Gulf Coast Carbon Center 2018-2022 Aspirational Multi-year “Big” Plan

Topic 1: CCUS ecosystem

1.1 Problem statement

CCUS deployment is not happening at the rate and scale needed to achieve emissions-reduction goals. Many influential stakeholders, from industrial investors to policymakers to journalists, do not have information needed to see the critical role in attaining these goals and the viability of CCUS. In this task we consider what information various stakeholders are missing and what formats of communication are most effective for informing diverse users.

1.2 Goals

The goal of this topic is to **unite elements through which GCCC can improve relevance and availability of technical information needed by decision makers and the public**. We aim to focus on geotechnical elements where GCCC has strong background to provide context for stakeholders to develop policy-neutral, fact driven conclusions. We will make improvements in the following areas:

- Improved dialogue with key stakeholders, including sponsors, CO_2 sources industries, CO_2 storage and use practitioners, regulators and policy developers.
- Increase the quality and availability of technical data on the viability and potential for CCS and its intersection with other elements of the energy ecosystem. Examples are:
  - Economic implications of technical findings; for example, costs of monitoring recommendations or value from carbon balance calculation.
  - Connections among energy options, for example CCS + renewables or CCS and increased gas production and use, and CCS in the hydrogen value chain.
  - Policy and ecosystem implications of Net Carbon Negative Oil (see also technical advances proposed in task 4) strategies for providing emissions reductions for CO_2-EOR.
- Expanded dialogue with a wider audience about CCS and CCUS. This includes technical communications, education at all levels, stakeholders, the press, policy makers, the public, and diverse other stakeholders. Consider “rebranding” CCS options and processes
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1.3 Methods

- With GCCC sponsor input as a critical guiding process, ***we will maintain and enhance connections with diverse stakeholders across the broad array of CCS interest groups and seek to develop new relationships as interest matures***. We also will serve as organizers and participants in various types of local to global collaborations, such as workshops, meetings, side events, open houses, hearings, and review panels where the conversations are occurring.
- Conduct targeted studies (review studies or original analysis) as needed to provide information.
- Use outcomes and insights gained from stakeholder dialogues to inform the ***focus of studies that evaluate the economic implications of technical data*** generated by the other topics in the Big Plan and the evolving energy landscape. We will develop ideas in consultation with sponsors. Several seed ideas on potential activities have already been generated and will be pursued:
  - Further our existing carbon balance estimation, including adding feedback from upstream and downstream components and diverse types of operations

- Determine the implications of increases in gas production and gas use, considering potential technology evolution for regional and global source to sink matching
- Define the implications of intermittency (as a result of greater penetration by renewables) on geologic storage.
- Utilize Interactive Google Earth-based source-sink database for assessments.
- Link EOR + storage to saline storage temporally and spatially, with examples from the Texas Gulf Coast and Permian Basin.

- ***Update, optimize and continue communication across available platforms***, including technical and non-technical publications, digital communications, and in-person communications.

1.4 Four-year target accomplishments

- Utilization of stakeholder perspective to inform GCCC assessment of how geologic storage fits into the energy ecosystem
- Increased number and diversity of stakeholders reached
- Evidence of incorporation of GCCC input into the evolving wider ecosystem

Topic 2: Preparing for large volume storage – BIGFOOT

2.1 Problem statement:

Significant progress has been made in assessing CO_2 storage capacity in terms of how fast and how much CO_2 can be injected in a storage complex. From this work we have come to identify a number of **factors which have strong impacts on capacity** which need further in-depth assessment. To prepare for large-scale injection with many sites in the same basin (and potentially same stratigraphy), advances in our understanding are necessary in areas such as:

- Pressure propagation (vertical and lateral), interference, and dissipation at stratigraphic scale. This activity could evolve to include dynamic aspects such as geomechanics, fault stability, and microseismicity.
- Pressure boundaries (baffles, seals, and faults) that compartmentalize or isolate injected fluids and pressure response; above and below-zone geomechanical influence
- Impacts of pressure change in zones displaced by faults
- Conceptualization and assumptions about expected CO_2 saturations and flow behavior during migration through large subsurface volumes

2.2 Goals

Improve structural and stratigraphic characterization methods and simulation approaches to increase confidence in siting very large volume storage within a basin; apply to one or more important basins.

2.3 Methods:

Assessment will focus on the Gulf of Mexico (onshore and offshore) with a vision to apply these concepts broadly:

- Conduct geologic assessment and numerical modeling at stratigraphic and site scales augmented by literature and global collaboration

- Use sequence stratigraphy and depositional systems as tools for understanding CO_2 migration and pressure propagation at basin scale; consider further relationships of trapping mechanisms (structural or capillary trapping etc) to static and dynamic capacity
- Assess the impact of structural and tectonic components on fluid flow and capacity; compartmentalization, connectivity and geomechanical impacts ; impact of regional fault systems.e.g between onshore and offshore Miocene
- Consider how petroleum systems analysis and concepts can inform CCS
- Evaluate and apply resource quantification methods at project-scale, beginning with SPE Storage Resource Management System (SRMS)

2.4 Four-year target accomplishments

Improved and demonstrated workflows for characterization at basin-scale that prepares for multiple sites to be operated at maximum injection rates and over prolonged time periods.

