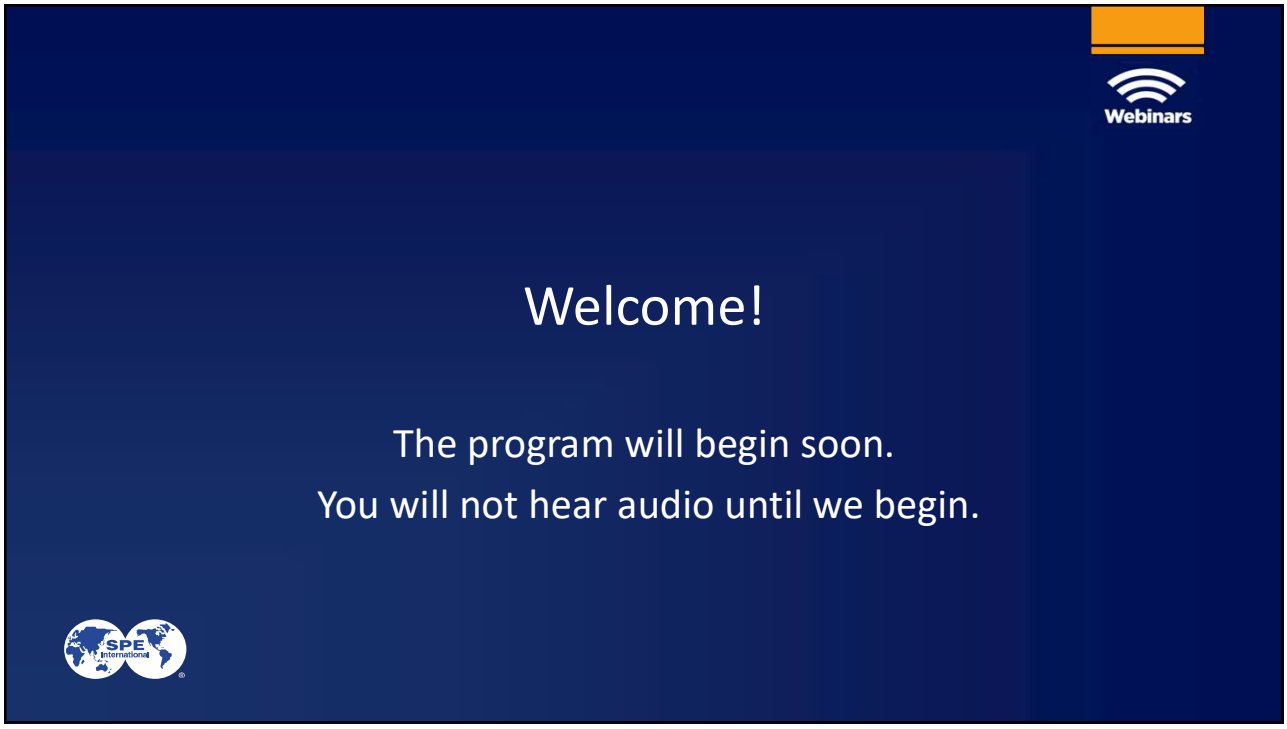
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My Storage is Bigger Than Your Storage: Use of SPE's CO_2 Storage Resources Management System

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September 7, 2023

SPE International

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- The slides presented here were developed by the presenter for this presentation and from previous presentations.
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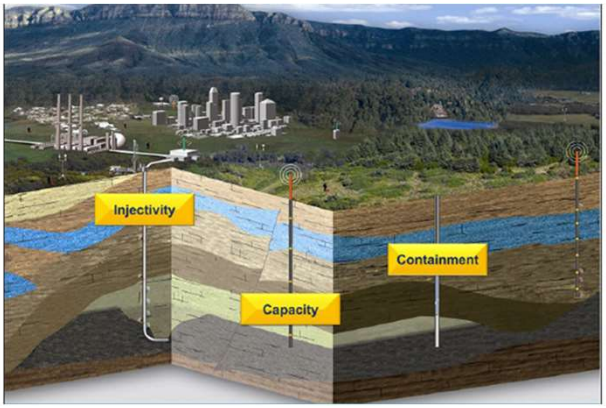
Storage Resources Management System (SRMS) Outline

- Background
- SRMS Structure:
  - Classification
  - Categorization
- Example Applications
- Summary



