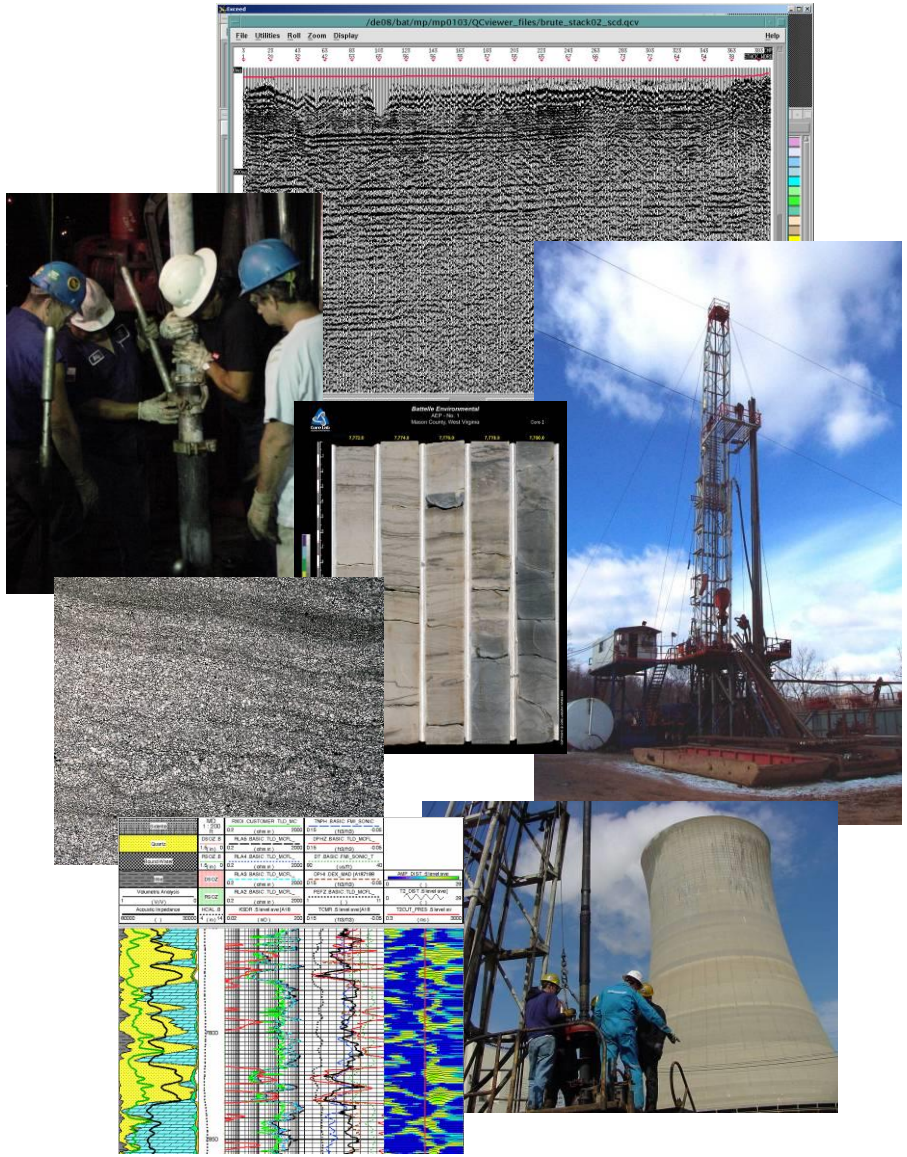
An Example Case Study of CO_2 Storage Site Development in the MRCI

MRCI

October 2023

Steps to Implementing CO_2 Storage Projects

- Key steps to developing a CCS project in the MRCI:
  - Site feasibility study,
  - Front End Engineering and Design,
  - Test well drilling & characterization,
  - Acquisition of land/pore space assets,
  - Capture system construction,
  - Pipeline construction,
  - Permitting,
  - Injection system construction,
  - Baseline monitoring.
  - System operations and routine monitoring.
  - Post-injection site closure/well plugging & abandonment.



Steps to Implementing CO_2 Storage Projects

- 2-4 year timeline for CCS system development
- Financing & economics are important factors for CCS
- Initial capital costs can be offset by 45Q tax credits during operations

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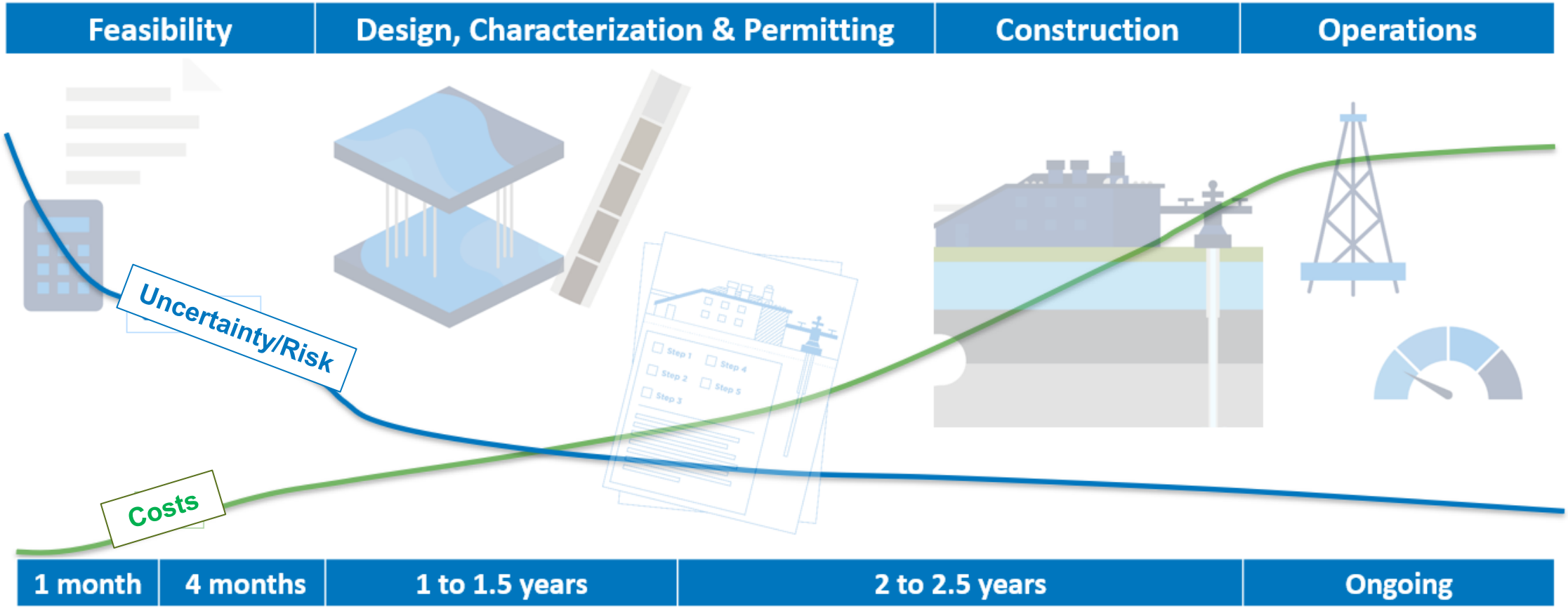
Steps to Implementing CO_2 Storage Projects