Topic 3: Real-world leakage assessment

3.1 Problem statement:

Theoretical and field work to assess risk of leakage from carbon storage reservoirs has been well developed, but a short-fall in critical assessment of leakage models for correctness and completeness and sparse real-world validation can cause inadequate or miss-targeted monitoring. In particular, the mechanisms, rates, processes, and reactivity of fluid transport through non-reservoir rocks has been considered only simply. **To prepare for either a leakage incident or a leakage allegation, realistic experience with the possible leakage scenarios is needed**.

3.2 Goals:

3.2.1 To improve conceptualization of the migration mechanisms by which out-of-zone leakage and leakage to atmosphere or groundwater can occur. Example are:

- **Determining what flux rate of leakage is significant to storage security and what is detectable**.
- Determining the importance of, and ways in which, leakage flux be separated from background flux for more accurate accounting. Considering operational and site closure timeframes as well as extended time frame permanence.
- Determining the factors that most affect reactivity and interaction of fluids with rock, the factors that change fluid chemical and physical properties, and understanding flow path, and the temporal characteristics of leakage
    - Determine the realistic properties and geometries of various types of pathways through overburden including where fluids will migrate in focused pathways, where fluids will accumulate prior to spilling or exceeding capillary entry pressure, and how saturation may evolve. We will also seek to better understand when and where leakage is vertical as opposed to when and where risk is dominated by horizontal migration.
- Resolve how multiphase fluid flow mechanisms impact fluid-fluid and fluid-rock interactions. This goal will incorporate improving the combination of multiphase flow and geochemical reaction beyond flash calculations.
- Determining which geologic variables play dominant controls on leakage and the methods for identifying these variables for any specific site.

3.2.2 Assess implications of migration mechanisms Focus on above-zone but also includes some work in-zone) for detection to **improve monitoring,** for example via:

- Better targeting of detection strategy
- Quantifying and predicting the attenuation and retardation of leakage, including predicting how these processes will affect the use of tracers (natural and introduced) for leakage assessment.
- Improved understanding and prediction of signal to noise (e.g. seismic sensitivity to leakage)
- Improved strategies for quantification of leakage across all points of surface emission.

3.2.3 **Implications of migration mechanisms for environmental impact and remediation**, for example diffuse versus focused leakage and/or variations in flux rate and environmental impact.

3.3 Methods

We propose a broad spectrum of interconnected studies including numerical models, physical models and experiments, and potentially field experiments to accomplish these goals. Examples are:

- Apply pore scale models to assess directional relative permeability
- Use head-gas sampling for monitoring the bottom hole liquids
- Validate Invasion Percolation/Darcy simulators to assesses saturation resulting from different migration mechanisms through various geologic fabrics and architectures
- Use image analysis for quantification of flow through models
- Apply physical and numerical models of flow paths to consider various geometries, including low dips and trapping at various scales (e.g., from bedform to regional)
- Develop numerical and laboratory methods of assessing processes, timing and rates of dissolution of CO_2 in two-phase and possible multi-phase settings in porous media and wellbore.
- Assess the degree to which petroleum systems can be used as a proxy for site characterization and/or leakage detection. One example is to use GoMCarb project to understand the implications for storage security in areas with low hydrocarbon accumulations such as Chandeleur Sound. We will also evaluate concepts of fluid inclusion stratigraphy using data derived from well cuttings to evaluate regional and local seal quality.

3.4 Four-year target accomplishments

- Improve recognition of significant leakage, thereby **increasing confidence in methods for identification of sites and conditions that are unlikely to leak**
- Improve risk assessment in terms of more realistic likelihood and impact
- Develop a more effective monitoring framework including better-defined strategies for lowering monitoring cost. Improved leakage conceptualization will also provide for more targeted leakage assessment with respect to when, where and how to look for leakage. Such an approach will therefore **improve our ability to both 1) state with more confidence that leakage has not occurred and, 2) should leakage occur, this approach will improve our ability to locate, attribute and quantify leakage.** Better leakage assessment will also help prepare for staged integration of monitoring in different zones (link to topic 5)

Topic 4: The U in CCUS

4.1 Problem statement:

Substantive progress has been made demonstrating the value of captured CO_2 for EOR as well as analysis of CO_2 EOR's role in storage (for example, calculation of carbon balance for EOR lifecycle). This understanding of use of CO_2 for EOR increases the already high attractiveness of this high quality, value-added offtake for captured CO_2. However **gaps exist in our understanding of the role of CCUS in CO_2 emissions mitigation**, and filling these gaps with data may illuminate the value, costs, limits, and risks of carbon capture, use and storage (CCUS) as part of the energy landscape discussed in topic 1.

