Preliminary Infrastructure Assessment Report

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Contents

Introduction

The "Optimizing Alabama's CO_2 Storage in Shelby County: Project OASIS" CarbonSAFE Phase II Project seeks to build on regional data sets that demonstrate that the subsurface within Shelby County, Alabama has the potential to store commercial volumes of CO_2 safely, permanently, and economically. This work builds on the initiatives of the Southeast Regional Carbon Utilization and Storage Acceleration Partnership (SECARB-USA, DE-FE0031830) that identified nearly 500 million metric tonnes of CO_2 emitted on an annual basis that is not collocated with prospective storage geology (the Coastal Plain of the Southeastern U.S. in this context). This observation suggests costly investments in connective infrastructure (e.g., pipelines) or exploratory well drilling campaigns to identify CO_2 storage opportunities in under explored areas. While not traditionally thought of for saline storage, these studies suggest that storage prospects in the Valley and Ridge Province occur in relatively flat lying structural panels between thrust faults. For the Project OASIS region, available geologic studies related to hydrocarbon exploration suggest that Cambro-Ordovician carbonates and Cambrian clastic units offer multiple potential storage intervals, and that regional confining systems are present, such as the tectonically thickened Floyd-Parkwood Shale. The Project OASIS surface property is owned by a timber and land stewardship company, The Westervelt Company, Inc., who worked with the Project Team to select and prepare adequate sites for geologic assessment.

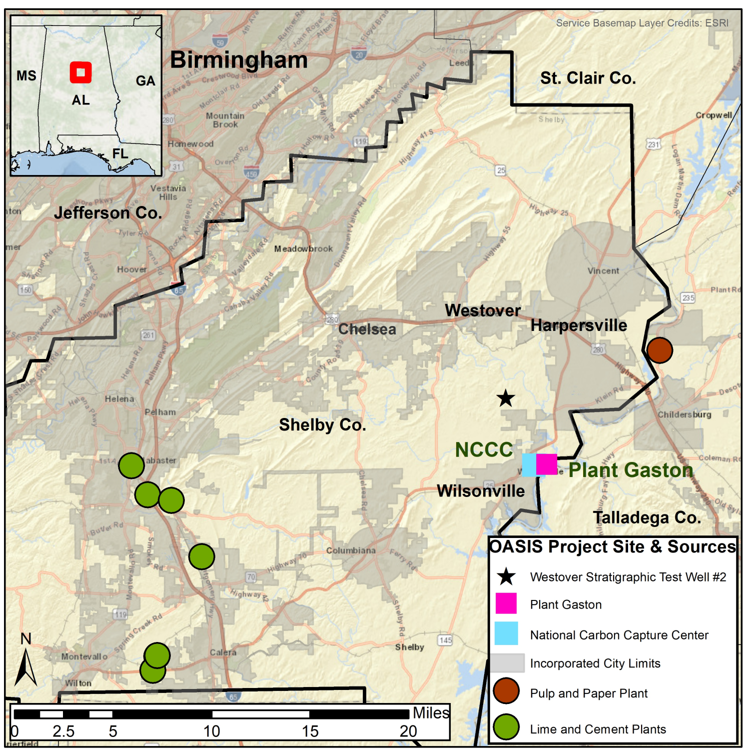

Figure 1. Location of Project OASIS in eastern Shelby County, Alabama. Also shown are regional emitters within relatively close proximity of the site.

To date, the Project Team have drilled a deep stratigraphic test well that penetrated a repeat section (fault bend fold and thrust ramp) of Cambro-Ordovician carbonates, which allowed for the collection of sidewall core and geophysical data of intervals of interest over multiple depths. The drilling program is detailed in the *Task 3.0 Milestone: Site Specific Drilling Report* which was completed and submitted on January 26, 2024. Collected sidewall core and whole core were sent for routine and special core analysis at a commercial laboratory. Existing regional seismic data, downhole geophysical data, and core data were utilized to create an update geologic model for the OASIS site. Following this static storage resource estimates were calculated for each target formation (the Knox Group and the Rome Formation) in the local stratigraphy. It should be noted that because the OASIS stratigraphic test well did not penetrate the Rome Formation, reservoir properties were inferred from the closest legacy well penetration (Arco/Anshutz No. 1, approximately 10 miles away).[1] In general, these calculations suggest limited storage resource for the Knox Group ranging from 0.03 to 0.08 million metric tonnes of CO2 per square mile at the P10 interval to 0.07 to 0.18 Mmt per square mile at the P90 interval. These numbers are significantly higher when contemplating the Rome Formation (2.23 Mmt per square mile and 7.23 at the P10 and P90 interval, respectively) primarily owing to its greater net thickness (approximately 500 ft) and porosity (average of 10%). Dynamic injection scenarios have been explored and are captured in more detail in the *Task 6.0 Milestone: Evaluation of Class VI Readiness.* A vertical injection model targeting the Copper Ridge Dolomite of the Knox Group found an average injection rate of 0.02 Mmt of CO2 per annum, or 0.55 Mmt of CO2 over 30 years. A scenario exploring horizontal injection found improved injectivities of 0.14 Mmt of CO2 per annum and 4.31 Mmt of CO2 over 30 years. Dynamic modeling for the Rome Formation shows vastly superior injectivities of 1.6 Mmt of CO2 per annum or 48.02 Mmt of CO2 over 30 years. It is important to note that the parameters used for the Rome Formation were taken from the Arco/Anshutz No. 1 well and that the assumption for these calculations is consistent reservoir properties over a structural complex region. It is likely that these parameters are different at the OASIS location, which adds uncertainty to the viability of this location for the storage of commercial volumes of CO2. Indeed, the Project OASIS site does not enjoy the storage efficiencies observed in other parts of the Southeastern United States, such as the Cretaceous sands observed in the Gulf South, and as a result, commercial scenarios, and correspondingly, infrastructure scenarios, are difficult to assess. Nevertheless, this document explores relevant considerations for area, and infrastructure considerations will be reexamined as more data become available and as part of the *Task 8.0 Deliverable: Commercialization Plan.*