- Higher risk in early activities related to geologic uncertainty.



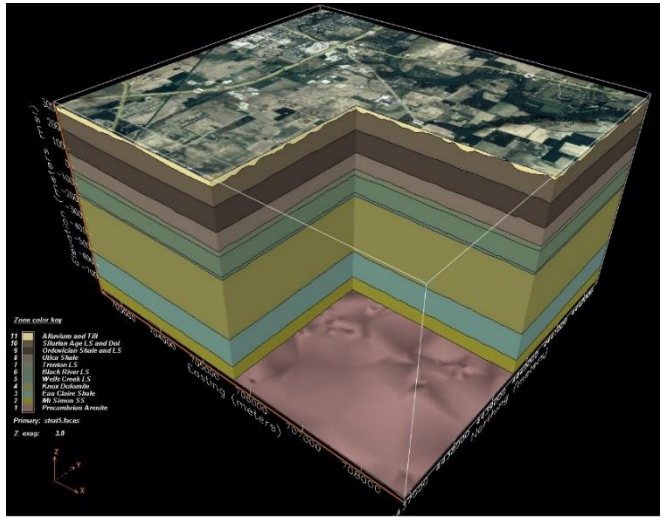
Example CO_2 Storage Case Study for MRCI

Generic Ethanol Plant

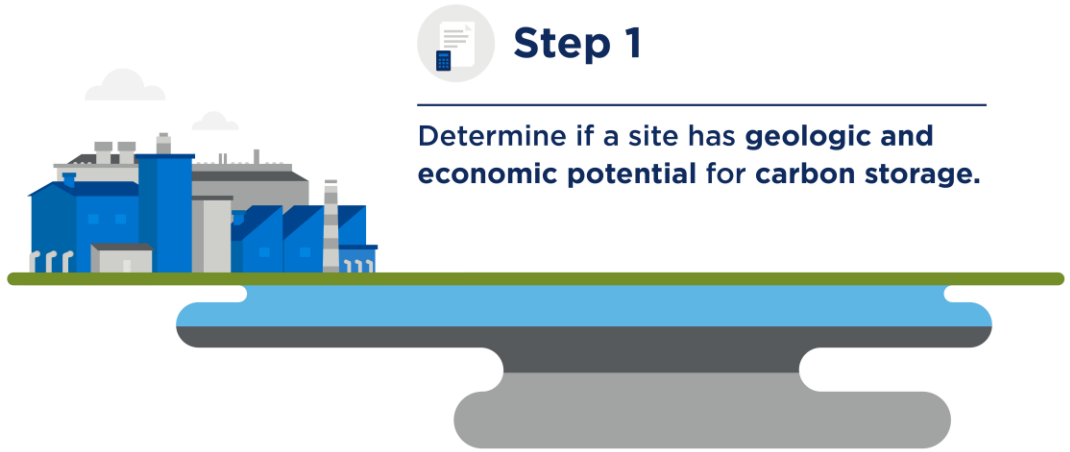
- 200,000 metric ton/yr CO_2
- 4 million metric tons over 20 years
- ~$17M/yr 45Q (~$100M-150M total)
- Farmland and industry land use
- Plant owner working with developer for CCS financing, design, construction

Example CO_2 Storage Site Case Study

- Sedimentary basin with few deep wells nearby, only regional data avail.
- Basal Sandstone storage zone
- Agricultural area with large farms and landowners



Feasibility Study



RISK

Scope

- High level analysis of a plant location
- Local geologic interpretation
- Social factors and permitting assessment
- All work is completed with readily available public data

Battelle Advantage

Highly experienced team with extensive history of study throughout different US regions

Deliverable: Professional recommendation to move forward or stop pursuit, including some indications of challenges to be faced in Step 2.

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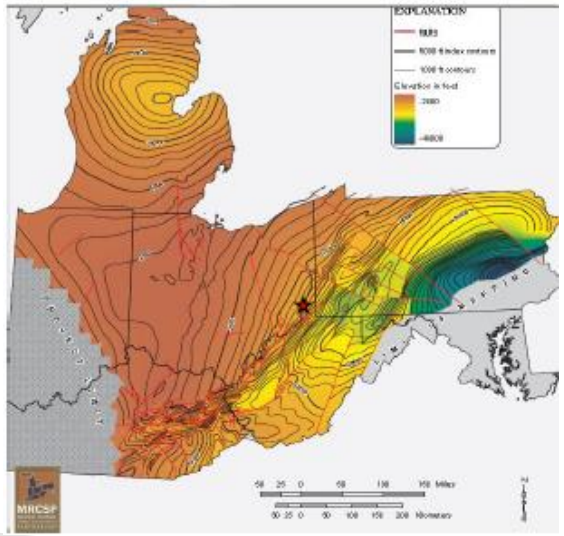
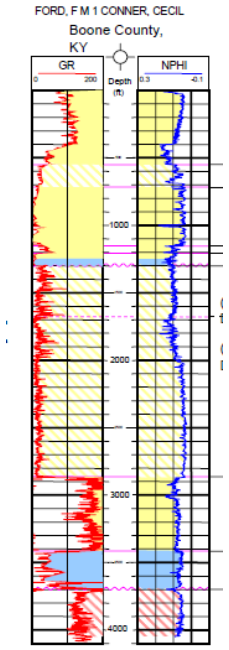
Feasibility Study

