The Data Challenge and Opportunity in Carbon Storage:

Baseline Monitoring in Shallow Environments

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Data in the Carbon Capture and Storage Space

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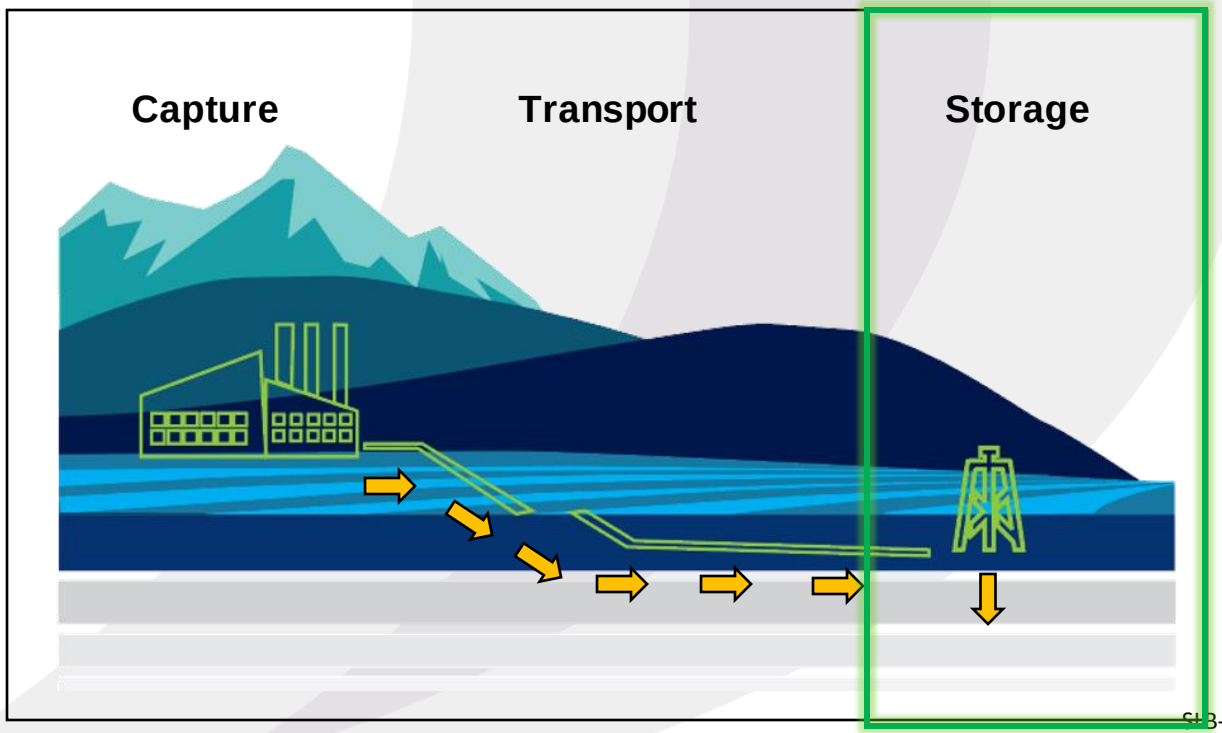
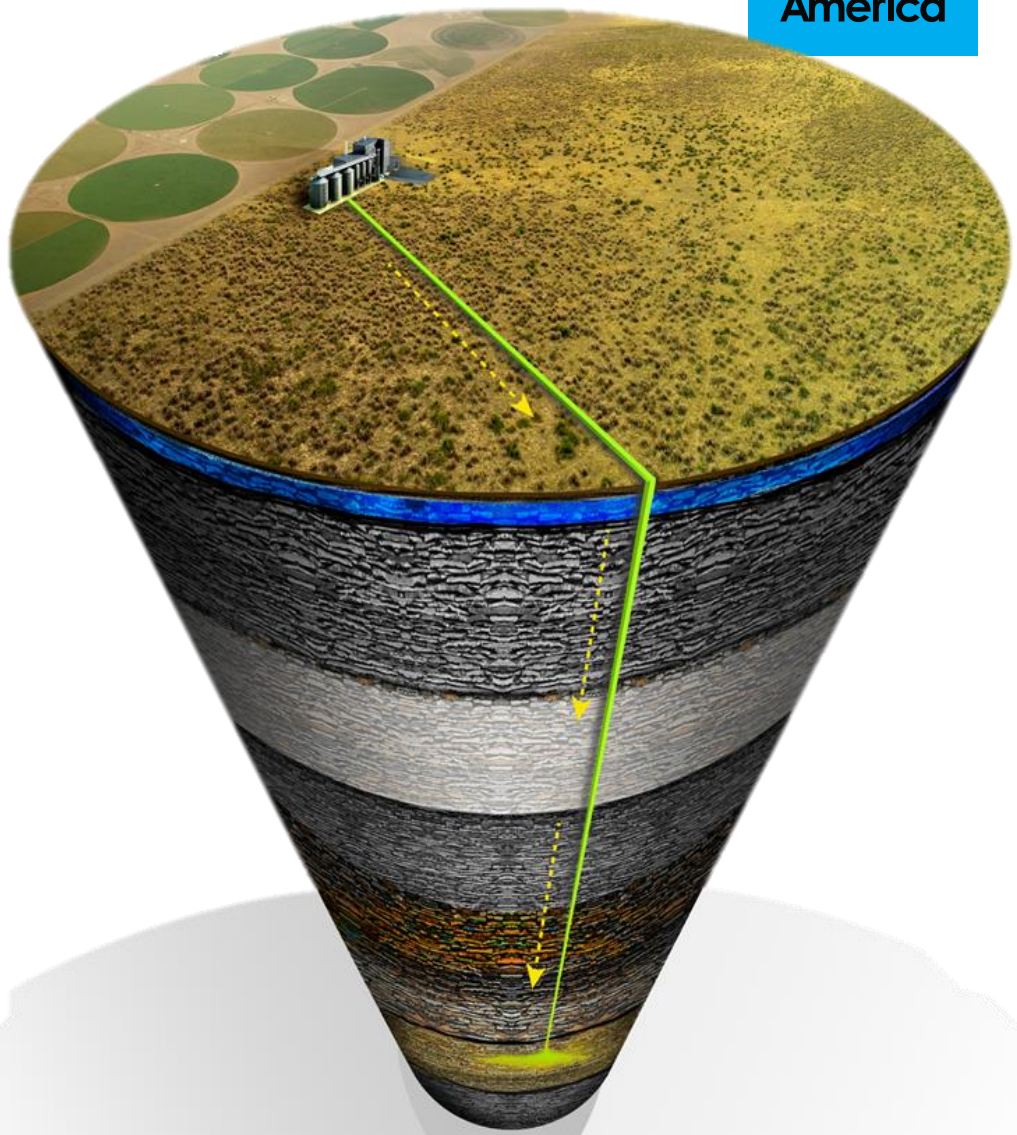
- Effective gathering, processing, and interpretation of data is critical in all fields that seek to characterize the subsurface
- CCS Industry demands a paradigm shift from oil and gas E&P
- Carbon Capture and Storage presents unique data challenges and opportunities that we will explore
  - Reservoir Characterization
  - Monitoring
  - Public Perception