Table 1. Project OASIS dynamic modeling results. Results are from the Project OASIS Task 6.0 Milestone: Evaluation of Class VI Readiness.

Model Scenario	Cumulative Injection, 30 Years (million tonnes)	Average Injection per Year (million tonnes/year)
Copper Ridge Sweet Spot ONLY	0.55	0.02
Rome Injection Only	48.02	1.6
5,400 ft Horizontal in Copper Ridge	4.31	0.14
Whole Knox Injection	0.84	0.03

[1] Arco-Anshutz No. 1 Well: https://www.gsa.state.al.us/ogb/wells/details/construct/3518/9942/4403/0/

Storage Opportunity and Cost Considerations

As described in the preceding section, both static and dynamic modeling suggest that the known storage resource at the Project OASIS site (excluding the Rome Formation) is limited. Table 1 above shows the modeled dynamic capacity for the OASIS site for four separate modeling scenarios. While the area benefits from thick (as much as 8,000 ft thick) sequences of Carbo-Ordovician carbonate rocks, limited porosities and permeabilities dramatically decrease storage efficiencies. For example, the most favorable dynamic modeling scenario (5,400 ft Horizontal in Copper Ridge) will require a minimum of 12 injection wells to satisfy the CarbonSAFE annual require of 1.7 Mmt of CO_2 stored on an annual basis. This represents a 6-fold increase in number of wells to achieve these volumes when compared to projects located in the Gulf South, where storage costs on a per ton basis range from \$5 to \$10 per ton of CO_2. These observations suggest that CO_2 storage costs may range from \$30 to \$60 per ton of CO_2 for the Project OASIS site. Capital costs associated with permitting and constructing 12 separate injection wells and the associated monitoring program may prove cost prohibitive, before considering the project area of review and associated land considerations.

CO_2 Sources in the Region

There are several large-volume regional CO_2 emitters including pulp and paper facilities, lime and cement facilities, and Alabama Power's Plant Gaston (see Figure 1). Significant volumes of CO_2 are emitted by these power and industrial facilities. According to data available through the US Environmental Protection Agency's Greenhouse Gas Reporting Program FLIGHT database, Plant Gaston emitted 2.9 million metric tons (MMmt) of CO_2 in 2023. The seven cement plants emitted 4.1 MMmt of CO2 in 2023. In sum, over 7 MMmt tons of CO2 were emitted in 2023 within 23 miles of the Project OASIS site location. Figure 1 shows the location of the Project OASIS location in Shelby County to the CO_2 sources from Plant Gaston, from the seven cement plants (20 miles), and from the pulp and paper plant (5 miles).

For the broader region, there are other notable emitters such as Alabama Power Company's Plant Miller, which is a coal-fueled power plant located in northern Jefferson County, Alabama that emits nearly 16.5 Mmt of CO_2 on annual basis. In total, there are nearly 27 Mmt of CO_2 emitted from 20 separate facilities on annual basis within a 60-mile radius of the Project OASIS location. While there is certainly demand for decarbonization solutions in the region, challenges associated with pipeline routing around urban centers and public opposition to linear infrastructure are well documented. Because of this, the Project Team elected to focus this assessment on those emissions closest to the Project OASIS site (Figure 1). Table 1 enumerates proximal facilities by type and shows annual emissions as well as proximity to the Project OASIS site.