Identify any “show-stoppers”, evaluate reservoir, injection, confinement

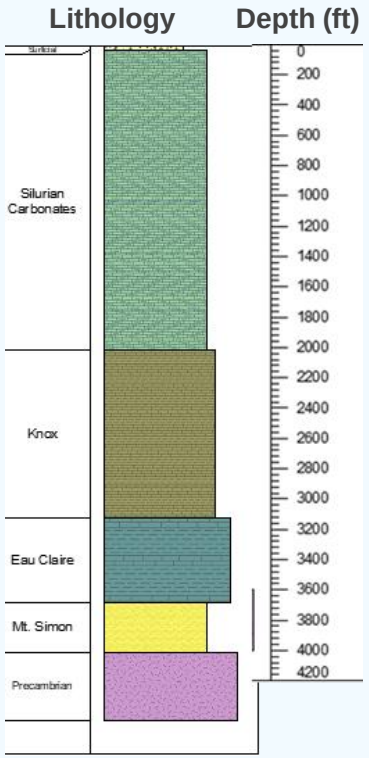
- Regional geological maps
- Regional Well logs, rock core test data
- Estimated downhole hydrologic conditions





Case Study

- Regional data shows basal sandstone ~3,700-4,050 ft deep
- Multiple shale and carbonate caprocks ~2,000-3,700 ft
- No geological structures nearby, no history of seismic activity
- No nearby CO_2 sources
- Agricultural land use, no wetlands, no deep drinking water aquifers



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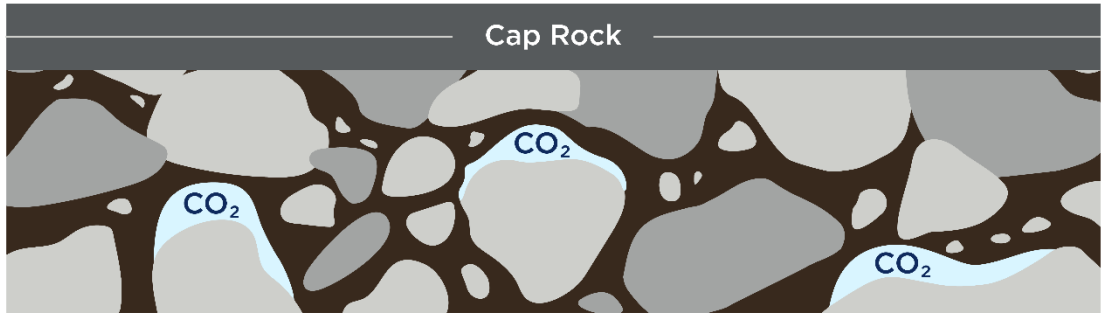
Modeling

Step 2

Perform a detailed **geologic assessment** and begin the **permitting plan** using existing data.



RISK

Scope

- Detailed geologic assessment
- Geologic and reservoir model development
- Well design and costs
- Data collection plan
- Permitting plan and contact with US EPA
- Existing data used, some purchased

Battelle Advantage

Proprietary, accelerated data analysis workflows that increase confidence and agility in model generation

Deliverable: Site identification, detailed characterization well plan, and informed no/no-go decision

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Pore Space/Financing/Liability

- Pore space
  - Pore space defined by area of review
  - May involve leasing 2-15 sq. mile area at $/acre
- Financing options

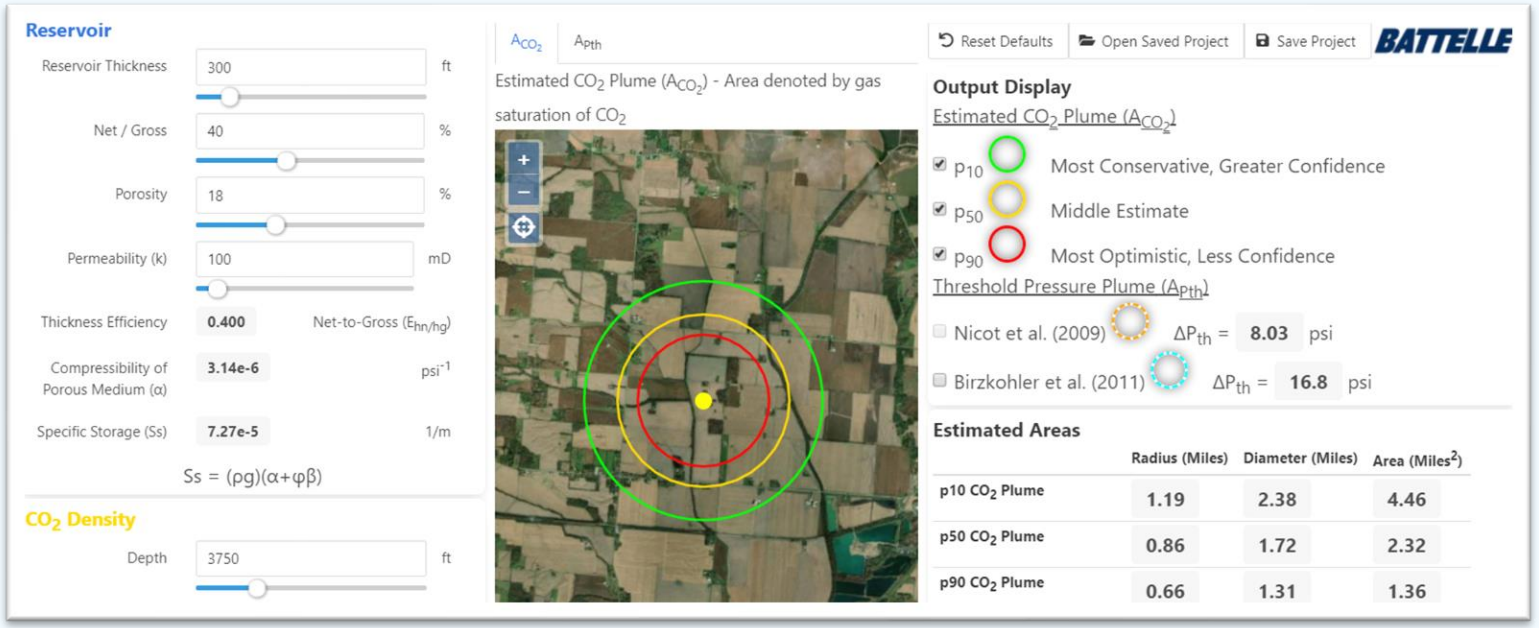
  1. Plant self-financing and own the capture/storage site