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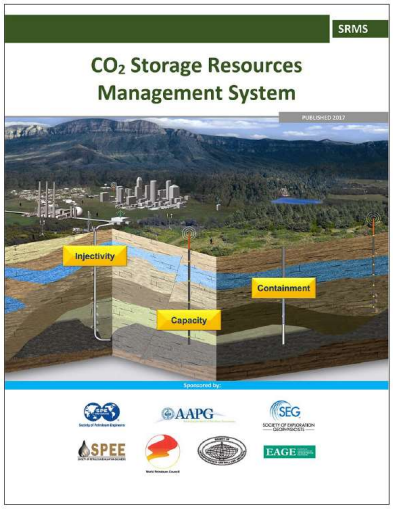
Background
SRMS: Purpose and Intended Users

- Intended users: financial, corporate, government organizations involved **commercial** CO_2 storage projects
- Purpose: to provide
  - **common terminology** and **clear definitions** needed to classify storable quantities in the context of defined projects intended to be matured to commerciality.
  - context for investment and performance tracking
- Applicable to
  - regional or basin resource assessments via a **notional** storage project
  - Brine aquifers (S_w = 100%) and depleted oil and gas reservoirs
  - ***Note**: 2024 SRMS expected to include CO_2 EOR.*



2017 SRMS

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Background: SRMS Development

- CO_2 Storage Resources Committee (CSRC) member selection
  - PRMS and/or CO_2 storage expertise
  - Represent seven professional societies
- Petroleum Resources Management System (PRMS)
  - Seed Document
  - Time tested and applied system
  - Supported by financiers, security exchanges, and governments (world)

- Fall 2017: SRMS Published by SPE
- Summer 2021: Sponsoring Societies
  - SPEE, AAPG, EAGE, SEG, SPWLA, WPC
- February 2022: First published commercial usage:
  - Santos booked, with external auditors:
    - 100 Mt of CO_2 Capacity, at 1.7 Mt/yr
    - 1.2-1.6 B$
- June 2022: SRMS-Guidelines published by SPE

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Storable Quantities

- Quantities of CO_2 (mass or standard volume) that can be stored as part of an estimated pore volume of a geologic formation that is accessible to CO_2 via a storage project sometime in the future
- Requires containment
- Directly related to project specifications

Definition in 2017 SRMS

- For a geologic formation to have storable quantities, it must have
  - pore volume accessible to CO_2 (quantity and sustained injection rate commensurate with the **project specifications**) and
  - containment (e.g., existing wellbore and caprock integrity) of the **Stored** CO_2 over a time period established by the **project specifications**

2022 SRMS Guidelines

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Project Specifications

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Commercial Projects

- Development plan with details to mature the project to active, commercial storage
- Standalone project
  - CO_2 storage as a business with expenses and income directly related to the storage of CO_2
- Integrated project
  - CO_2 storage is integrated into a project with other revenue generating product, e.g. an industrial plant to power generating plant
  - CO_2 storage part may be expense only or generate revenue and expenses

Notional Projects

- Development plan to scope resource to provide general understanding of the storable quantities
- Exclusively used for very immature projects
- Primarily defines the **area**, **geologic formation** (i.e. thickness), and **containment**
- May lead to
  - Region for site *screening*
  - Area for site *selection*
  - Location to drill characterization well
  - Identification of existing well to characterize

2022 SRMS Guidelines, Section 2.1.4.4

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SRMS Structure: Classification of Storable Quantities

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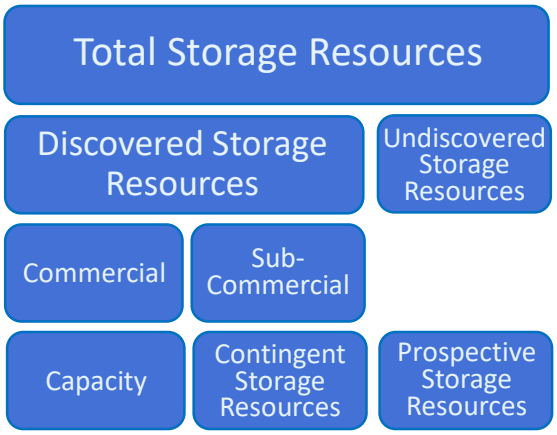
Based on Project Maturation

- **Discovered** (DSR) vs **Undiscovered** (USR)
  - storable quantities for which one or more wells established through testing, sampling, and/or logging the existence of storable quantities sufficient to meet project specifications.
- **Commercial** vs. **Sub-commercial DSR**
  - essential social, environmental, and economic conditions are met, including political, legal, regulatory, and contractual conditions.
  - degree of management commitment is such that storage project is expected to be developed and placed on injection within a reasonable timeframe.

