Carbon Capture, Utilization, and Storage in the Southeastern U.S.: Cost Competitive?

Rich Simmons
Sharon Murphy
Energy, Policy, and Innovation Center
Georgia Institute of Technology

November 2022

Georgia Tech
Energy, Policy, and Innovation Center

Introduction

Achieving net zero carbon emissions will require a combination of renewable energy technologies and carbon capture. Indeed, a great deal of investment has been devoted to the source side of the ledger, such as replacing fossil fuels with renewables, making combustion processes more efficient, and leveraging nuclear energy. Considerably less funding has flowed toward solving the problem of accumulating emissions in the atmosphere, for instance by capturing carbon at the point of electricity generation, or extracting carbon prior to combustion. Nonetheless, a variety of studies have shown that the lowest societal cost means of achieving net zero emissions, as well as ensuring a resilient grid, must include carbon capture. This whitepaper discusses the role of the southeast in this broader nation carbon capture landscape, particularly focusing on the question **"What will be the role of Southeast region in this broader national carbon capture effort in the United States?"**

Background

A report released in 2019 by the National Petroleum Council on the state of carbon capture, utilization, and storage (CCUS) in the U.S. provides a foundation to help us understand how a given region compares to others, or the U.S. at large. The NPC report asserts that the U.S. has significant storage resources. Released in December of 2019, the report, *Meeting the Dual Challenge: A Roadmap to At-Scale Deployment of Carbon Capture, Use, and Storage*[1], establishes the baseline of the current state of CCUS in the U.S., addresses barriers to adoption, and also provides recommendations on how to overcome these barriers in order to deploy CCUS technologies at scale in the energy and industrial sectors. According to the study, the U.S. has several significant assets which can accelerate the pace of progress. The United States has:

- ample geologic formations suitable for CO_2 storage;
- a robust regulatory framework underpinned by policy support;
- world class research capacity; and
- a business climate that fosters innovation.

These assets make the U.S. the global leader in CCUS deployment representing nearly 80% of the world's CO_2 capture capacity. However, the reality is that the world's current CO_2 capture capacity is exceedingly small relative to overall CO_2 emissions from stationary sources. More precisely, only about 1% of the annual U.S. CO_2 emissions from stationary sources are captured and stored or utilized. The share is obviously even lower if mobile sources are included. With growing public concern about the environment, and increasing discourse among governments, businesses and academia, there is clearly a desire to improve the effectiveness and pace of CCUS deployment. At the same time, every project seems unique, technically challenging, regionally sensitive, and extremely expensive.

1 https://dualchallenge.npc.org/

Technical Challenges

While these challenges are somewhat intertwined, let us first briefly address the technical challenge, then regional factors, followed by the cost. Beginning in 2002, Energy Secretary Abraham announced a new phase of DOE research devoted to carbon storage technologies. Over the ensuing two decades, a national network of Regional Carbon Sequestration Partnerships (RCSP)[2] has been developed, leading to a number of innovations, technological insights and lessons learned. The objective of this multi-decade, interdisciplinary program was to help determine and implement the technology, infrastructure, and regulations most appropriate to promote carbon storage in different regions of the U.S. and portions of Canada. The project milestones include successfully concluding multiple small- and large-scale injection test projects and storing more than 12 million metric tons (MMT) of carbon dioxide (CO_2) in geologic formations with no indications of negative impacts to either human health or the environment. While some technological challenges are site-specific or scale-dependent, DOE states that enabling technologies have been characterized, validated, and that this program has successfully set the stage for commercial-scale deployment of safe and durable geologic storage of captured CO_2. In fact, the very presence of the National Carbon Capture Center, (NCCC)[3], housed in Alabama, attests to the public-private commitments to explore and validate CCUS technologies at a full full-scale electricity generation facility. Other significant technical lessons were also learned from the Kemper, Mississippi Integrated Combined Cycle Plant with CCS[4]. Though the intent to sequester and utilize CO_2 derived from lignite coal was deemed technically feasible at scale through partial validation (2010-2017), the pre-combustion CCUS technology was not put into service because of constrained economics and regulatory decisions at the state level. Instead it was converted to a natural gas combined cycle plant. Of the original seven DOE RCSP projects, four were competitively selected in late 2019 to kick off the most recent phase of regional scale up and demonstration. The estimated government funding for the DOE' RCSP initiative over the past twenty years is about $2.5B.