  2. Developer financing with plant override on the project

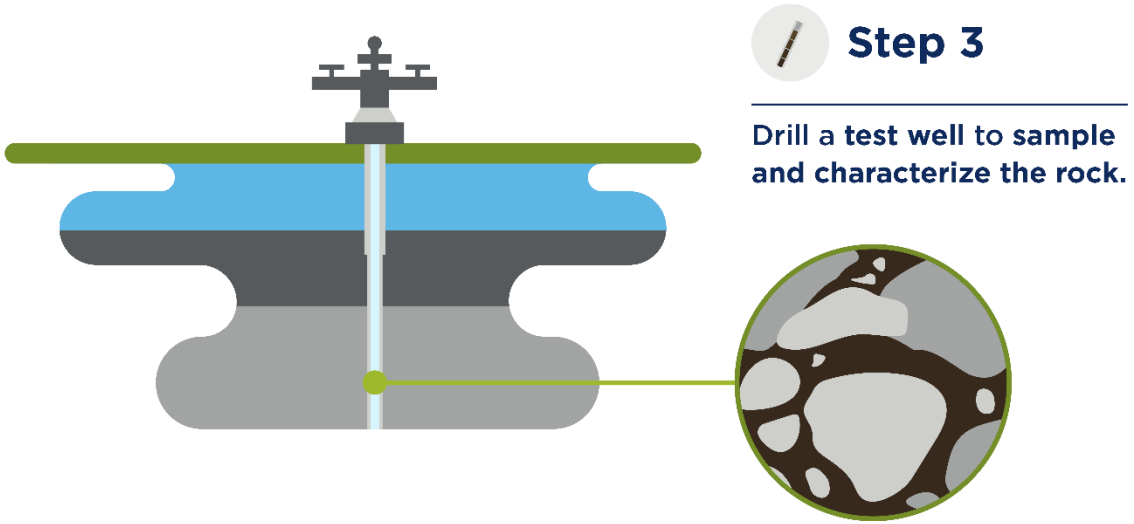
  3. Combination of 1 & 2
- Liability
  - Fit-for-purpose insurance products, ‘Operators Extra Expense’ insurance for drilling, Class VI UIC financial responsibility bond
  - Insurance market for CO_2 storage is evolving

Case Study

- Preliminary analysis suggests 2.3 square mile area of review for 4 Mt total storage volume (200,000 mt/yr X 20 years)
- ~1500 acres for pore space, plan out $50/acre = $75,000/yr



Characterization and Permitting



RISK

Scope

- Drilling of a characterization well, built to regulatory specs
- Seismic data collection if required
- Data analysis and reporting
- Initial permit filing
- Detailed modeling and injectivity estimations
- Capture system scoping
- Construction Plan

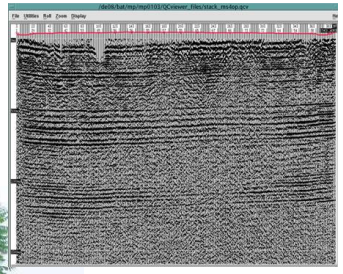
Battelle Advantage

In-house well construction and data collection expertise and extensive network for field work in several locales

Deliverable: Recommendations for a Final Investment Decision

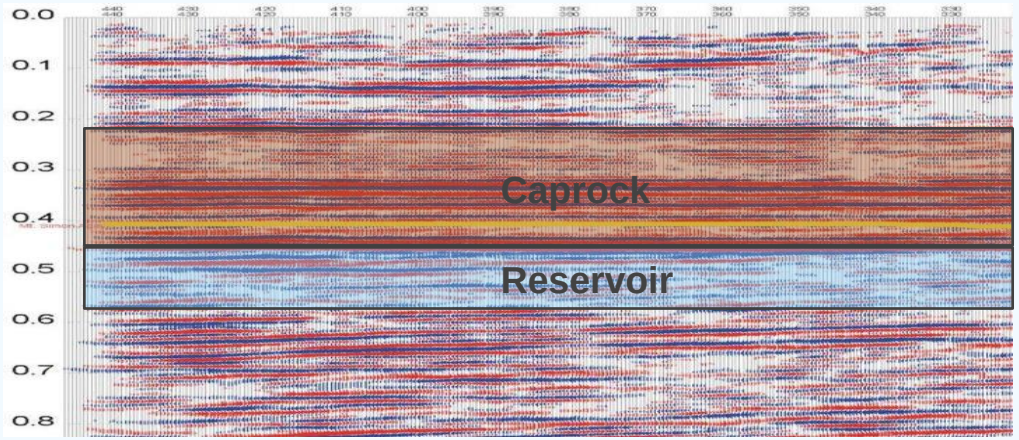
Site Characterization and Testing

- Seismic Survey through site (if necessary)
- Highly visible for local community



Case Study

- 6 mile 2-D seismic survey through CO_2 storage site shows fairly flat, continuous reservoir and caprocks
- No significant faults, fractures in reservoir, caprock, basement. Difficult to discern reservoir quality



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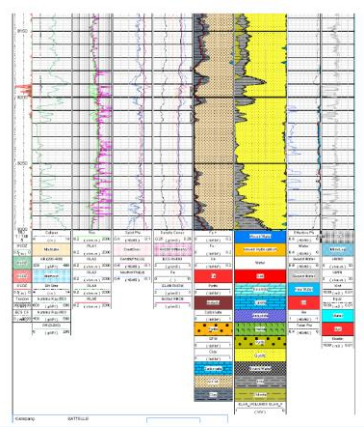
Site Characterization and Testing

- Drill test well
  - 2-3 acre well pad site prep and mobilization of drill rig
  - 2-6 weeks drilling depending on total depth
  - 24/7 drilling during
- Rock core sampling/tests
  - full core or sidewall coring or both in selected reservoir and caprock zones
- Wireline logging
  - geophysical logging runs to delineate rock properties
- Reservoir injection tests
  - brine injection tests to confirm sustainable injection rates, pressures

Case Study

- Drilling test well shows basal sandstone 3755-4019 ft (264 ft thick...less than expected)
- Main porosity, permeability zone in middle SS.
- Shale stringers in upper zones. Low permeability caprocks >1000 ft total thickness.
- Injection test at 3 BBL/min at 600 psi (~540 metric tons CO_2/day equivalent or 197,000 metric tons per year.)