Specific to Commercial or Notional Project



**Not shown, Inaccessible SR, which has no project.*
Total SR includes Inaccessible SR: Discovered and Undiscovered ISR

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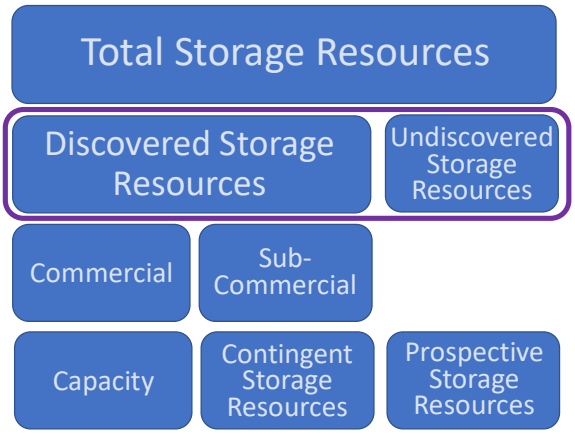
Discovery

- Refers to storable quantities for which at least one well has established through testing, sampling, and/or logging the existence of *significant* storable quantities.
  - *Storable quantities requires containment*
- "Significant" implies evidence of sufficient storable quantities to justify evaluation of commercial storage via a project's specifications

Definition in 2017 SRMS

Specific to a Defined or Notional Project



Excludes inaccessible storage resources (ISR)

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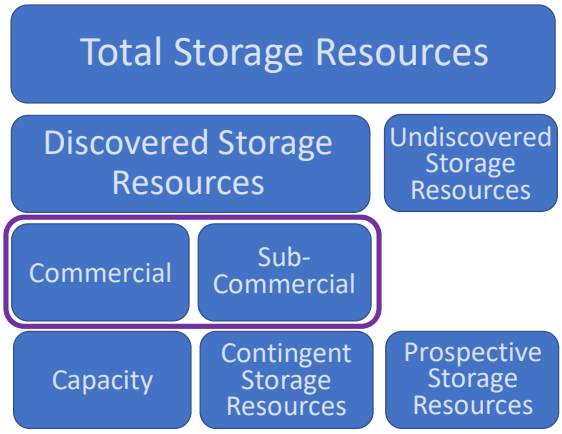
Commerciality

- Social, environmental, economic conditions are (or will be) met
- Political, legal, regulatory, contractual conditions are (or will be) met
- Commitment: project expected to be developed and placed on injection within a reasonable timeframe.
  - five years recommended, but longer timeframe could be used
    - for example, development of project deferred at the option of the operator for, among other things, market-related reasons, or to meet contractual or strategic objectives.

Definition in 2017 SRMS

Specific to Commercial or Notional Project



Excludes inaccessible storage resources (ISR)

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Classification: **Prospective** Storage Resources (*Undiscovered* Storage Resources)

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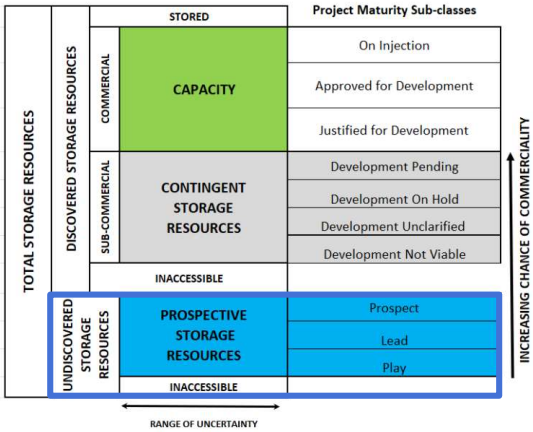
Well does not exist or not assessed

Increasing Chance of Commerciality

- Play: project associated with a prospective trend of potential prospects that requires more data acquisition and/or evaluation to define specific leads or prospects.
- Lead: 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: project associated w/ undiscovered storable quantities sufficiently defined to represent a viable drilling target or identification and evaluation of existing well
- PSR maturation process "ends" with a drilling prospect or existing well identified to assess



Revised figure 2.1 in errata of 2017 SRMS

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Classification: **Contingent** Storage Resources (*Discovered, Sub-Commercial* Storage Resources)