Oil & Gas vs CO_2 Sequestration – the Paradigm Shift

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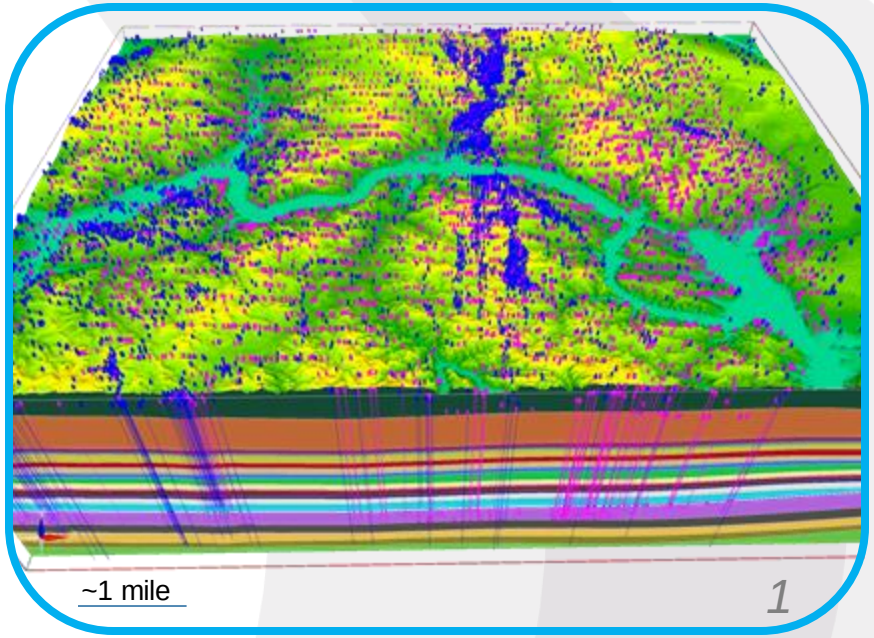
Oil and Gas E&P		Geologic Carbon Storage
Source- TOC, Kerogen Type, Maturity Reservoir- Unconventional or Conventional Seal – Timing, Migration and Retention	**Reservoir Characterization**	Reservoir- high porosity & permeability, depth >2,900' pressure >1070 psi*, temperature >88F, salinity >10,000 ppm TDS Seal – containment, especially from surrounding aquifers
Limited monitoring requirements, timelines are dictated by operators	**Monitoring and Timelines**	Extensive monitoring requirements, timelines are dictated by regulators Several years of work required before injection can begin, and subsequent monitoring will extend for decades
Oil and gas are both commodities with intrinsic free market value, though prices are volatile	**Policy & Economics**	CO_2 is a commodity with minimal to no value without institutionalized subsidies
Mineral rights are well established, and legal precedent exists for land agreements	**Permitting and Legality**	Pore space rights are often not clearly assigned Long term liability and issues of trespass are also not clear

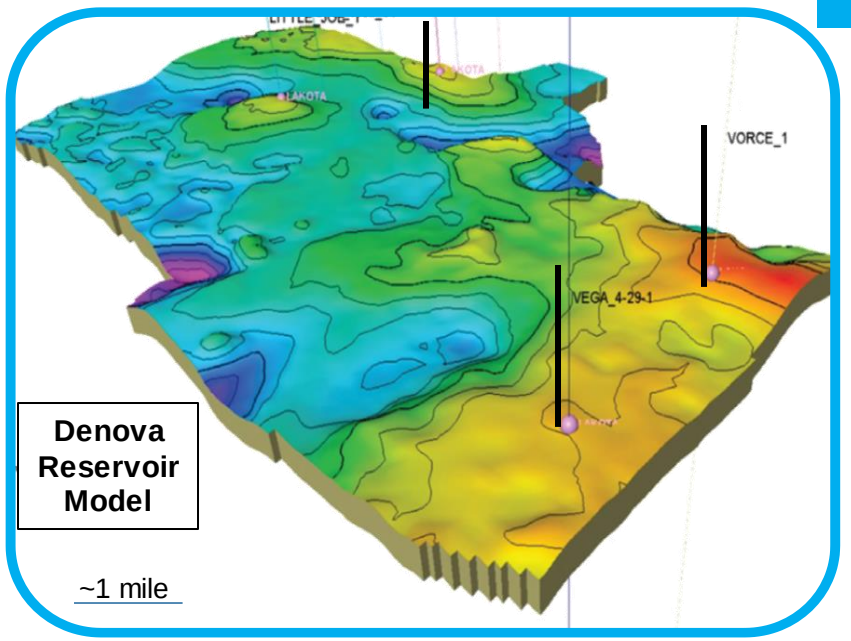
** Pressure required to keep CO_2 in supercritical phase (non-gas).*

Site Selection and Characterization - The Data Paradox



Developed Oil and Gas Field

- Dense well penetrations
  - Wireline logs available
  - Pressure, temperature, and other reservoir data throughout field area
- De-risking and Uncertainty
  - Play is continually de-risked with each new penetration