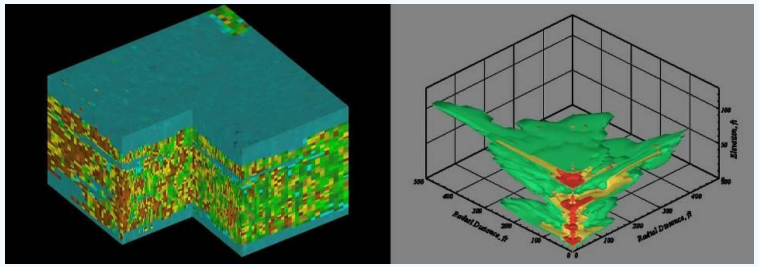


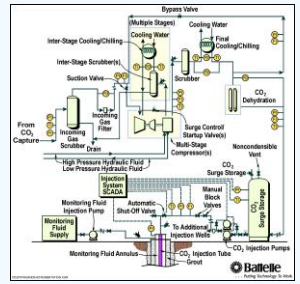
System Design

- Design of surface injection system, pipeline, surge tanks, SCADA system, compression, etc.
- Injection well design
- Reservoir modeling
- UIC Permitting

Case Study

- Static earth model suggests best reservoir zone in middle basal sand.
- Reservoir simulations show area of review of 2.8 square miles or 1800 acres. Long-term pressure buildup possible, 2 injection wells recommended.
- Multi-stage compression, glycol dehydration for 1,100 psi design specified to reach supercritical CO_2 conditions.
- 7-mile pipeline to injection site.
- Submit Class VI permit for EPA review.





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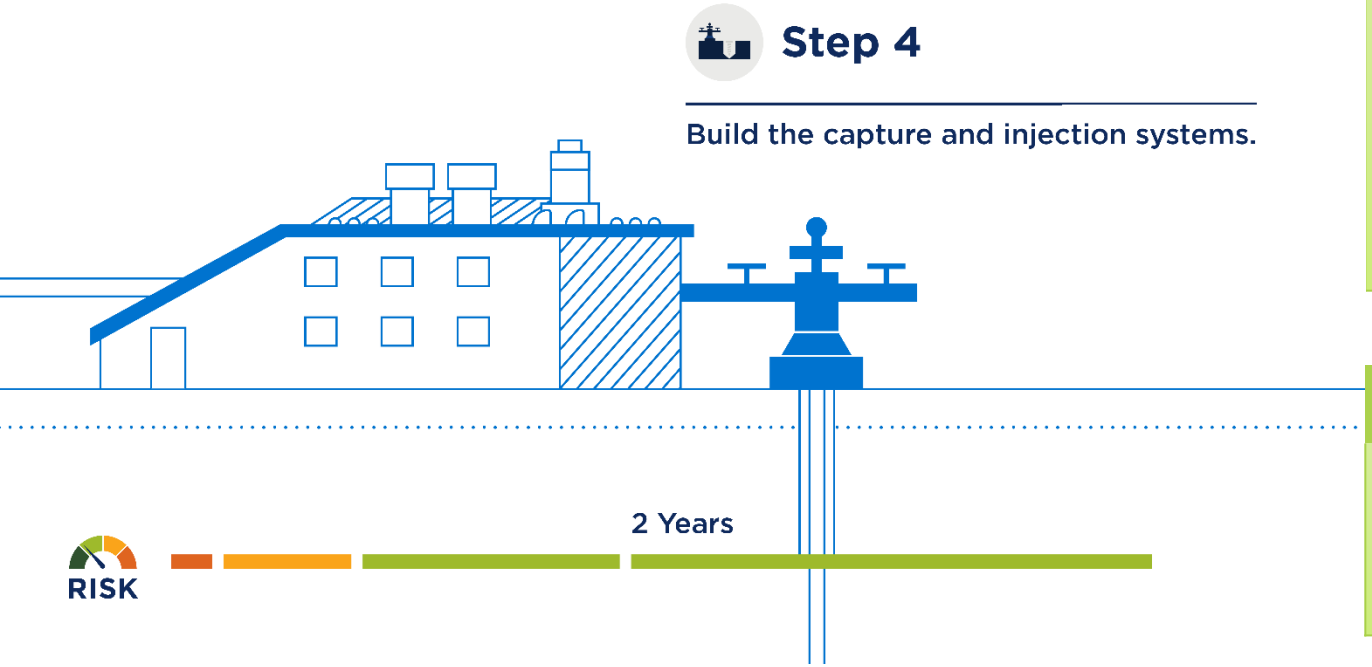
Construction



Scope

- Complete injection system construction
- Complete capture system construction
- Complete necessary pipeline installation
- Permit application and shepherding
- Management of Battelle staff, subcontractors and partners

Battelle Advantage

Multidisciplinary Project Management experience, and historical relationships with regulatory bodies

Deliverable: Permitted, functional and operational CO_2 injection well with capture, compression, monitoring and regulation tools in place.