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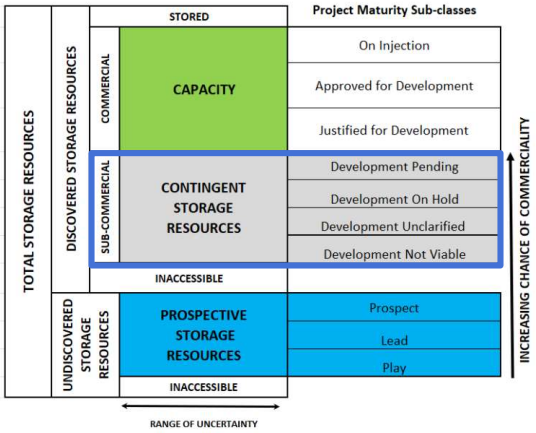
Increasing Chance of Commerciality

Well exists and assessed or being assessed

- Development Not Viable: Discovered storable quantities for which there are no current plans to develop or to acquire additional data at the time of assessment as a result of limited storage.
- Development Unclarified: Discovered storable quantities where **project** activities are under evaluation and where justification as a commercial development is unknown on the basis of available information.
- Development On Hold: Discovered storable quantities where **project** activities are on hold and/or where justification as a commercial development may be subject to significant delay
- Development Pending: Discovered storable quantities where **project** activities are ongoing to justify commercial development in the foreseeable future.
- CSR maturation process "ends" with commercial proposal to management



Classification: **Capacity**

(*Discovered*, *Commercial* Storage Resources)

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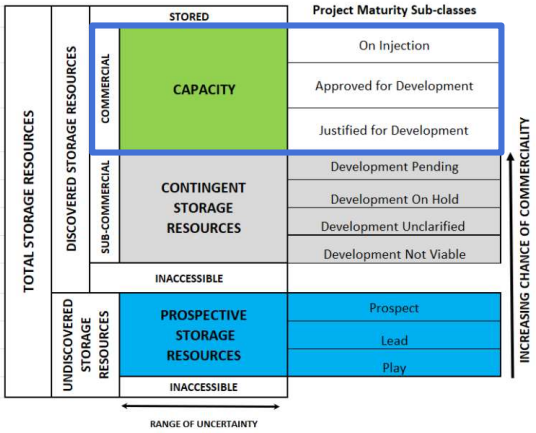
Increasing Chance of Commerciality

No Contingencies Exist

- Justified for Development:
  Implementation of the development project justified on basis of reasonable forecast commercial conditions at time of reporting and ***reasonable expectations*** that **all** necessary approvals/contracts will be obtained.
- Approved for Development:
  All necessary approvals have been ***obtained***, capital funds have been committed, and implementation of the development project is underway.
- On Injection: development project is currently injecting and storing CO_2.



Classes: Decision Gates for Maturing a Project

- **PSR**: A well has NOT been characterized for storable quantities
- **PSR** to **CSR**: At least one well is being actively characterized for storable quantities in the context of a project's specifications
- **CSR** to **Capacity**:
  - No technical or commercial contingencies exist
  - Management committed to actively storing CO_2 with the current development plan and project specifications
  - Project is forecasted to be commercial
  - Approvals and permissions forecasted to be obtained
  - Financing forecasted to be obtained

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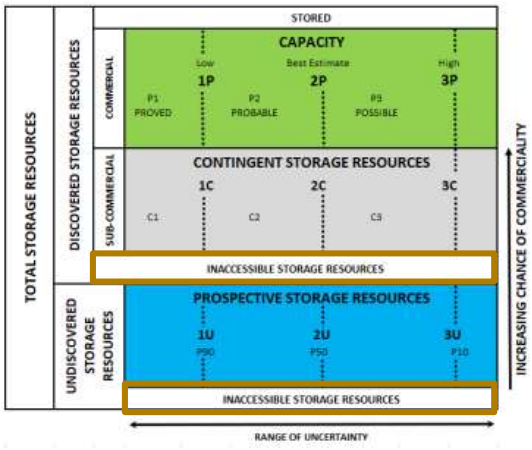
Classification: Inaccessible Storage Resources

- Storable quantities classified as Discovered or Undiscovered Storage Resources, which are estimated as of a given date, not to be developed for storage.
- These quantities may be developed for storage in the future if circumstances change.
- For example, current regulatory restrictions may prohibit storage at the time of the assessment and foreseeable future.