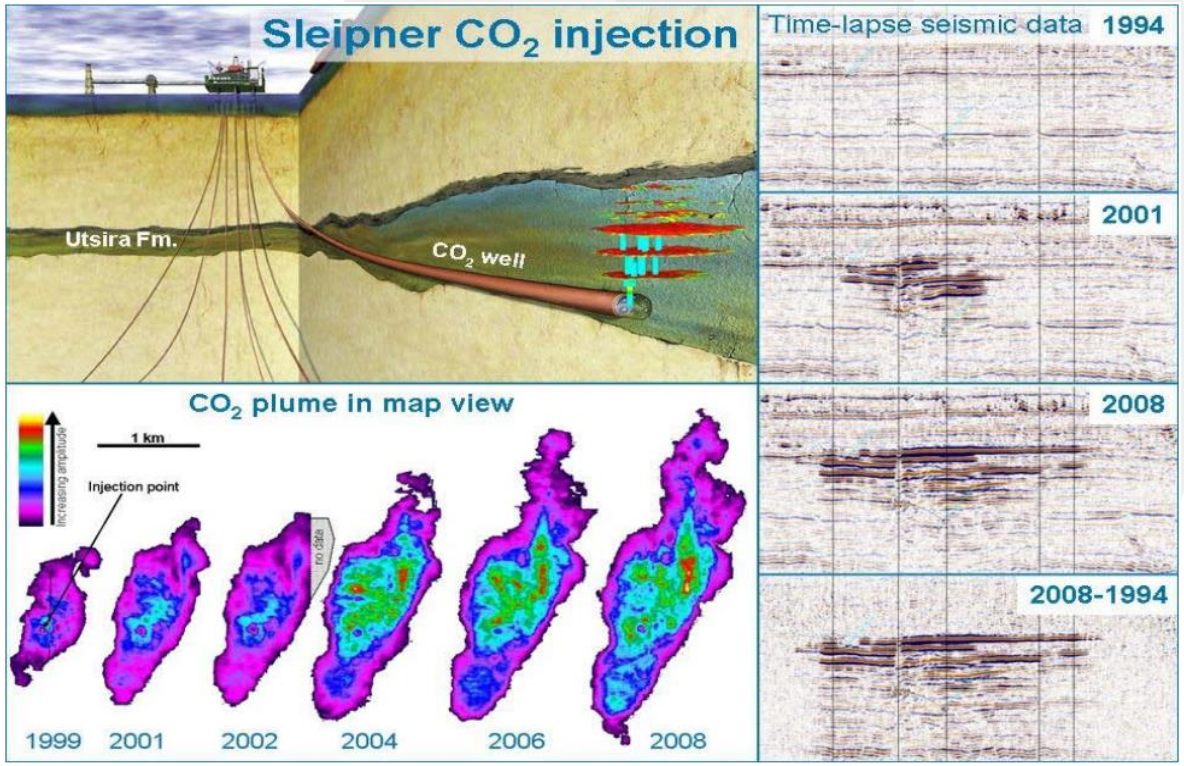
Undeveloped Acreage

- Few well penetrations
  - Must acquire new data (stratigraphic well)
  - Seismic interpretation is crucial
  - Heavily dependent on geologic modelling
- De-risking and Uncertainty
  - Plume behavior is assessed through monitoring

Subsurface Monitoring

Deep Subsurface

- Injection target and overlying formations
- Is the CO_2 plume behaving as expected?



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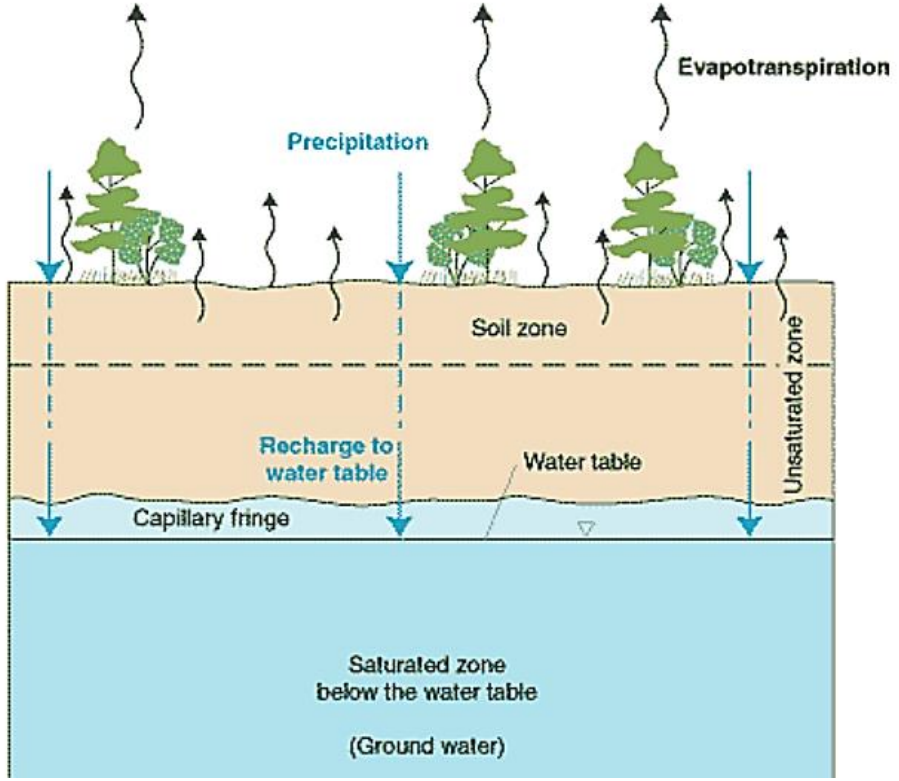
The deep subsurface is difficult to characterize without extensive data collection

Shallow Subsurface

- Soil, groundwater, and atmosphere
- Ensuring that environmental quality is preserved