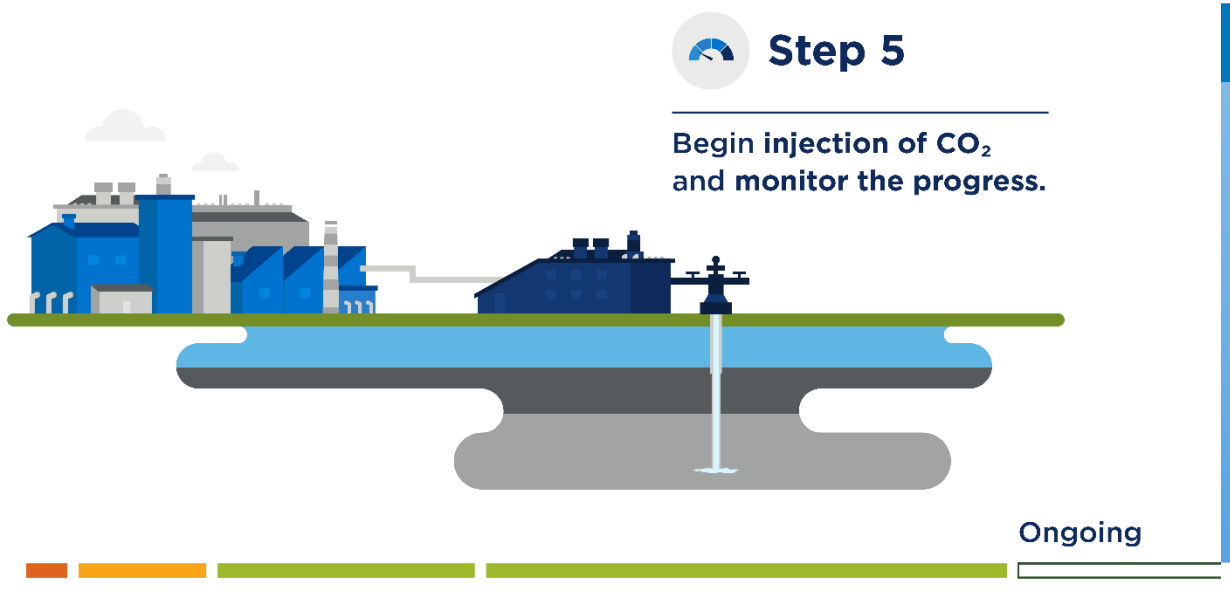
Injection System Construction

- Drill additional Injection well(s)
  - Pending USEPA UIC Class VI “permit to construct,” drill additional injection wells
  - Well completion (tubing, packer, interannulus fluid, SCADA system, etc.)
- Pipeline metering and construction
  - local distribution system at minimum (<20 km)
  - larger effort for “trunkline” system (>20 km)
- Surface Injection system construction
  - booster pumps, metering, safety, support buildings

Case Study

- UIC Class VI ‘permit to construct’ passed.
- Drill 2nd injection well, which has better reservoir thickness, quality.
- Compression/dehydration capital/operating costs higher than expected.
- Local pipeline to injection site requires additional land acquisition.

Operation and Monitoring



Scope

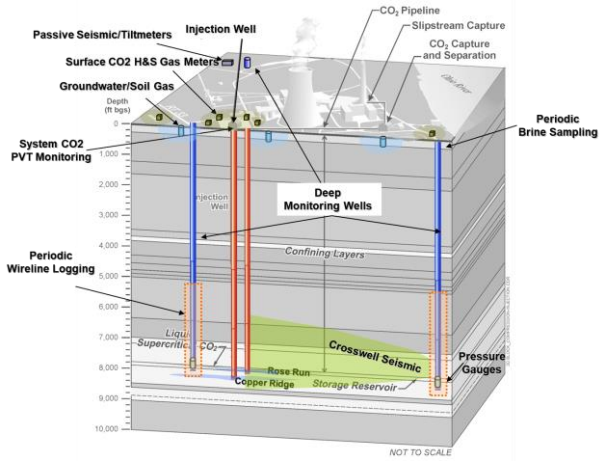
- Full execution of plant operations
- Ongoing reporting for Class VI
- Life cycle analysis
- Monitoring and accounting
- Credit validation
- Planning and execution of monitoring and site closure plans
- Battelle can manage, or transfer locally

Deliverable: Annual reporting as required by US EPA and IRS

Monitoring, Mitigation, and Verification (MMV)

- Prepare MMV plan
- Baseline testing and sampling
- Continuous system safety monitoring
- Periodic MMV of injected CO_2
- Associated UIC well workovers, monitoring and reporting

Time (Months)	-12	-10	-8	-6	-4	-2	0	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36
Phase	Preinjection Baseline Monitoring						Active Injection																Post-injection		
Capture System																									
Compression																									
Transport																									
Injection System																									
SCADA																									
Health and Safety																									
Mechanical Integrity Test						X							X						X						X
Well Workover													X						X						X
Passive Seismic																									
Groundwater Monitoring	X			X			X			X			X			X			X			X			X
Soil-gas	X			X			X			X			X			X			X			X			X
Atmospheric Flux				X			X						X						X						X
Wireline						X				X			X			X			X			X			X
VSP/X-well Sesimic						X							X						X						X
Tracer Testing																									
Reservoir Sampling						X							X						X						X
Well Indicator sensors																									



Case Study

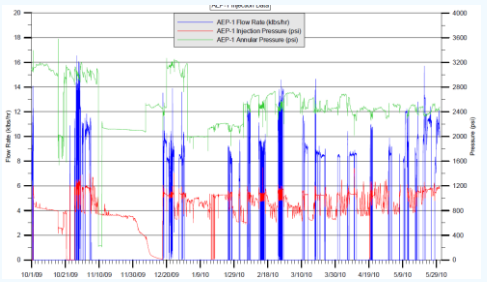
- Monitoring plan uses 2nd well for verification well during early stages of injection.
- Reservoir pressure and temperature key parameters for monitoring.
- Cost-benefit approach utilized to streamline monitoring program, prioritizing most useful monitoring methods.
- Class VI permit approved, “permit to inject.”

Injection O&M

- Active CO_2 injection
- System/injection-well operation and maintenance (O&M)
- Pipeline O&M
- Associated MMV

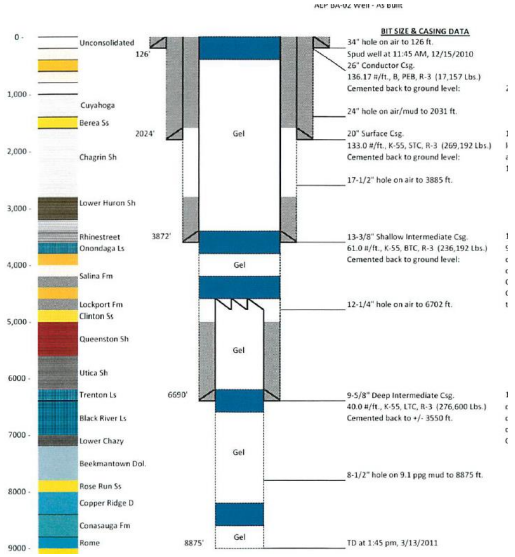
Case Study

- Pressure buildup in primary injection well requires injection in 2nd well after 9 months operation. 2nd well has better injectivity.
- Reservoir injection pressures remain several hundred psi below safety limits.
- CO_2 spreads less than models suggested.
- Some corrosion of wellhead materials requires workovers every 2-3 years.