Definition in errata of 2017 SRMS

Revised figure 1.1 in errata of 2017 SRMS

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Process of Classifying Resources

- Is subjective and may vary from assessor to assessor, company to company
- Does not require starting with PSR-Play
  - Especially if an emissions site looking for storage site in an area or region with publicly available storage assessments; would likely start with PSR-Prospect
  - Examples available storage assessments: DOE RCSP and CarbonSAFE Phase I projects)
- May not require every class or subclass to be used
  - Will be dependent on the stakeholders involved. For example:
    - Financiers may require more detailed timeline of the project maturation using every subclass to track their investment
    - Private companies may focus only on Capacity or Proved Capacity as company assets

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SRMS Structure: Categorization of Storable Quantities

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Categories

- **Low** estimate
  - High probability
  - P_{90}
- **Best** estimate
  - Most-likely (median)
  - P_{50}
- **High** (low probability) estimate
  - Low probability
  - P_{10}

Categorization: *(2017 SRMS, p 12, sect 2.2)*

- Indicative of certainty in storable quantities
- Includes technical and commercial uncertainty
- Based on project's specifications, but **NOT** the project's maturity

Project Maturity ←

Geologic Certainty ↑

Category	Probability	Capacity	Contingent	Prospective
Low Estimate	P_{90}	1P	1C	1U
Best Estimate	P_{50}	2P	2C	2U
High Estimate	P_{10}	3P	3C	3U

Capacity, Low Estimate: ***highest*** *geologic certainty and* ***highest*** *project maturity*
Prospective SR, High Estimate: ***lowest*** *geologic certainty and* ***lowest*** *project maturity*

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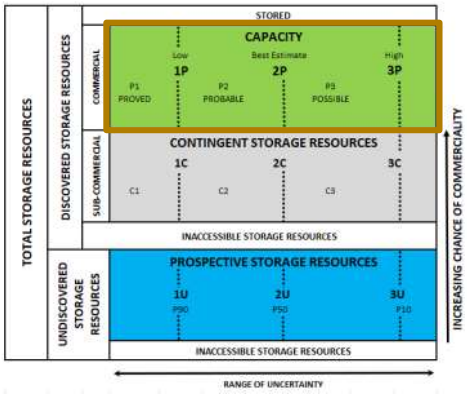
Categorization: Certainty in Storable Quantities

Capacity Categories <u>not</u> directly affected by project maturity.



Ex: P1 + P2 + P3 = 3P

- <u>Proved (P1)</u>: **Proved Capacity** (P_{90}) quantity of storage that, by analysis of geoscience and engineering data, can be estimated with <u>reasonable certainty</u> to be <u>commercially</u> used for storage, from a given date forward, from known geologic formations and under defined economic conditions, operating methods, and government regulations.
- <u>Probable (P2)</u>: **Probable Capacity** (P_{50}) additional Capacity that analysis of geoscience and engineering data indicate are less likely to be used for storage than Proved Capacity, but more certain to be used for storage than Possible Capacity
- <u>Possible (P3)</u>: **Possible Capacity** (P_{10}) additional Capacity that analysis of geoscience and engineering data suggest are less likely to be stored than Probable Capacity.

***Note**: All Capacity <u>categories</u> are subordinate to **<u>all</u>** Capacity <u>class</u> requirements.*

***Examples**: Management commitment exists; permit allows development; capital committed*

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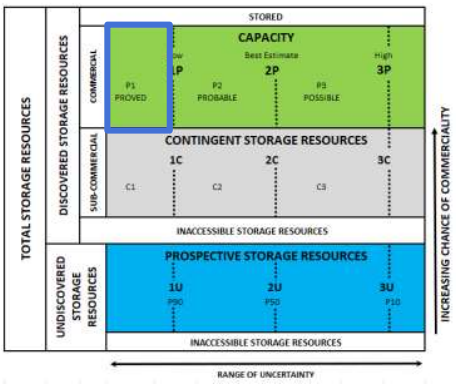
Proved Capacity's Operational Status

- Proved, Developed, Injecting: Developed Injecting Capacity is expected to be stored from completion intervals that are open and injecting at the time of the estimate.
- Proved, Developed, Non-injecting: Developed Non-injecting Capacity includes shut-in and behind-pipe Capacity.
- Proved, Undeveloped: Undeveloped Capacity is the quantity expected to be stored through future investments.



