undiscovered (Prospective)	30	13,377
Aggregated	96.6	13,954

Project and Non-Project Storage Resource (Gt)





Storage resources classes and subclasses based on project maturity (SRMS, 2017)

(Oil and Gas Climate Initiative (OGCI), 2022)

Comparison to Petroleum Resource Management System (PRMS)

1. The PRMS is “project–based” – so is SRMS
2. Classification is based on project’s chance of commerciality
   Categorization is based on recoverable/storage uncertainty
3. Uses evaluator’s forecast of future conditions
4. Provides granularity for project management
5. Estimates based on deterministic and/or probabilistic methods
6. Applies to both conventional and unconventional resources
7. Reserves/resources are estimated in terms of the sales products
8. Net resources in terms of entitlement and recognition

Major Principles of PRMS and SRMS are identical

PRMS and SRMS Resource Classification Comparison

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PRMS

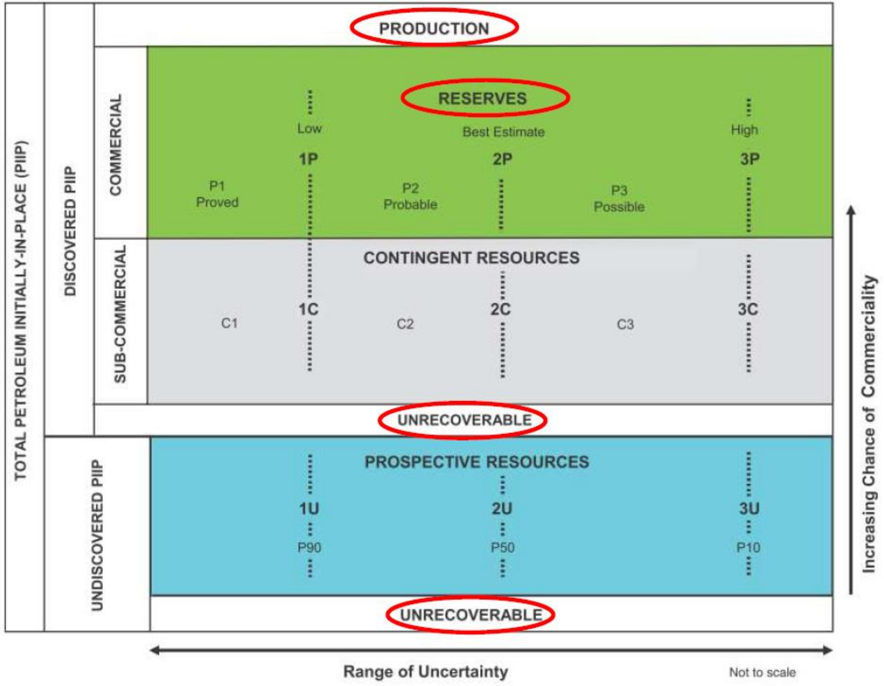

Figure 1.1—Resources classification framework

SRMS

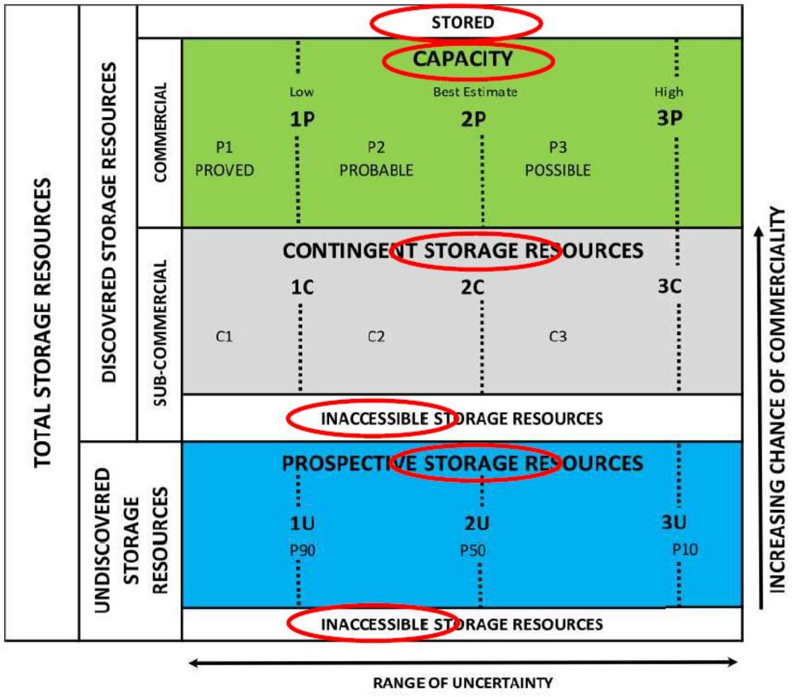

Fig. 1.1 – Resources Classification Framework

Approaches to Estimating Storable Quantities

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- Analog-based
- Volumetric method-based
- Traditional and enhanced material balance method
- Reservoir (Numerical) simulation
- Performance-based estimates