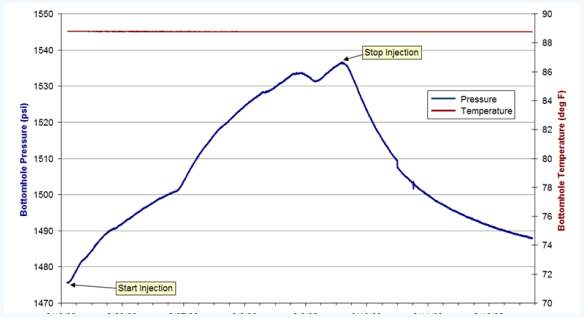
Post Injection Site Closure

- Post-injection site closure- monitor pressure, CO_2 plume to demonstrate safety, containment, stabilization
- Plug & abandon wells



Case Study

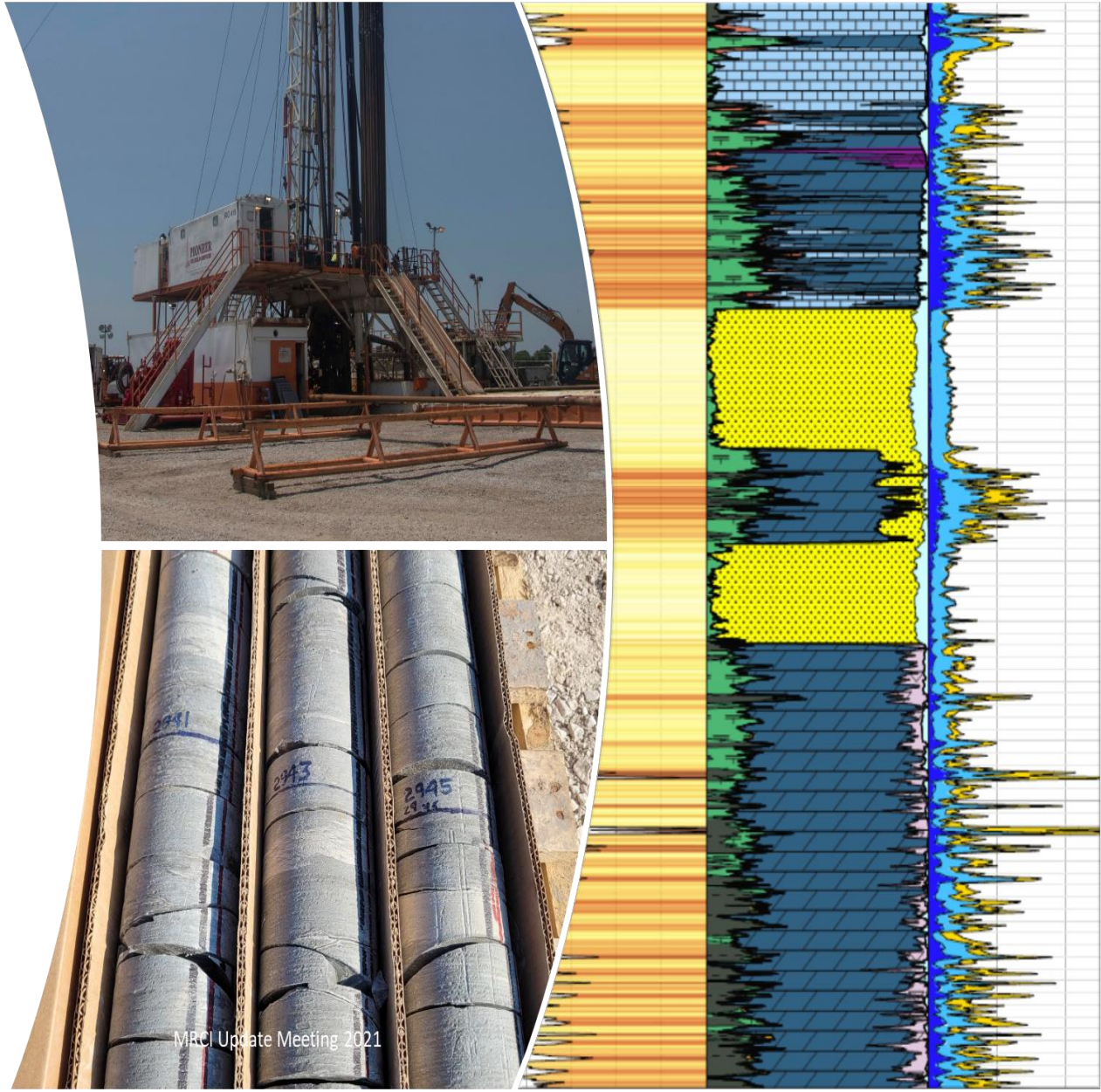
- Monitor pressure fall off after injection stops, monitor any CO_2 migration
- Reservoir pressures return to within 10% baseline in 7-8 years
- Plug and abandon 2 injection wells
- Apply for early site closeout of Class VI permit
- Restore surface site