Regional Considerations

Which brings us to the **regional considerations**. A key goal in the government-funded program was to determine the most suitable technologies, regulations and infrastructure for CCUS **in each region**. The emphasis on regional sensitivity is important, because it should be explicitly noted that it is exceedingly complex to compare CCUS projects of different technologies or under various regulatory frameworks, let alone between varying US regions having unique geological characteristics. Each of these variables introduces uncertainty, and there are additional unknown uncertainties introduced by interactions thereof. That said, the current four demonstration projects are located across diverse U.S. regions and based in the following states: N. Dakota, Illinois, Texas, and Alabama.

Through the then current phase, one important aspect that the DOE programs did not fully include in their scope, nor could sufficiently address due to a lack of data, was the cost of CCS. Another important aspect that was not fully addressed was the relative merit of onshore vs. off-shore CCUS project siting. This made sense in the early days of the program, given the need to validate projects in states and regions with both significant sources of CO_2 as well as potential sites and uses for it (e.g., geologies

---

2 https://netl.doe.gov/carbon-management/carbon-storage/RCSP

3 https://www.nationalcarboncapturecenter.com/
The NCCC was created by the DOE in 2009, and is managed and operated by Southern Co.

4 For more on the technology readiness and feasibility of the Kemper project, please see the "Report out of the Technical Review of the Kemper IGCC Plant with CCS" at: https://epicenter.energy.gatech.edu/studies/

and applications, including Enhanced Oil Recovery or EOR). It was also a practical matter- first of a kind demonstrations are simply more feasible onshore. The dramatic scale of wind energy across the world is further testament to this progression from on-shore to off-shore if/when viable. In the current phase of the partnerships, two efforts are now underway to explore the potential for offshore CCUS projects, both of which touch the Southeast region. The first, is the Gulf of Mexico Partnership for Offshore Carbon Storage (GoMCarb)[5] and the second, is the Southeast Regional Carbon Storage Parternship: Offshore Gulf of Mexico (SECARB Offshore)[6]. While the Southeastern U.S. is rich in subsurface geologic storage sites , much of the future potential occurs offshore. While this brings certain challenges related to technology and economics, it also may offer significant opportunities to navigate direct risks to population centers associated with leakage, seismic activity, access, and land use.

CCUS Costs

There are several reasons why **CCUS costs** seem exorbitant relative to their existing limited contributions to decarbonization. First, markets and regulations have generally avoided taxing carbon directly, which makes incumbent technologies comparatively cheaper, since externalities associated with CO_2 emissions are ignored, or considered of zero market value on a first-order basis. That said, some states have policies that may intervene to influence how carbon is regulated (e.g., Renewable Portfolio Standards (RPS), tax incentives on renewables, etc.). In addition to high costs, there are additional considerations that make it complicated to compare CCUS or abatement costs between states. Second, costs to implement CCUS at scale are driven by supply chain factors that require significant capital investment and on-going operational expenses. Again, this can be influenced by local or state business contexts and regulations. To encourage the development of CCUS infrastructure, economic incentives that reduce capital and operational costs across the supply chain are necessary at many jurisdictions (e.g., Federal, State). In summary, CCUS projects at scale have generally been characterized by both high costs and high levels of uncertainty, but ongoing R&D expenditures and policy support have been designed to mitigate both high costs and uncertainty.

In addition to the formal DOE funding that has targeted research, development and demonstration of CCS technologies, the **Bipartisan Infrastructure Bill** signed by President Biden in November of 2021 includes approximately $12b (U.S.D.) in appropriations earmarked for CCUS research and development that aims to alleviate the cost barrier and spur innovation. About $4B from these funds will be allocated to support new R&D and demonstration aimed at Direct Air Capture (DAC), which is the field of CCS devoted to dilute capture of CO_2 (for example from the air in the atmosphere as opposed to a flue stack of a power plant or an industrial facility). These unprecedented increases in federal funding for R&D and demonstration for CCUS technologies are augmented by other rapidly evolving policies at the national level such as the **Section 45Q Carbon Capture Tax Credit**.