4.2 Goals

- To critically assess the economic value of various CO_2 EOR approaches and the potential relations with environmental elements of CCS.
- To evaluate the various settings where CO_2 might be injected for economic profit in terms of their added value to CCS, such as:
    - tight reservoirs,
    - naturally fractured or hydro-fractured reservoirs,
    - residual oil zones,
    - gravity-dominated floods
    - offshore settings
    - Carbonate and clastic settings

4.3 Methods

- Review and synthesize global projects, studies, and literature.
- Analyze outcomes of real projects where possible
- For the identified reservoir settings, consider various scenarios:
    - Evaluate economic value of hydrocarbon recovery, and volumes, locations, risk for CO_2 storage.
    - Integrate options such as
        - lifecycle emission,
        - interactions among components of the value chain and the
        - impact of policy
        - project cost and value, and
        - source-sink matching
    - Run numerical and analytic models ranging from multi-component simulations to economic models

4.4 Four-year target accomplishments

- A mature understanding of CCUS economics including:
    - The impact of oil price, potential carbon markets or tax incentives
    - the value of carbon balance and NCNO
    - the business opportunity for CCUS
- Broadened range of application
    - Understanding of reservoir settings currently excluded from CCUS commercialization and their role in an energy ecosystem

- Improved efficiency in standard applications
    - Best reservoir management

Topic 5: Monitoring Lifecycle

5.1 Problem statement:

We observe globally a **lack of consensus or precedent about how much monitoring is sufficient**. In past assessments, we observe this comes from 1) lack of clear goals about what is to be accomplished via monitoring; 2) lack of a reproducible process for matching monitoring to goals, and 3) lack of process for action to either document that goals have been met or what should be done if goals fail to be met.

We see this problem in many of the proposed and implemented accounting, accreditation, permitting and financing mechanisms. Examples of specific gaps in need of improvement are:

- Lack of optimization of when/where/how to use tools to achieve goals
- Missing skills and tools to achieve some goals. For example, how can instrumentation be kept active over project lifespan and possibly during a long post injection-site closure period? Approaches that support long term predictions of no loss, specifically that demonstrate plume stabilization are needed.
- Lack of strategies for coping with noise limits on detection
- Inability to detect focused leakage paths with low saturation overall, such as fracture or failed-well completion leakage
- Need for remote monitoring and other optimizations that can lower cost.
- Need for strategies for communicating monitoring approaches to affected non-technical stakeholders

5.2 Goals

To develop effective monitoring strategies that meet the evolving needs for monitoring in different settings, under different risk-tolerance conditions, and in different regulatory environments. These strategies will consider cost for value assessment, geologic and social/regulatory/cost considerations, and effectiveness for non-technical stakeholder engagement. Outcomes will focus on the following qualities:

- Enhancements in the role of pre-injection characterization in improved risk assessment and monitoring design
- Improvements in operational monitoring tools, skills, and approaches
- **Populating the time series of monitoring activities (e.g. attribution-quantification – consequences - remediation) with case studies.**
- **Developing methods for documenting site closure attainment**

5.3 Methods:

5.3.1 Use pre-injection characterization to improve risk assessment and monitoring design

- Traditionally, characterization is completed before injection and monitoring begins during operation. However, in a dynamic basin (compacting, actively generating hydrocarbons) – monitoring for leakage can be done as part of site selection. Examples of features that can be studied are sea bottom seeps, fluid chimneys, hydrocarbon shows (sea floor, logs, thin sections)
- Extend application of understanding gained from dynamic basins to older basins

5.3.2 Consider targeted improvements on operational monitoring

- Attention to the most common outcome – documenting storage success
- Anomaly/leakage assessment workflow of attribution-quantification-consequences-remediation of leakage.
    - Bring real-world experience into design
    - Issues of blowouts – seek development of BMP's
- Targeted improvements of tools, skills, and approaches
    - High resolution 3D Seismic (P-cable) offshore
    - Automated and remote surveillance
    - Improved geochemical approaches (links to topic 3)
    - Head space gas assessments, maturing a process-based approach for attribution.
    - Work on issues in lab models (links to topic 2)
    - Collaboration with other research groups on prospective field tests in collaboration, small scale, and large scale.

5.3.3 Role of monitoring in attaining site closure

- Viable methods with demonstrable value for long-term surveillance
- Strategies for accelerating confidence in site performance and avoiding the need for prolonged surveillance (links to proposal 1)
- Research on plume stabilization – efficient and low-cost, rapid determination

5.4 Four-year target accomplishments

- Develop a mature matrix for matching monitoring tools to needs that has ties to various project stages (including site selection) and includes project success justification, attribution steps, reduction in the need for long-duration closure monitoring by via improved approaches to assessing stabilization.
- Develop targeted incremental development in tools and approaches utilizing many domains from numerical models to physical models for small and large demonstrations.
- Develop better-quantified cost-value approaches.