MRCI Midwest Regional Carbon Initiative

Summary

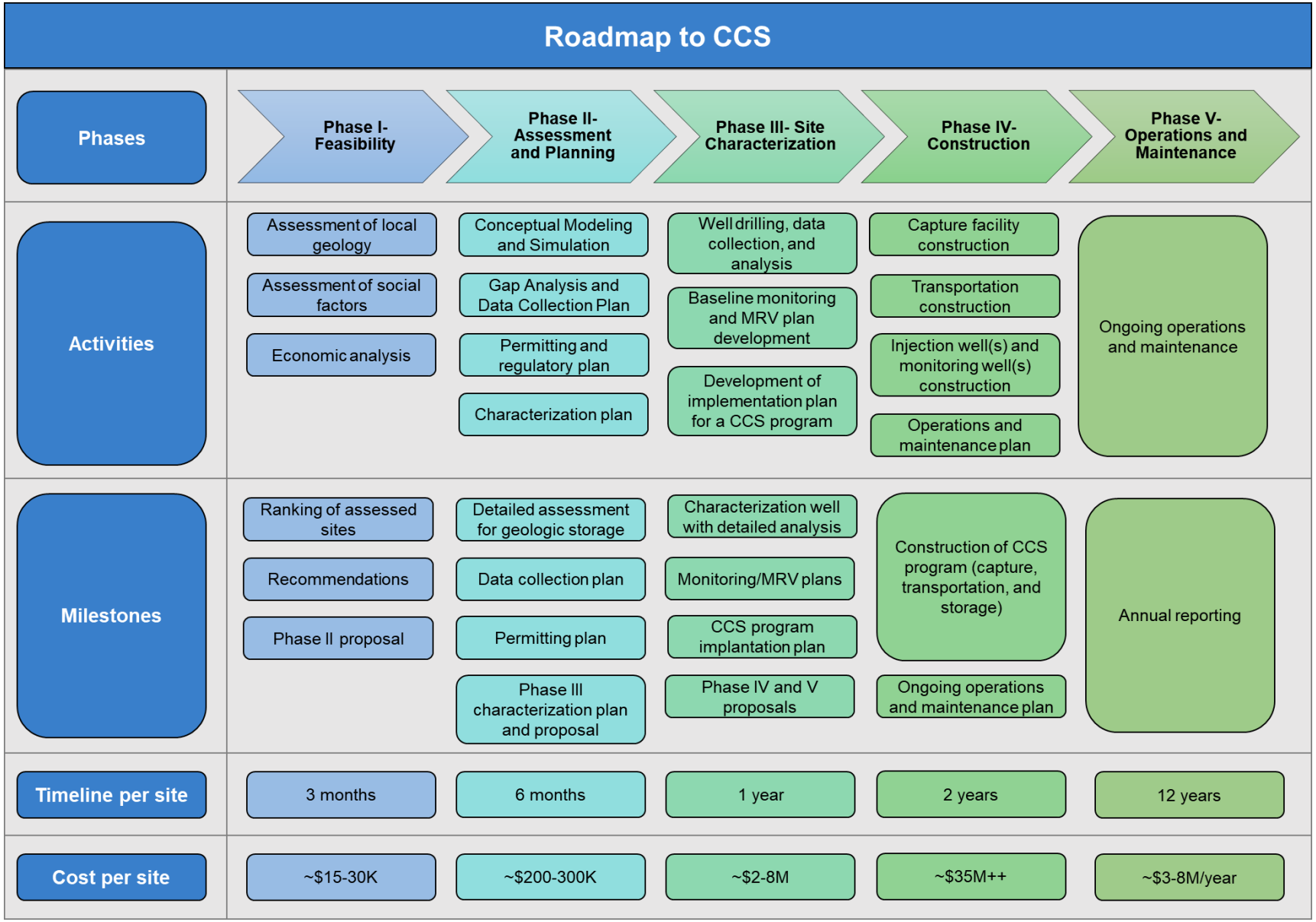
- CCS projects are being implemented in the MRCI
- Timeline for project development 2-4 years
- Phased approach can limit initial costs, reduce risks, and ensure safety
- Broadly seeing progress in:
  - Pore space ownership
  - Liability
  - Insurance
  - Injection field logistics




MRCI
Midwest Regional Carbon Initiative

Timeline

Phased approach can minimize upfront costs, reduce risk, accommodate permitting, and ensure safety.



CO_2 Storage Projects in MRCI

(not including CO2-EOR)

- **1 Active Class VI Well.**
- **~9 CCS project sites pending.**
- **~20 Class VI UIC permits** with EPA Region 5
- **~10-15 additional CCS projects** under development in MRCI.
- **4 post injection or closed out projects**

https://www.epa.gov/uic/class-vi-wells-permitted-epa (7/12/2023)

State	County	Permittee/Permit Applicant	Proposed CO2 Injection Rate	Maximum Total CO2 Injection Volume	Current Status	Current Project Phase
IL	Christian	Heartlnd Grnway Navigator	N/A	N/A	Pending (6 permits)	Pre-construction
IL	Ford	One Earth Sequestration, LLC	N/A	N/A	Pending (3 permits)	Pre-construction
IL	Sangamon	City, Water, Light, & Power	N/A	N/A	(FEED)	(CarbonSAFE)
IL	Macon	ADM (IBDP)	**1.0-1.2 Mt/year**	**6.0 Mt**	**Active**	**Injection**
IL	Macon	ADM (IL ICSP)	N/A	N/A	Pending	Pre-Construction
IL	Macon	ADM (Maroa Campus)	N/A	N/A	Pending (3 permits)	Pre-Construction
IL	Mclean	Heartlnd Grnway Navigator	N/A	N/A	Pending (2 permits)	Pre-Construction
IL	Putnam	Marquis Carbon Injection, LLC	N/A	N/A	Pending	Pre-Construction
IL	St. Clair	Carbon SAFE IL Corridor	NA	NA	Class VI prepared	Pre-Construction
IN	Randolph	One Carbon Partnership, LP	N/A	N/A	Pending	Pre-Construction
IN	Vigo	Wabash Carbon Services, LLC	0.834 Mt/year	10 Mt	Pending	Pre-Construction
			0.834 Mt/year	10 Mt	Pending	Pre-Construction
IN	Lawrence	Heidelberg Materials	N/A	N/A	(FEED)	(CarbonSAFE)
OH	Lorain	Lorain Carbon Zero Solutions	N/A	N/A	Pending	Pre-Construction
KY	Boone	Duke East Bend	0.001 Mt/yr	0.001 Mt	Class V	Closed
IL	Macon	ADM	0.3 Mt	1.0 Mt	Class V	Post-Injection
MI	Otsego	Core Energy	0.5 Mt/year	0.06 Mt	Class V	Closed
WV	Mason	AEP Mountaineer	0.12 million metric tons/year	0.037 million metric tons total	Class V	Closed