Section 45Q was first enacted in 2008 and was designed to incentivize the reduction of carbon oxides (monoxide, dioxide, suboxide) emissions and bolster the infrastructure for the storage and repurposing of CO_2, such as geologic storage and enhanced oil recovery (EOR). Since then, section 45Q has been periodically updated by increasing the available tax credit, but in 2022 it received an unprecedented level of federal support with the passage of the **Inflation Reduction Act (IRA)**[7, 8].

---

5 https://www.beg.utexas.edu/gccc/research/gomcarb
6 https://www.sseb.org/programs/offshore/
7 https://www.congress.gov/bill/117th-congress/house-bill/5376/text
8 For an overview and key implications of the Inflation Reduction Act, please see, for example, the Carbon Management Section of: https://bipartisanpolicy.org/blog/inflation-reduction-act-summary-energy-climate-provisions/

The IRA:

- Provides an increase of CCUS tax credits across the board, making CCUS more accessible and attractive to investors.
- Provides an extension of 7 years to the commence-construction window.
- Creates a direct-pay option for entities deploying CCUS to receive tax credits.
- Broadens the definition of a qualifying entity by decreasing the threshold of CO_2 emissions needed to qualify, thereby increasing the number of facilities who can claim 45Q tax credits.

All of these measures have been architected to incentivize innovation, investment, and scale up specifically for CCUS technologies. The overall goal is to increase economic viability and reduce risk incurred by public and private entities. Technological assessments throughout the country that were previously deemed non-economic will likely be reassessed against these new support measures.

Among other decarbonization provisions aimed predominantly at renewables, the **Advanced Energy Project Credit**[4, 5] extends a 30% investment tax credit to several technologies explicitly including carbon capture, transport, utilization, and storage systems. The intent of all these policies is to help mitigate research investment, technical risk, and fixed and variable expenses incurred when implementing CCUS technologies.

Analysis and Discussion

So, back to the key question of this whitepaper, What does the future of CCUS in the Southeastern U.S. look like? The costs to implement a robust CCUS supply chain are dependent on CO_2 concentrations at the emissions source, transportation costs from source to storage site, and storage costs. The Southeast lacks extensive CO_2 transportation assets (such as pipelines) but has abundant geologic storage options (such as suitable rock formations and saline reservoirs). How much will it cost to build out the CO_2 transportation infrastructure and leverage the geologic storage capacity in the Southeast?

The first step toward this answer relies upon a standardized methodology for cost estimation, in spite of obvious differences between projects. The researchers involved in the NPC report have taken rigorous steps to ensure the modeled results can be fairly compared. The NPC study included the costs to capture (excludes direct air capture), transport, and store CO_2 emissions from the largest 80% of stationary sources, according to the EPA FLIGHT database, in the contiguous United States. The result was the inclusion of roughly 850 facilities across the country. The analysis also included the following assumptions[9]:

- 20 year asset life
- 12% internal rate of return
- 100% equity financing
- 2.5% inflation rate
- 21% federal tax rate

Though granular data identified, derived or modeled within the study were not made available to the public (for reasons of data privacy and ownership rights), the NPC agreed to provide a subset of data to help our team compare Southeastern projects to U.S. projects overall. As such, the NPC

9 The National Petroleum Council report can be found here: https://dualchallenge.npc.org/. Methodology can be found in chapter 2.

collaborators provided a cost curve for the southeastern U.S., based on the same assumptions they used to produce the national cost curve from their 2019 report.

We determined from this that the SE accounts for about ¼ of all US stationary source CO_2 emissions. This is significant and means is it roughly on par with other US regions in terms of aggregate emissions. The blue line in Figure 1 shows the cost curve for the cumulative CO_2 emissions abated against the cost for capturing, transporting, and storing CO_2 in the Southeast[10]. CCS cost (in $/ton) appears on the Y-axis and the cumulative emissions are shown on the X-axis. To help interpret this, it is useful to consider that projects are plotted in rank order of increasing cost (lowest cost projects appear nearest the origin, since they would presumably be implemented first).