*Note: All Status are subordinate to **all** Capacity requirements.*
Examples: Management commitment exists; permit allows development; capital committed

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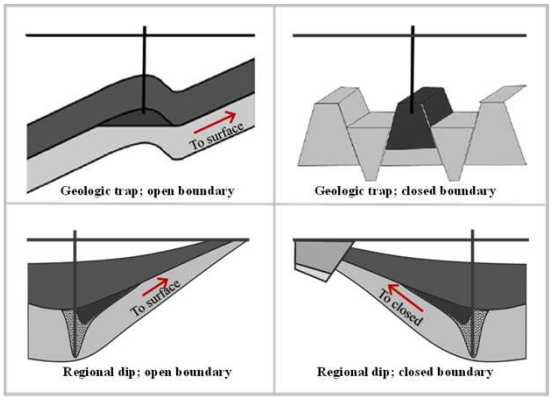
Estimating Storable Quantities

- Deterministic and Probabilistic approaches
  - Volumetric Methods (including analogs)
  - Material Balance
  - Reservoir simulation
  - Injection Performance Analysis
- Estimate ranges or distributions recommended
- Single value approach:
  - *best* or *most likely* estimate



2022 SRMS Guidelines, fig 4-1

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Storable Quantities: Containment

- Containment
  - Geologic containment
  - Wellbore containment
- Storable quantities coincide with containment and management of all displaced fluids
  - Must be defined and described in the project specifications
  - Include all geologic formations in which CO_2 is stored and brine displaced
- Containment uncertainty reflected in storable quantities uncertainty
- Containment assessment area is area of projected CO_2 plume and pressure footprint *and* the displaced in situ fluids
- Progression of containment assessment should be consistent with maturity of project and financial commitment associated with project's development plan

2022 SRMS Guidelines, sections 2.2.4 and 4.2

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SRMS Applications Examples

PROJECT MATURATION: FROM REGIONAL STUDY TO ACTIVE INJECTION

Assumptions Common to the Examples

- Thick, pervasive, basal sandstone (single geologic formation)
- Containment:
  - Wellbore: Few wellbore penetrations (No known minerals)
  - Geologic: Extensive, thick, clay-rich shale caprock with minimal faulting
- Depth
  - Maximum: cementation lower porosity and permeability
  - Minimum: liquid-like CO_2 density; fresh water

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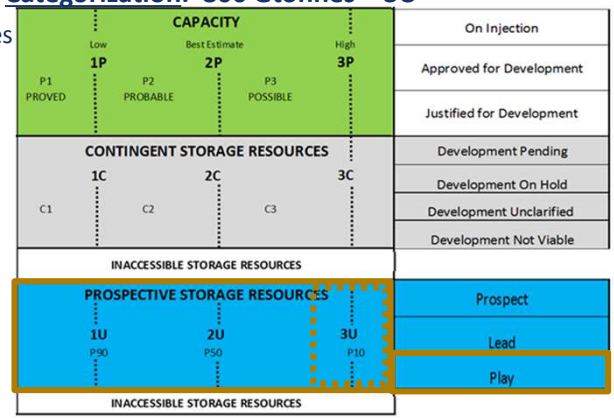
Regional Assessment: Notional Project

- Purpose: general storage assessment
- Notional project:
  - Total regional emissions from stationary sources
  - Fully developed infrastructure
- Volumetric approach
  - Pore volume with storage efficiency
  - Single value (deterministic)
- Boundaries:
  - Perimeter: State lines
- Outcome:
  - General geographical area for a site
  - Estimate: 800 Gtonnes (high estimate)

Classification: Prospective Storage Resources–Play
Categorization: 800 Gtonnes – 3U



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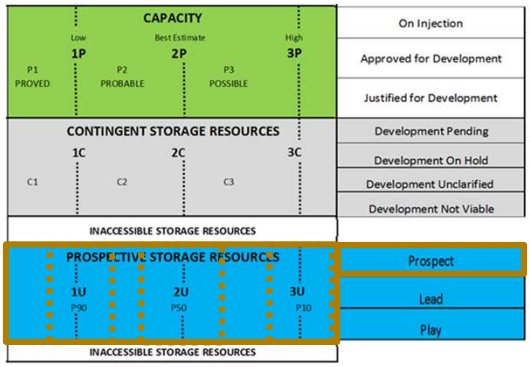
Regional Assessment: Notional Project Use of New Data and New Analysis