State of project development, maturity, and available assessment of methods

Case	Maturity	Assessment Methods: Analog	Volumetric Methods	Reservoir Simulation	Material Balance	Injection Performance
Basin Assessment	Prospective	X	X	X		
Characterization Well	Contingent	X	X	X		
Well with Injection Test	Contingent	X	X	X		
Development Well	Probable/Possible	X	X	X		
Ongoing Injection	Proved	X		X	X	X

(Frailey et al., 2018)

Not all storable quantities are created equal

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Volumetric Method

$$M_{CO_2} = A \times h \times \phi \times \rho_{CO_2} \times E$$

3730 km^2 (~40 townships), h – 43m, ϕ - 9%, ρ – 814 kg/m3, E – 3.1% (0.8-8.4%)

253 Mt CO_2

Material Balance/Compressibility Method

$$M_{CO_2} = A \times h \times \phi \times \rho_{CO_2} \times C_t \times \Delta P$$

3730 km2 (~40 townships), h – 43m, ϕ - 9%, ρ – 814 kg/m3, P_{max} – 28 MPa, P_0 – 20 MPa, Ct – 0.406 E-6 1/kPa, 70% Storage Efficiency

27 Mt CO_2

0.2x-0.5x

2x

Reservoir Simulation

(Most accurate)

3 Injection Wells, 5.2 Mtpa. P_{max} – 28 MPa, 25 year life, mid property and low connectivity scenario

56 Mt CO_2 or 5.2 Mtpa (130 Mt without bottom hole pressure constraint)

Shell Quest Example adapted from Winkler et al. (2011)

Numerical simulation-based methods provide greater certainty to advance CO_2 storage opportunities

Maturation of Project - Case Study (Alberta, Canada)

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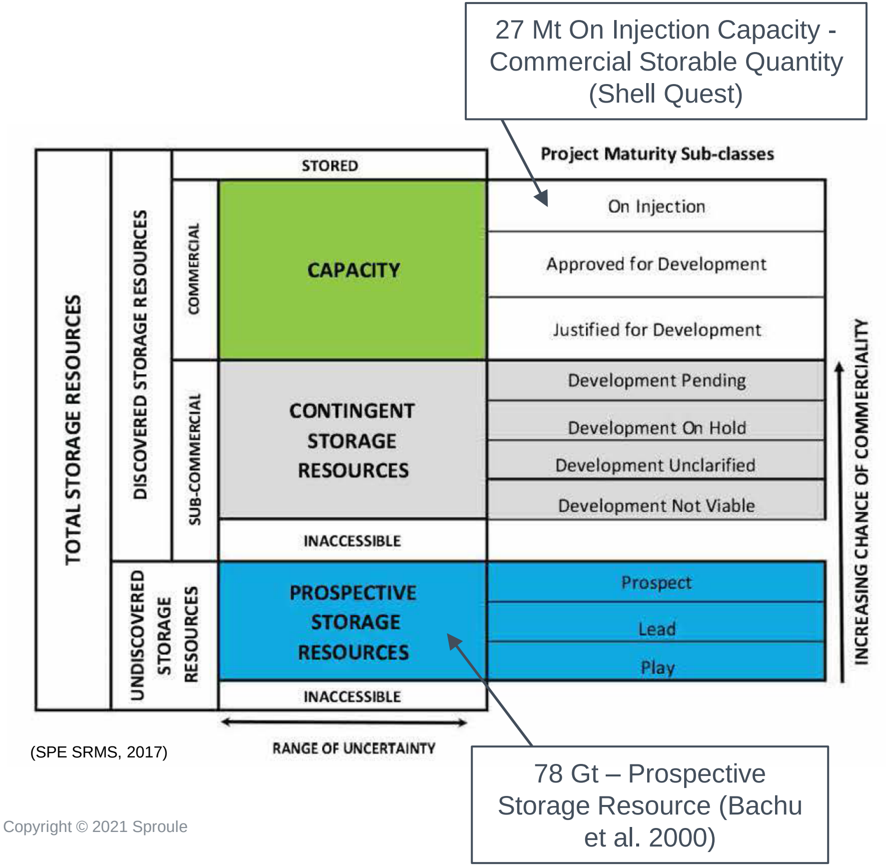
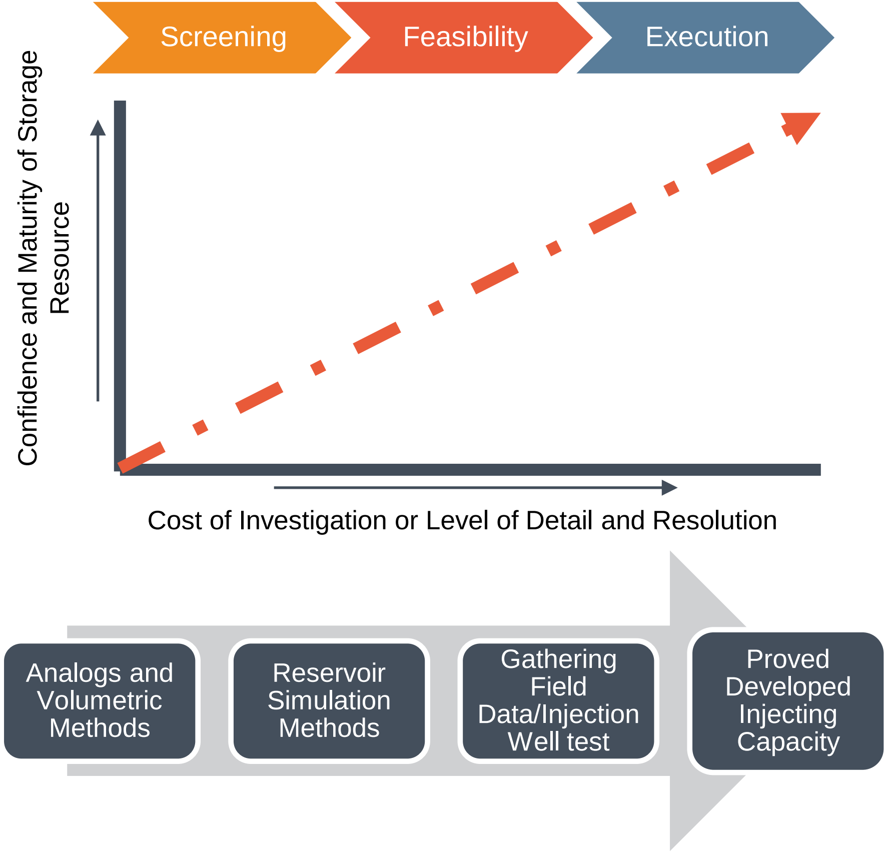
Storage Resource Classification