In order to facilitate a cost-curve comparison between the SE and CCS projects throughout the rest of the country, we perform a simple adjustment to the aggregated national data. We make an assumption that national projects have a unique distribution for costs across a larger volume of aggregated emissions (about 4x). However, we can retain the full (cost-side) characteristic of the national cost-curve by compressing the x-axis by an amount equal to ratio of SE/US projects. In other words, we assume the US has the potential to sequester a volume only equal to the SE share, but at the cost/ton of the specific project regardless of its region. In this way, we can see where, in terms of cumulative project size, the SE region is competitive with the national trend, and also where the SE is more expensive. It should be noted that by following this methodology, we would never expect to see a case where the SE is lower than the national trend. The reason is that when the SE is the lowest (most competitive) project at a given storage volume, it would then be exactly equal to the US national value. So, this comparative approach illuminates areas where the SE projects are "nearly the same" as the nation more broadly, and when they are "more expensive."

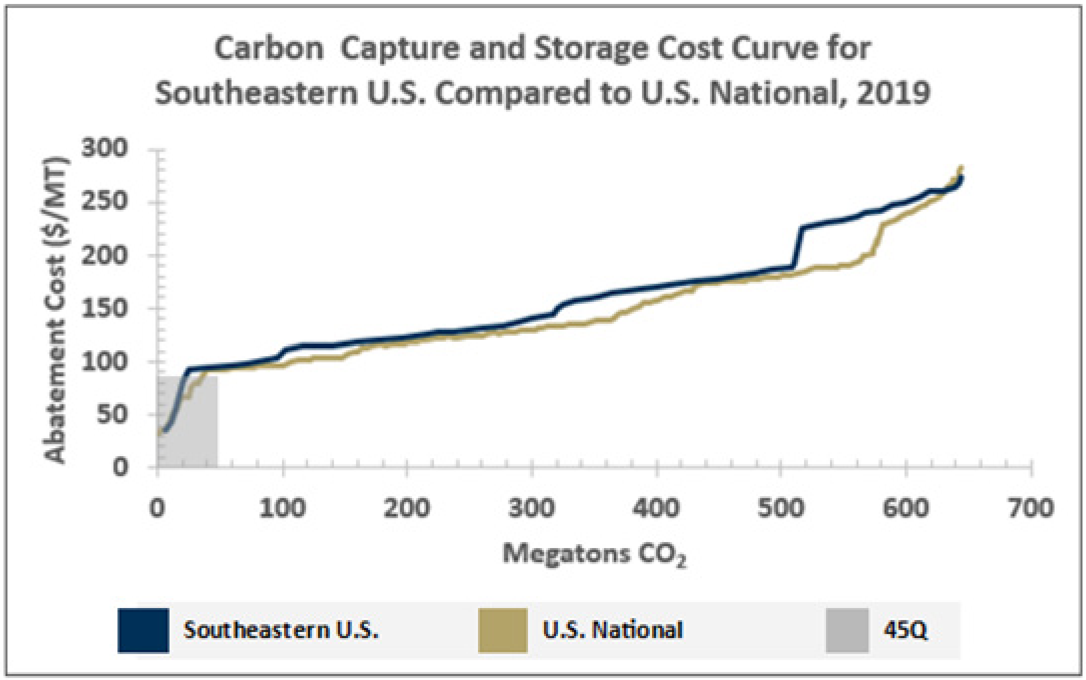

Figure 1. Cost Curve for CCUS projects in the Southeast Region compared to Scale-Adjusted Data for CCUS projects throughout the entire United States.

10 We define the Southeastern U.S. as including the following states: Alabama, Florida, Georgia, Virginia, South Carolina, North Carolina, Mississippi, Kentucky, and Tennessee.

As a result, the southeast line (blue) and the national line (gold) should be fully aligned for about 1/4 of the data points by volume, since this is how the compression of the national plot has been developed. And that is roughly what we observe. And further, this approach is a convenient way to see on a cost vs. volume basis, where those particular SE projects fall relative to the country overall.