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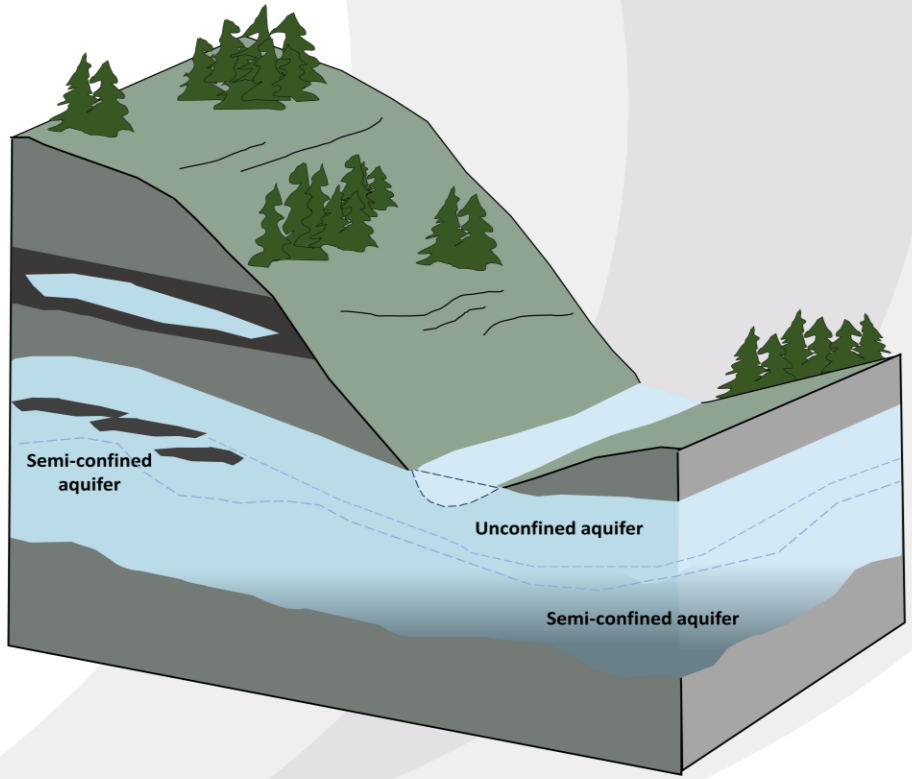
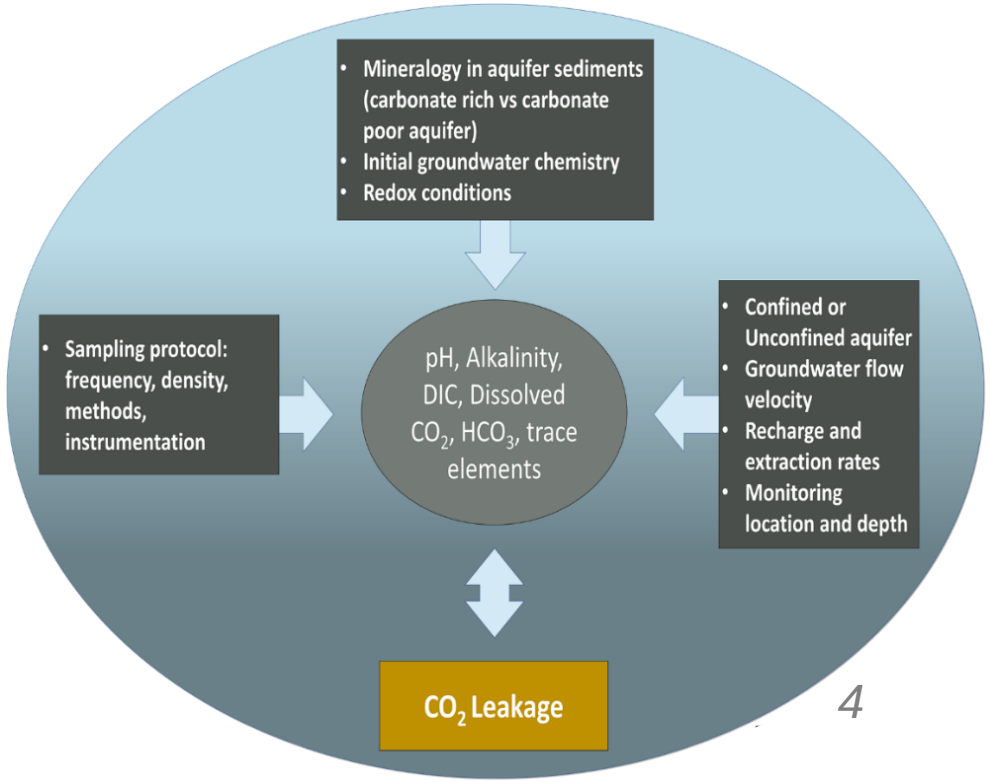
The shallow subsurface is dynamic, and experiences natural fluctuations

Groundwater Monitoring

- Groundwater monitoring involves the establishment of a natural baseline for multiple geochemical analytes
  - In the US, the EPA requires at least one year of monitoring to capture seasonal variance
- Analytes that have been shown to react to CO_2 in aquifers are sampled
  - pH, Alkalinity, HCO_3, trace elements, dissolved inorganic carbon