Table 2. List of emitters shown in Figure 1, annual CO_2 emissions, location, and proximity to the OASIS site. Emissions data are from the US EPA GHGRP FLIGHT database.[2]

Cement and Limestone Industry	CO_2 Emissions	Latitude	Longitude	Distance to OASIS Site
ARGOS Cement LLC	1,054,894	33.104	-86.799	22
Carmeuse Lime & Stone Inc.	516,089	33.219	-86.786	18
Cheney Lime and Cement Company	493,165	33.223	-86.807	19
Mississippi Lime Co	462,637	33.094	-86.795	22
Lhoist North America - O'Neal Plant	600,146	33.177	-86.759	17
Lhoist North America - Montevallo Plant	974,682	33.093	-86.802	23
Power Generation	**CO_2 Emissions**	**Latitude**	**Longitude**	
E C Gaston	2,978,599	33.244	-86.457	4
Pulp and Paper	**CO_2 Emissions**	**Latitude**	**Longitude**	
Resolute Forest Product - Coosa Pines Operation	153,567	33.327	-86.358	8

Transportation Options

The development of the fossil fuel industry and support for fossil-fuel based power generation has resulted in a robust transportation system that may be well suited to support the movement of CO_2 throughout the state in the form of existing rights-of-way. The transportation of CO_2 can be achieved through pipelines, tanker truck, rail, or barge. Optimizing the cost of transporting CO_2 has an outsized impact on the deployment of CCS projects as the costs associated (on a per ton basis) with constructing capture facilities leaves little room for excess costs associated with transportation and storage. Table 3 summarizes CO_2 transportation mode, estimated costs, and relevant considerations. While there are merits to transportation via ship and train in other settings, the remainder of this assessment for Project OASIS will focus on pipeline and truck transportation options.

Table 3. Summary of CO_2 transportation modes and use cases. Capacity and situational uses are derived from sources such as the Global CCS Institute.[3]

Mode	Capacity	Best For
Pipeline	High	Long-term, large volumes
Ship	Large	Long distances, overseas
Truck	Low	Short distances, small volumes
Train	Moderate	Medium to long distances

[2] US Environmental Protection Agency Greenhouse Gas Reporting Program FLIGHT 2023 Database: https://ghgdata.epa.gov/ghgp/main.do?site_preference=normal

[3] Global CCS Institute, CCS Explained: Transport: https://www.globalccsinstitute.com/ccs-explained-transport/

Transportation Corridors

Figure 2. Satellite image illustrating transmission lines (white lines) emanating from Plant Gaston (green circle), and the location of Project OASIS (white diamond). OASIS is 4 miles north-northwest of Plant Gaston.

Alabama has an extensive pipeline and electrical distribution systems delivering natural gas and energy to industrial and power generators across the state. Utilizing existing pipeline and utility transmission line easements may allow for the simplification of potential permitting issues and may reduce the environmental impact of the construction of new pipelines. While the use of existing power and pipeline rights of ways may reduce the cost and potential environmental impact of new CO_2 pipelines, they also align with many of the point sources of CO_2. A good example of this is the relationship between the Project OASIS site and transmission lines emanating from Plant Gaston (see Figure). In general, pipeline transportation for CO_2 is the most effective and cost-efficient way to transport large volumes of CO_2 over long distances. The cost of pipeline construction may be significant for some of the smaller emitters near the OASIS project and for their projects to be commercially viable the use of alternative methods to transport captured CO_2 may need to be considered.

Truck Transportation

In cases like those observed for Project OASIS, it is possible that transportation of CO_2 via tanker trunk may prove more efficient. Alabama has an existing and robust trucking industry that could be used to support the use of truck to transport CO_2. Based on information from the Alabama Trucking Association, 80% of total manufacturing tonnage in the state is transported via truck with over 86% of Alabama communities relying exclusively on trucking to send or receive goods. In 2021, Alabama trucking businesses provided 125,110 jobs, or about one in 13 in the state.[4]

Economics of Trucking vs. Pipeline Transportation

As noted above, the use of trucking may provide an opportunity for smaller projects to begin operation and as volumes of captured CO_2 increases, alternative options, including pipelines, may prove to be more economical to operate. Lawrence Berkley National Laboratory conducted a study to quantify the costs of transporting CO_2 by truck, considering both the volume and distance of CO_2 transported. Of the viable transportation options, trucking CO_2 was found to be the lowest cost, non-pipeline, CO_2 transportation option. A typical tanker truck can transport 23 metric tons of CO_2.

[4] Alabama Trucking Association: https://www.alabamatrucking.org/about/fast-facts-and-stats/

Using the information developed by Lawrence Berkley National Laboratory[5] on CO_2 transport trucking costs and information from Advanced Resource International's CO_2 Pipeline Cost Model it can be determined that CO_2 pipelines are the lowest cost transportation option for any volume of CO_2 greater than 400,000 tons per year. However, as the data in Figure 3 shows, tanker truck transportation is the lowest-cost option for transporting any volume of CO_2 under 400,000 tons per year over a distance greater than 200 miles. Truck transportation is also the lowest cost option for transporting 100,000 metric tons greater than 50 miles, and 200,000 tons greater than 75 miles. As noted in Table 1, there are over 7 Mmt of CO_2 emitted within 23 miles of the Project OASIS site, suggesting that transporting any single facility's CO_2 emissions in the region to the OASIS site will be most economic via CO_2 pipeline (if ignoring the poor storage efficiencies observed at the site).