The data show that, by and large, the Southeastern U.S. is fairly well positioned to be cost competitive with the rest of the nation. Figure 1 suggests that, for instance, one would not necessarily invest in "low hanging fruit" exclusively outside the Southeast, since there are meaningful quantities of cost competitive projects in the southeast region. However, it is apparent that the projects of lowest cost are cheaper elsewhere in the US than they are in the SE. This is evidenced by the fact that the gold line (US) in the (IRA/2022-updated) 45Q shaded block lies below the blue line (SE). This means that the "early projects" near the origin, or the ones most likely to be pursued first on an economic basis, would not generally be in the SE. However, several SE-based projects appear to be feasible at a cost of just below $100/ton, which is much closer to the newly revised 45Q tax credit value of $85/ton (IRA/2022).

Conclusion

This means that once the projects having net costs of below the tax credit value of $85/ton are funded, the next least expensive projects would fall in a sequestration volume between 40-100 MT, at a cost of around $100/ton. The Figure illustrates that these many of these projects could be just as competitive in the SE as some other region of the U.S. (by virtue of the fact that the blue and gold lines are roughly aligned). There are two additional segments along the cumulative sequestration axis where the two lines are again nearly aligned (range 2: 200-300MT/$110-$130/ton) and (range 3: 440-520MT/$170-190/ton). Notwithstanding a few important departures around the early-to-deploy projects, it would generally be accurate to state that the Southeast is not at a cost disadvantage when compared to the national cost curve. This does not mean that the Southeast is the most compelling U.S. region, as an in-depth look at the other regions in detail is beyond the scope of the present study. But it does suggest that any holistic plan to scale CCUS domestically should not exclude viable projects in the region.

In the 2019 report, the NPC recommended that Congress appropriate $1.5 billion per year for continued development of new and emerging CCUS technologies, including $300 million per year for large-scale pilot programs. With the passage of the Bipartisan Infrastructure Act and the Inflation Reduction Act, funding for CCUS will far exceed what the NPC recommended. In addition, the incentive to pursue new projects will be enhanced by the larger credits, lower minimum volume requirements, and extension of the in-service constraints. It is imperative that the Southeast be included early on in conversations regarding CCUS as a potential means to manage CO_2 emissions given the cost-competitiveness of the region.

At a high level, these data and observations suggest that the Southeast is a comparatively cost-effective location for Carbon Capture and Storage (CCS) relative to the United States, generally. Furthermore, given the recent enactment of Federal policy in support of clean energy and decarbonization technologies, the Southeast is as well positioned as other U.S. regions to take advantage of these funding opportunities to facilitate building CCUS capacity in the region. At the same time, all stakeholders would be wise to act quickly, partner prudently, and leverage insights and lessons learned from the United States and global leaders in CCUS. The interconnected factors involving CCUS technology, economics, and regulation will remain challenging, and will require innovative solutions and key public private partnerships everywhere.

Appendix

The source data and methodology that form the basis for the present Southeast regional investigation derive from a 2019 report by the National Petroleum Council entitled, “Meeting the Dual Challenge: A Roadmap to At-Scale Deployment of Carbon Capture, Use, and Storage.” A link to the website and more information is provided in this footnote.

The original 2019 NPC report was provided in part to address “the Secretary of Energy’s request for advice on the actions needed to deploy CCUS technologies at scale in the United States.” The report included several key conclusions about the scale-up and deployment of CCUS projects, stating that they require:

- strong collaboration between industry and government;
- improved policies, financial incentives, and regulations;
- broad-based innovation and technology development; and
- increased understanding and confidence in CCUS–to create a roadmap for achieving at-scale deployment over the next 25 years.

The NPC report includes an overview of the U.S. and global energy and CO_2 emissions landscape, the important role of CCUS to address both energy and climate change considerations, an overview of US-based deployment opportunities, a pathway that would enable the growth of CCUS in the United States over the next 25 years, and recommendations that enable each phase.

The NPC report considered U.S. stationary sources of CO_2 emissions including power plants, refineries and petrochemical plants, pulp and paper production, natural gas processing, ammonia production, industrial hydrogen production, industrial furnaces (including steel blast furnaces), cement plants, and the ethanol industry where the cost to capture, transport, and store CO_2 from each of the largest 80% of stationary sources is plotted against the volume of CO_2 abated from that source. The analysis comprises approximately 850 U.S. stationary sources of CO_2 emissions. The largest 80% of emitting sources in the 2018 EPA. Facility Level Information on GreenHouse gases Tool (FLIGHT) database, which tracks and reports U.S. CO_2 emissions, are included. In addition, fermentation emissions from ethanol plants larger than 100,000 tonnes/year that are not reported in the EPA FLIGHT database are included.