Data collection methods and other external factors complicate results



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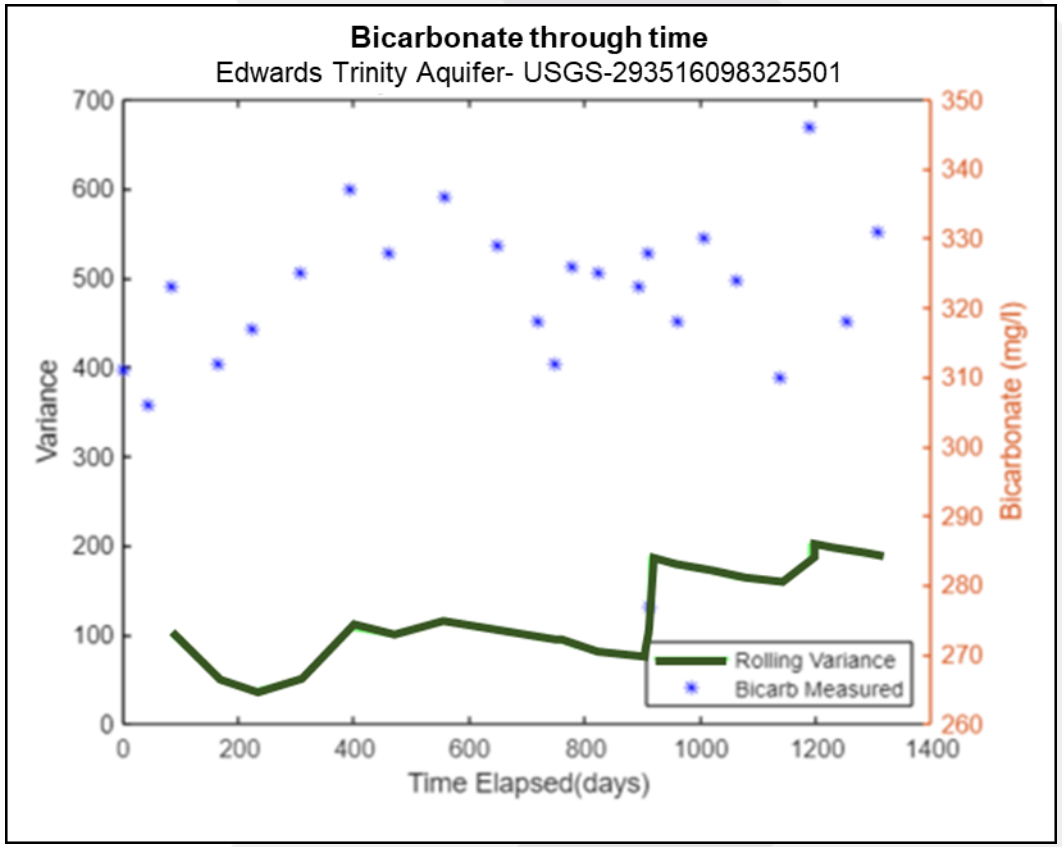
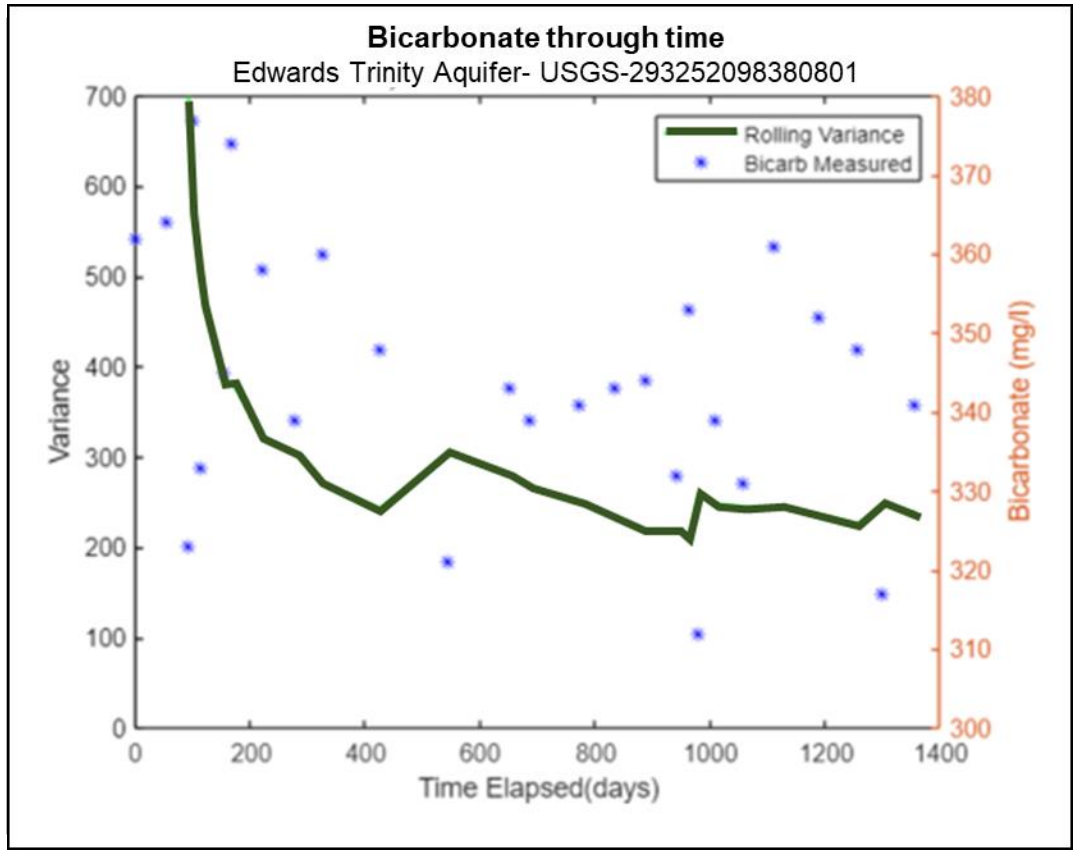
Groundwater Monitoring