(SPE SRMS, 2017)

CO_2 Storage Resource Development



Maturation of Project - Case Study (Illinois, US)

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Scenario

- Basal sandstone (Mt. Simon Formation) and caprock, across crosses two countries and eight States, has been identified as a good CO_2 storage candidate
- No known hydrocarbons of commercial interest in the sandstone or deeper formations and very few wellbore penetrations

Maturation of Project

1. **Initial Scoping Study** – Assess storage potential of sandstone and all CO_2 emissions sources.
2. **Storage Potential and Site-screening** - Assess storage potential limited to suspected geological structural traps – applied analogous displacement process in same formation
3. **Enhanced Site-screening –** Performed more rigorous calculation of storage resource using geologic and displacement efficiency factors and Monte Carlo sampling
4. **Site Selection and Drill Well –** Complete geological and numerical modelling. Select site, drill and test evaluation well within 1 mile of source.
5. **Project Execution** – Received management and regulatory approval to capture and store 1,000 tonnes per day over three years (1.0 Mt)

	Study Year	Storage Quantity	Class	Category	Method	Comment (Illustrative Cost)
1	1995	800 Gt (3U)	Prospective	Play	Volumetric – Regional	$250,000
2	2000	6.0 Gt (2U)	Prospective	Prospect	Volumetric – Defined Structure and applied analogous displacement process	$1,000,000
3	2005	25 Mt (1U) 50 Mt (2U) 100Mt (3U)	Prospective	Prospect	Volumetric – Monte Carlo simulation providing high, mid, low	$1,000,000 (No Well)
4	2010	70 Mt (2C)	Contingent	Development Pending	Numerical Simulation, Well and Well Test	$10,000,000
5	2015	1.0 Mt (1P)	Capacity	On Injection	Injection performance	$50,000,000

Comments and costs are for illustrative purposes and not intended to be specific to this study. Modified from Frailey et al., 2018.

Defined period of operation and size of the facility for this project defines the storage estimate to be classified as Capacity

Final Thoughts

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- **SRMS provides a standardized framework** that can be used to classify and categorize CO_2 storage estimates based on project certainty and maturity
- Storage classification **depends on data availability, field development plans, commercial terms, professional expertise and judgement**
- **Use SRMS to advance and mature CO_2 storage projects** – helps consider all possible technical feasible projects to maximize storage
- **Greater project de-risking is required to mature prospective storage resource to capacity** – future stored quantities from commercially mature projects
- Project proponents and evaluators have a **methodology to normalize and effectively compare CO_2 storage project**
- **SRMS will evolve** as more experience is gained in how commercial project frameworks are developed

Deepen Client's understanding and advance CO_2 sequestration opportunities through our data-driven analysis and solutions.

Questions and Thanks

Contact

Sheldon McDonough
Managing Director, Energy Advisory

sheldon.mcdonough@sproule.com
+1 403 444 0286

Richard Hares
Principal, Carbon Management

richard.hares@sproule.com
+1 403 444 0288

Richard Holst
Manager, Reservoir Characterization

richard.holst@sproule.com
+1 403 294 5566

Corporate Headquarters
140 Fourth Avenue SW, Suite 900
Calgary, AB, Canada T2P 3N3

T +1 403 294 5500
TF +1 877 777 6135

Brazil
Rio de Janeiro, RJ, Brazil
T+55 212 014 5134

Mexico
Mexico City, Mexico
T +52 55 5979 0670

Netherlands
The Hague, Netherlands
T +31 70 833 0033

United States
Bakersfield
T +1 661 325 0038

Denver
T +1 303 227 0270