This Appendix is included to draw the reader’s further attention to the source study and its original methodology as a basis for the present effort. The original study did not group projects by U.S. regions, but it did capture individual sources of emissions and project locations with high spatial resolution and links to specific project specifications, including economics. Those data were represented graphically as bars along the cumulative abatement line (x-axis), as shown below in Figures 2-6 and 2-1 respectively.

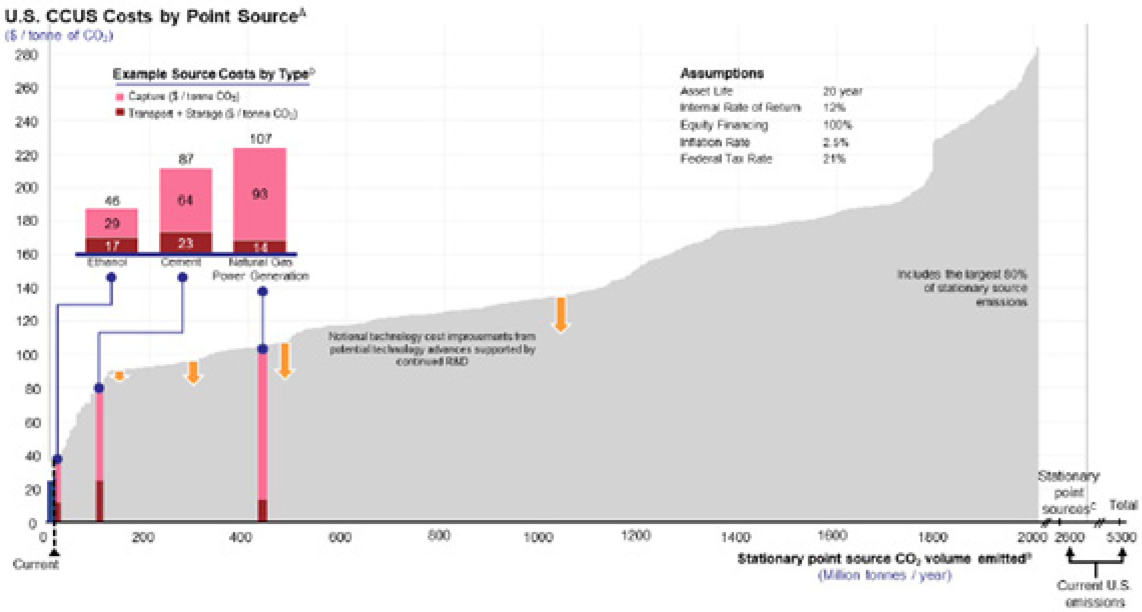

Figure 2-6. *U.S. CCUS Cost Curve*

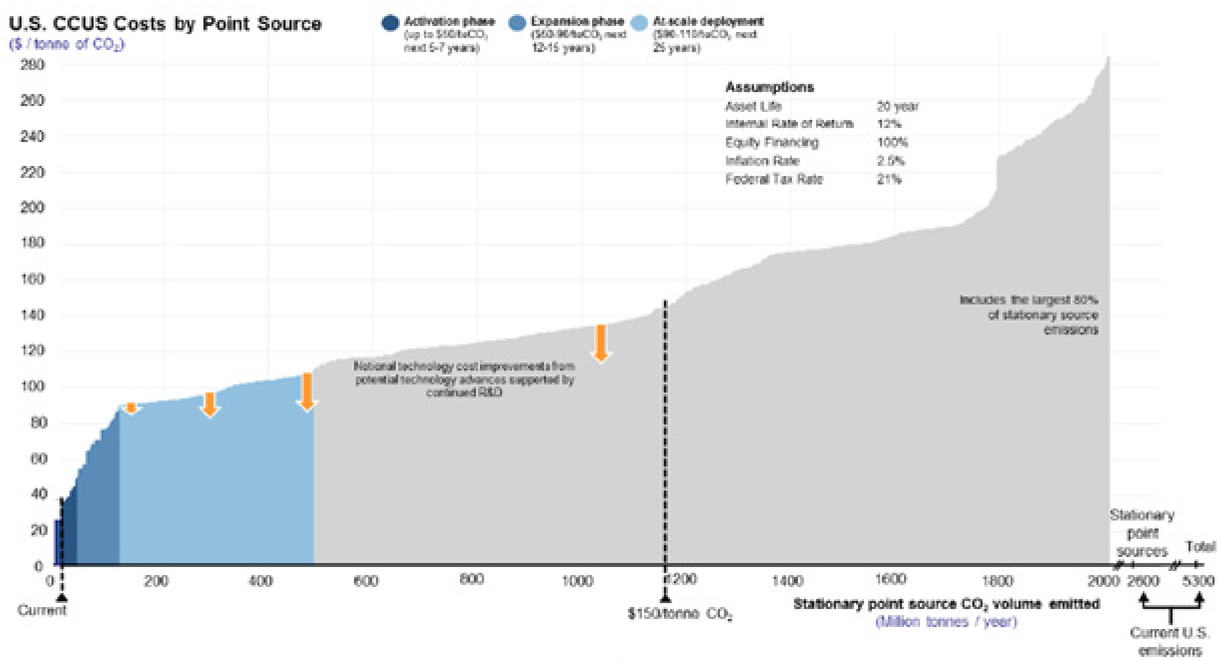

Figure 2-1. *U.S. CCUS Cost Curve*

Source: National Petroleum Council: "Meeting the Dual Challenge…"

The authors of the present study were intrigued by the NPC's aggregated national analysis, which inspired the present deeper look into projects located in states within the Southeastern United Stated. As noted earlier, we obtained an additional cost curve corresponding exclusively to Southeastern projects, which was culled from the original master set of U.S. projects. Then, to facilitate a comparison to the national curve, we reduced the scale of the entire U.S. curve by the ratio of the abatement volumes for the SE relative to the US as a whole, as explained.

About the Authors

Dr. Rich Simmons is the Director of Research and Studies at Georgia Tech's Strategic Energy Institute (SEI) where he leads cross-cutting energy projects with an emphasis on clean electric power, vehicle efficiency, and alternative fuels. He is also a Principal Research Engineer and part time instructor in the Georgia Tech Woodruff School of Mechanical Engineering, and holds a courtesy appointment in Georgia Tech's School of Public Policy. Rich received his BSME from Georgia Tech, MSME and PhD from Purdue, and is a licensed professional engineer (PE) with more than 25 years of RD&D and leadership experience in automotive, alternative energy, and fuels.