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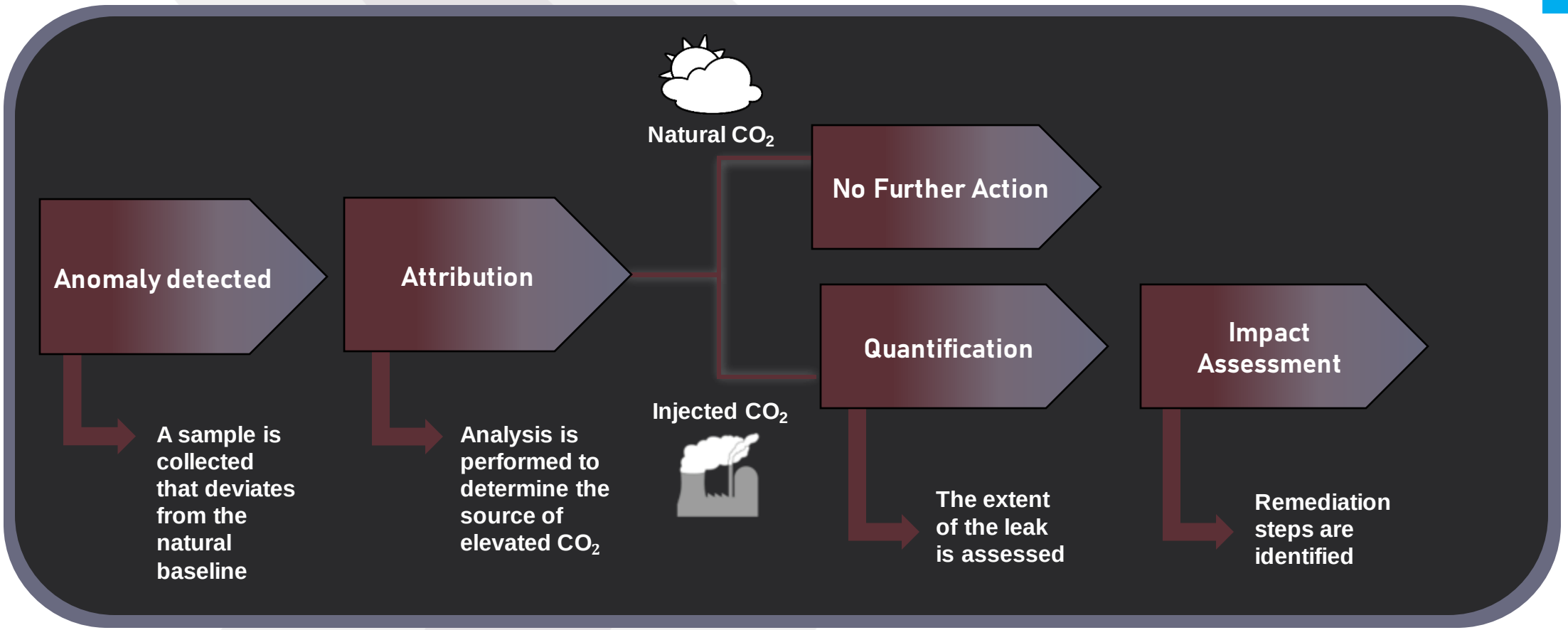
How you use the data is critical

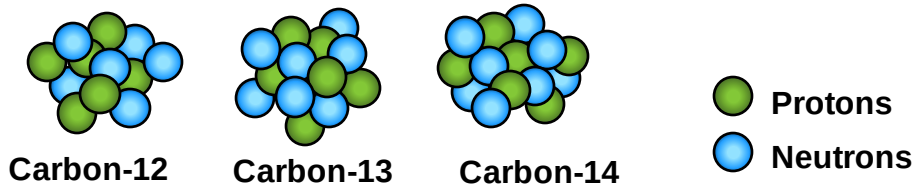


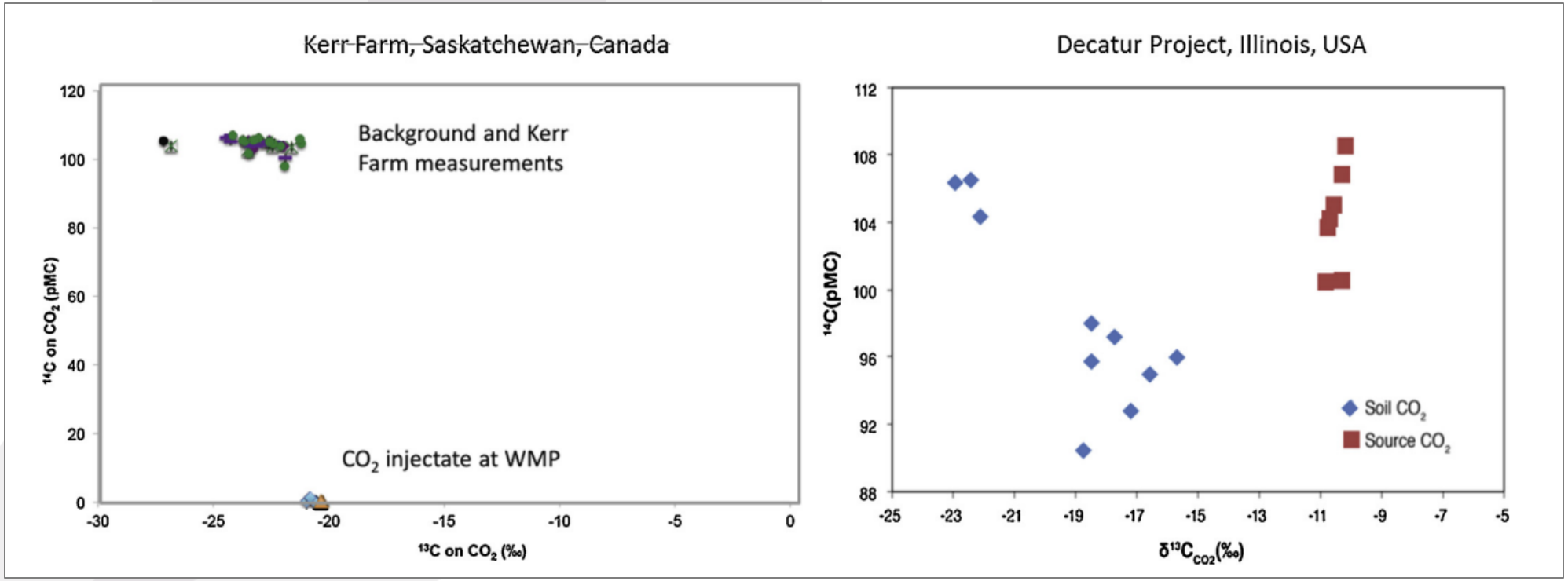
If the attribution step is not taken, operators may face unnecessary project delays

- Weyburn-Midale CO_2 Monitoring and Storage Project
  - 2011: Landowners made public allegations that CO_2 leakage had occurred from the subsurface injection interval based on elevated levels of CO_2 in soil gas
  - Subsequent analysis utilized relationships of CO_2, O_2, N_2, as well as isotopic analysis to determine the source, which proved elevated CO_2 was not due to a leakage