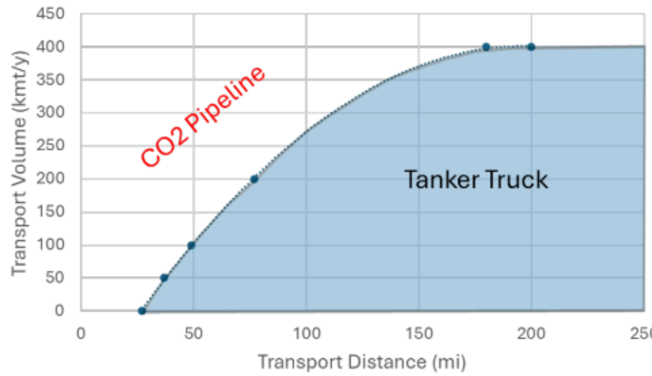

Figure 3. CO_2 transportation cost curve for tanker truck and CO_2 pipeline.

Scenario

A scenario is envisaged wherein Plant Gaston has installed a 650 MW capture island that operates at 85% capacity to capture CO_2 from two of the Plant's four 270 MW natural gas combined cycle units (F Class) to capture approximately 1.7 Mmt of CO_2 per annum. A 6-inch diameter pipeline connecting the Project OASIS site to Plant Gaston follows existing transmission line rights-of-way to minimize pipeline length to 4 miles across flat terrain. CO_2 is then transferred to 12 separate injection wells via infield pipelines where the CO_2 is ultimately stored in the Cambro-Ordovician Knox Group for permanent storage. The all in capital cost for this scenario approaches $1 billion without inclusion of site access costs, in-field monitoring wells, permitting costs, among other considerations. Assuming 12 years of capture at $85 a ton of CO_2 for saline storage (value of 45Q as of 2024), a total tax credit value of $1.7 billion is realized, resulting in a net benefit of approximately $700 million. It is important to note that these calculations do not include operations and maintenance (O&M) expenses which may approach $10 per ton of CO_2. Inclusion of other capital costs and O&M is likely to result in a project that is uneconomic.

[5] Myers, C. Wengin, Li. Markham, G. "The cost of CO_2 transport by truck and rail in the United States." International Journal of Greenhouse Gas Control, Volume 134, May 2024.

Table 4. Summary of capital cost estimates for a scenario wherein a 650 MW capture island is installed at Plant Gaston. Captured CO_2 is transported via a 4-mile pipeline to the Project OASIS site for injection.

Component	Scenario	Capital Cost	Source
Capture Island	650 MW ($1.3 million per MW)	$ 845,000,000.00	OCED Porfolio Insights: Carbon Capture in the Power Sector[6]
Pipeline Transportation	4-mile, 6-inch diameter	$ 7,500,000.00	National Energy Technology Laboratory, FECM/NETL CO_2 Transport Cost Model (2023)[7]
Injection Wells	12 total at 0.14 Mmt per annum	$ 120,000,000.00	CarbonSAFE Phase III Program

Next Steps

This preliminary infrastructure assessment will be updated in 2025 as the Project OASIS team generates more data. As part of this, the dynamic model will be updated to explore a scenario with 12 injectors to ascertain area of review and the necessary land requirements to support 50 Mmt over 30 years. In addition, tri-axial test data will be collected in collaboration with the National Energy Technology Laboratory to better constrain fracture gradient. These data may significantly impact observed injectivities at the Project OASIS site. In turn, the number of wells required to achieve CarbonSAFE objectives (50 Mmt of CO_2 over 30 years) and capital costs associated with storage field development may also change. Together, improvements to these factors could potentially expand the commercial (and infrastructure) discussions around Project OASIS. In addition, the Project OASIS team will evaluate the viability of a variety of commercial scenarios for the site including but not limited to (1) capture and transportation from a natural gas combined cycle power plant, (2) a cement manufacturing facility, and (3) bespoke project development such as intermittent use cases.

[6] OCED Porfolio Insights: Carbon Capture in the Power Sector: https://www.energy.gov/sites/default/files/2024-04/OCED_Portfolio_Insights_CC_part_i_FINAL.pdf

[7] National Energy Technology Laboratory, FECM/NETL CO2 Transport Cost Model (2023), National Energy Technology Laboratory, Last Update: Jul 2023 (Version 4), https://netl.doe.gov/energy-analysis/search?search=CO2TransportCostModel.