Sharon Murphy is the Energy and Public Health Program Lead for Georgia Tech's Strategic Energy Institute where she focuses on advancing public health and health equity issues that occur within the energy landscape. Sharon holds a Bachelor of Arts in Geography and a Masters of Science from Georgia State University, and a Masters of Applied Science in Spatial Analytics in Public Health from the Johns Hopkins University.

About the Energy, Policy, and Innovation Center

The Energy, Policy, and Innovation Center (EPICenter) was launched in the Fall of 2016 with the mission of conducting technical research, providing information on various contemporary topics in the energy field, and coordinating activities among leaders and innovators across industries and sectors. The Center explores the intersection of policy and technology, while leveraging the extensive expertise present across firms, research institutions, policymakers, and other government and non-government organizations in the Southeastern United States.

The Center is the first known implementation of a regional partnership to focus on the interdependencies of energy policy and technology in developing and implementing significant, cost-effective, and market-based carbon reductions. An assortment of deliverables will be produced by the Center, including but not limited to work products, events, educational outreach, and workforce development. Through these outputs, the Center strives to help accelerate a variety of reliable, affordable, and low-carbon energy options in the Southeast.

In executing its mission, EPICenter draws upon voluntary contributions from external organizations. The center is funded by an endowment and annual cash gifts to the Georgia Tech Foundation, and receives additional support in the form of personnel time and other in-kind contributions. Input from external entities that accompanies support, including recommendations related to center studies or operations, is subject to the discretion of EPICenter leadership. Similarly, no particular work product, findings, or implied results of center deliverables shall be linked, or give the perception of being linked, to a specific donation by any individual participant.

Joe Hagerman,
Director of EPICenter