Attribution: Isotopic Fingerprinting

- The relative amounts of C12, C13, and C14 will determine the 'fingerprint' of background CO2
- C14 is radioactive and decays predictably over time; young organic matter has more C14 than older organic matter
- Emitting source type will impact the isotopic signature





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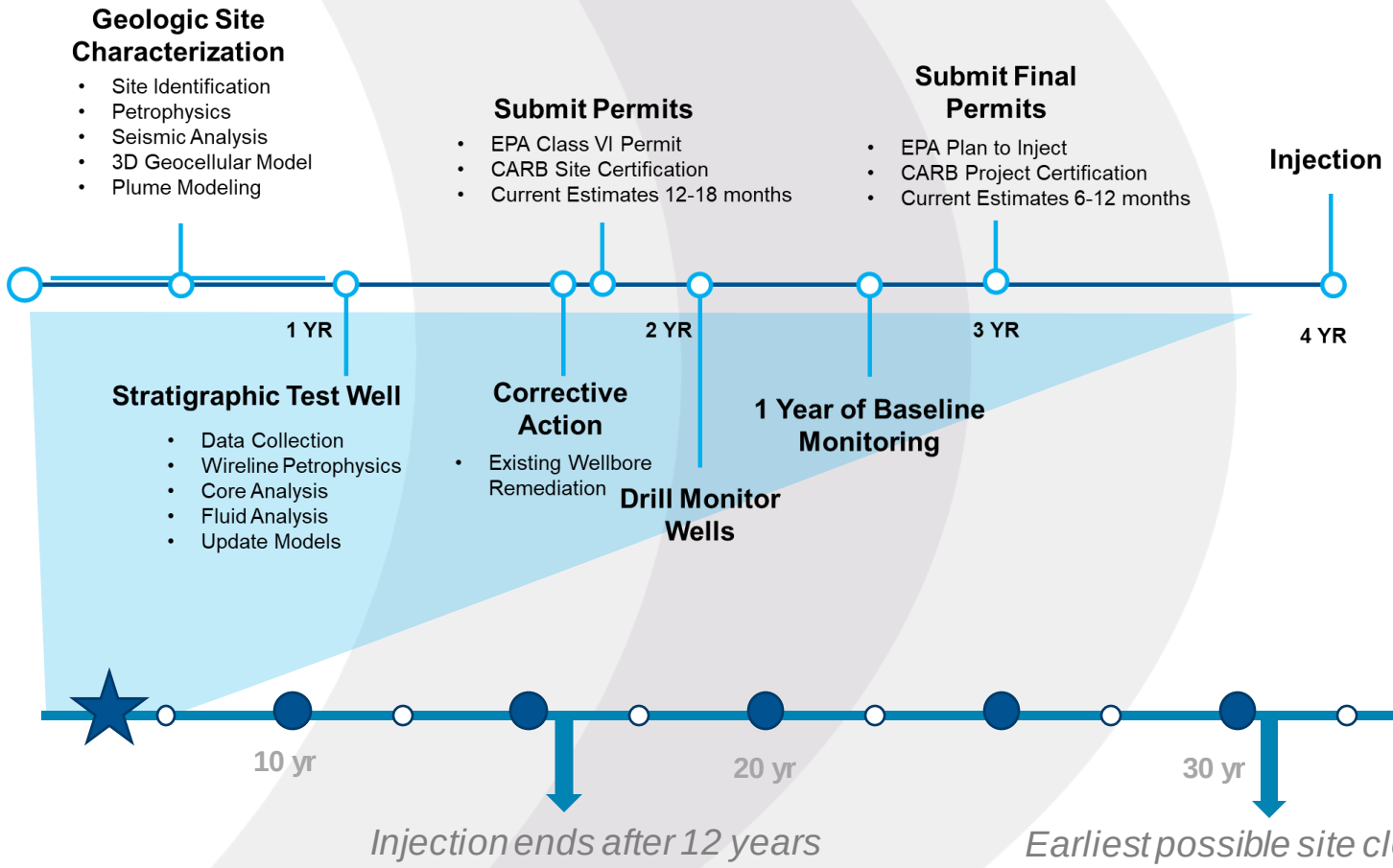
Shallow Monitoring - Data and the Public

- **The Purpose**
- Ensuring that CO_2 injection does not result in any near-surface contamination
- Primary interface between the public and CCS projects

- **The Challenge**
- The dynamic nature of the near-surface environments
- Extensive, but often difficult to follow regulatory guidelines

- Clearly communicating technical data and concepts such that community members are aware of risks and safety measures in place

Project Timeline - Why We're Talking Monitoring



- Monitoring dominates the project timeline
- Establishing a 'natural baseline' requires at least one year of sampling and analysis prior to injection commencing
- These decadal monitoring requirements are unique to the CCS industry

*In the US site closure is permitted within 15 years after injection ends, if the plume stability is verified