- Objective: general storage assessment, site screening
- Volumetric, GIS approach
  - Efficiency: displacement, and geologic attributes
  - High, medium, low values (E= 1, 2, 4%)
- Boundaries:
  - Perimeter: State Lines
- Outcome:
  - General geographical area for a site
  - Storing on regional dip
  - Estimate: 25, 50, 100 Gtonnes

Classification: Prospective Storage Resources – Prospect
Categorization: 25 Gt – 1U; 50 Gt – 2U; 100 Gt – 3U



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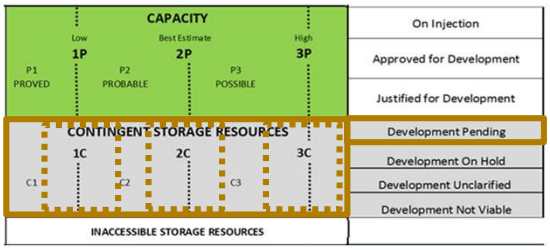
Site Selected, Well Drilled, Well Assessed, Awaiting Management Commitment

- Purpose: assess storage site single well injection and CO_2 emitted
- Storage Project Status (at time of assessment)
  - Site CO_2 emissions: 3,000 tpd
  - Capture facility (planned): 1,000 tpd,
  - Management commitment NOT finalized 25 yr life
- Deterministic-scenario approach *(2017 SRMS, p 13, sect 2.2.2)*
- Simulation: 8,000 tpd, well's max injection rate
- Boundaries: Storage rights and real estate ownership



Project	Class	Subclass	Comment	Stor Quantity	Category	Comment
Facility	**Contingent SR**	Development Pending	No Management commitment	9 Mt (1,000 tpd)	**1C**	Small facility
Site	**Contingent SR**	Development Pending	No Management commitment	30 Mt (3,000 tpd)	**2C**	Total site emissions
Well	**Contingent SR**	Development Pending	No management commitment	70 Mt (8,000 tpd)	**3C**	High estimate based on well

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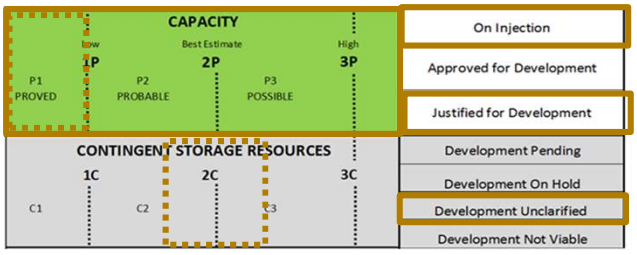
Active Injection: Defined, Management Approved Project

- Purpose: Assess active project(s)
- Final Project
  - Infrastructure purchased: 1,000 tpd
  - Management commitment: 12 years
  - Permits and contracts issued/completed
- Planned Project Expansion
  - Management commitment: 1,000 tpd (incremental)
  - Reasonable expectation of permit



Project	Class	Subclass	Comment	Stor Quanty	Category	Comment
Final	**Capacity**	On Injection	Management commitment	4 Mt	**Proved Developed Injecting, 1P**	Active injection, equip. available
Planned	**Capacity**	Justified for Development	Management commitment; Permit expected	8 Mt	**Proved Undeveloped, 1P**	Permit required
Site	**Contingent SR**	Development Unclarified	No management commitment	58 Mt	**2C**	Best estimate

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Summary of SRMS Applications Examples

- Classification: certainty in project
- Categorization: certainty in storable quantities
- SRMS intended use is in the context of storage project specifications
  - Active project specifications directly influences storable quantities
  - Notional project specifications acceptable for large scale resource assessments
- Storable quantities requires containment
- Prospective Storage Resources
  - no well available for assessment
- Contingent Storage Resources
  - well assessed or being assessed, and expected to meet project goals, but contingencies exist
- Capacity
  - solely for commercial/ economic projects
  - Reasonable expectation (minimum) that all permits/contracts obtained
  - Essential social and environmental project conditions met
- Classification and Categorization of storable quantities are subjective

Summary
SRMS Usage: Expected Outcomes

- Provides guidelines for developing commercial storage projects
- Gives standardized terminology and definitions in commercial contracts similar to other subsurface commodity industries
- Assessors and stakeholders have a management system to make comparisons between projects
- System that relates project certainty and geologic certainty to storable quantities estimate

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- Recommended by US Department of Energy

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