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A Final Data Paradox

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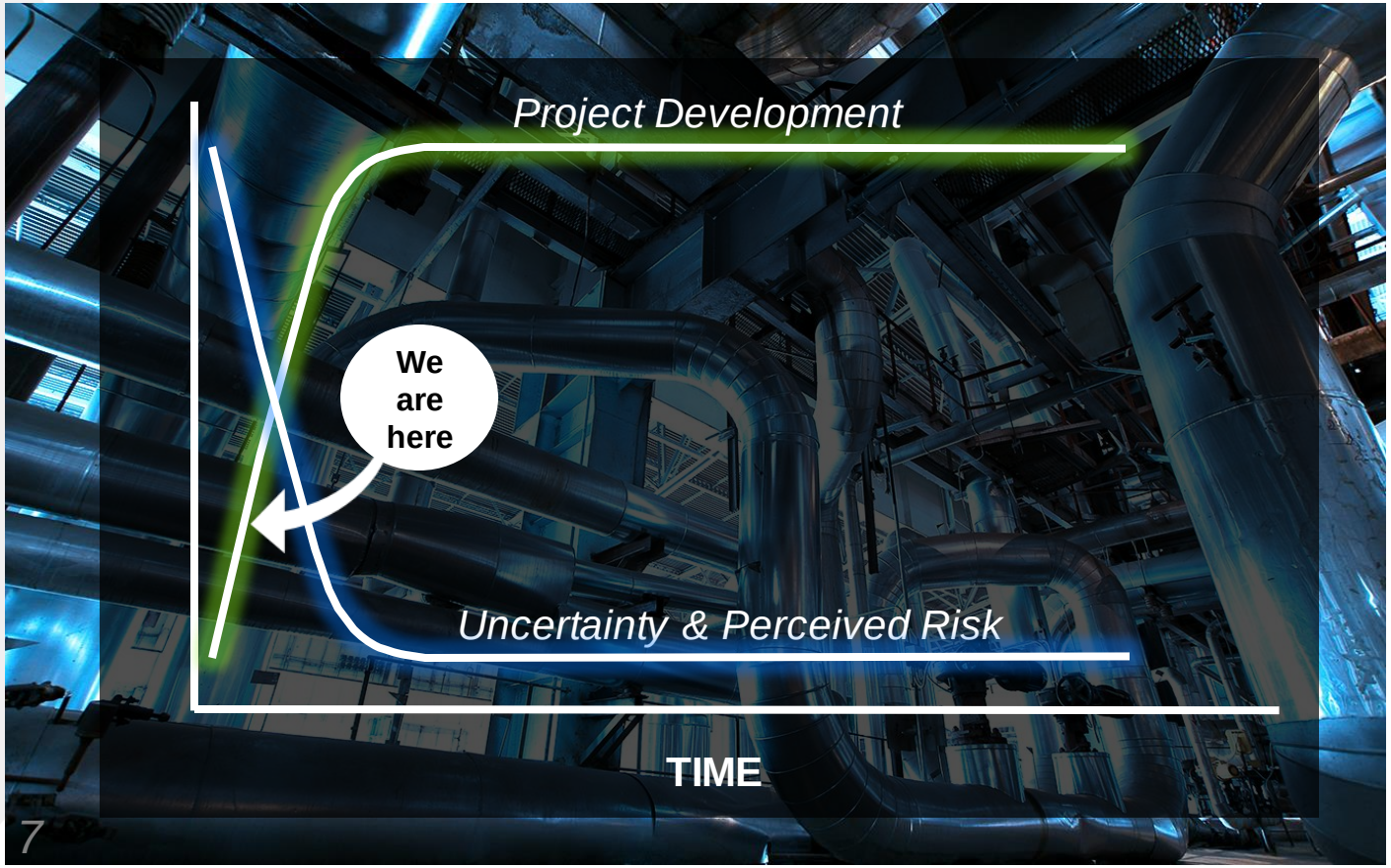
Unfamiliarity

- There is still little awareness of CCS in the general public

This Impacts:

- Insurability and Financial Support
- Public perception
  - Individual or community
  - Broader public opinion
- First Mover Challenges



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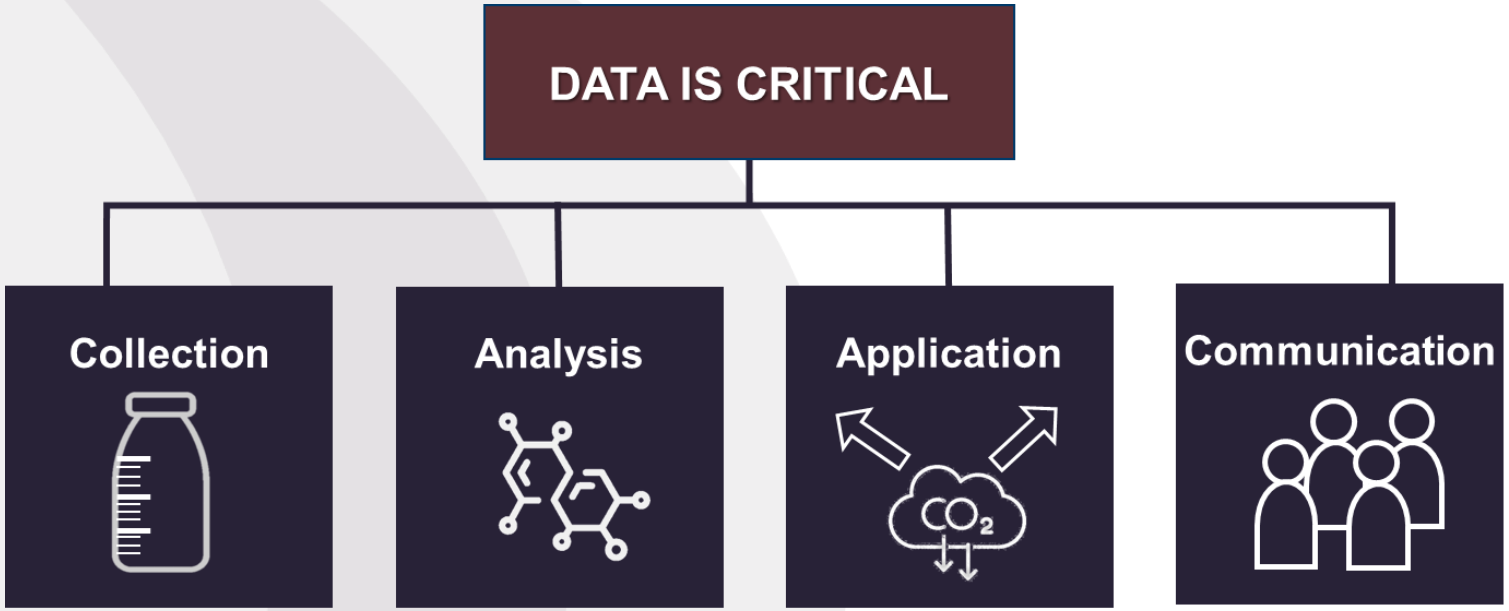
Concluding Remarks



- CCS presents distinct challenges to both operators and regulators
- Monitoring is a uniquely challenging component of these projects
- At every stage, data is critical
- The ability to communicate clearly with the public is paramount to success

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Acknowledgements

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