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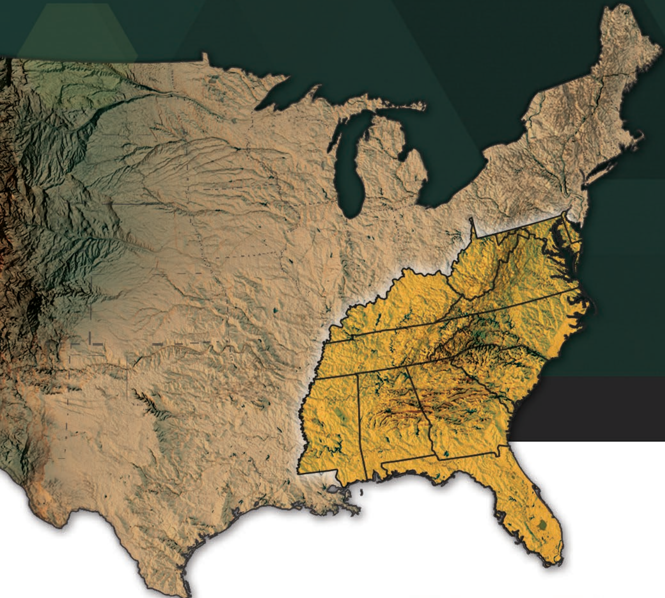

2023 SOUTHEAST DECARBONIZATION WORKSHOP

Activating science, business, and community partnerships

Marilyn A. Brown, Peter E. Thornton, Richard L. Gruber, Susan Hubbard, Melissa Lapsa, Edgar Lara-Curzio, Timothy C. Lieuwen, David McCollum, Michael Oxman, Richard A. Simmons, Don Stanton, Michael Twardy, Robert Wagner

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Prepared by
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Executive Summary

Decarbonization refers to a large-scale shift away from fossil fuel sources for energy production and toward energy sources, energy end-use practices, and land management approaches that do not result in a net increase of carbon dioxide in the atmosphere. Decarbonization in the Southeastern United States is distinguished from that of other regions in the country by its potential impact on historically underserved populations and the ways this region's human–environmental systems are predicted to fare in a climate-altered world. In parallel, ensuring a clean energy transition requires the ability to engage entire communities that are motivated to learn, build, and encourage the spread of so-called *clean tech*. In contrast to other technology trends from the past century, the foundation of clean tech is a shared sense of purpose—a collective strategy to mitigate the threats of climate change and support a better environment for everyone. As seen in the Office of Science and Technology Policy's (OSTP's) Net-Zero Technology Action Plan (2023), decarbonization is best accelerated by simultaneous investments in *Innovation*, *Demonstration*, and *Deployment* of technology in tandem with intentional policy and community-based solutions. The 2023 Southeast Decarbonization Workshop, hosted by the Georgia Institute of Technology (Georgia Tech) and Oak Ridge National Laboratory (ORNL), aimed to bring together members of our communities and a group of regional experts to strategize about opportunities in this important area, as well as to incorporate the important pillar of *System Interactions* to bridge the gap between clean tech's intent and its impact.

By bringing together diverse regional experts across non-governmental organizations (NGOs), academia, industry, national labs, and governmental/regulatory organizations, the Workshop succeeded in taking federal perspectives on climate change solutions and drawing out best-fit solutions for the Southeast in particular. For example, keynote speeches from Kelly Cummins (Office of Clean Energy Demonstrations, US Department of Energy [DOE]) and Mandy Mahoney (Building Technologies Office, DOE) allowed a federal perspective to ground the physical intention of clean technologies, while Keynote speeches from Nathaniel Smith (Chief Equity Officer, Partnership for Southern Equity) and Tim Echols (Vice-Chairman, Georgia Public Service Commission) emphasized the unique challenges and opportunities facing the Southeast. In addition to considering the federal perspective, we looked at clean tech through a local lens as well by, for example, featuring the multi-university work done by the Drawdown Georgia research team (focused largely on high-impact solutions ready for scaling). Inspired and motivated by these presentations, Workshop participants engaged in four Café Conversations—informal, intersectional working groups—to discuss key questions about the key themes of Innovation, Demonstration, Deployment, and System Interactions, adapted from the OSTP Net-Zero Technology Action Plan.

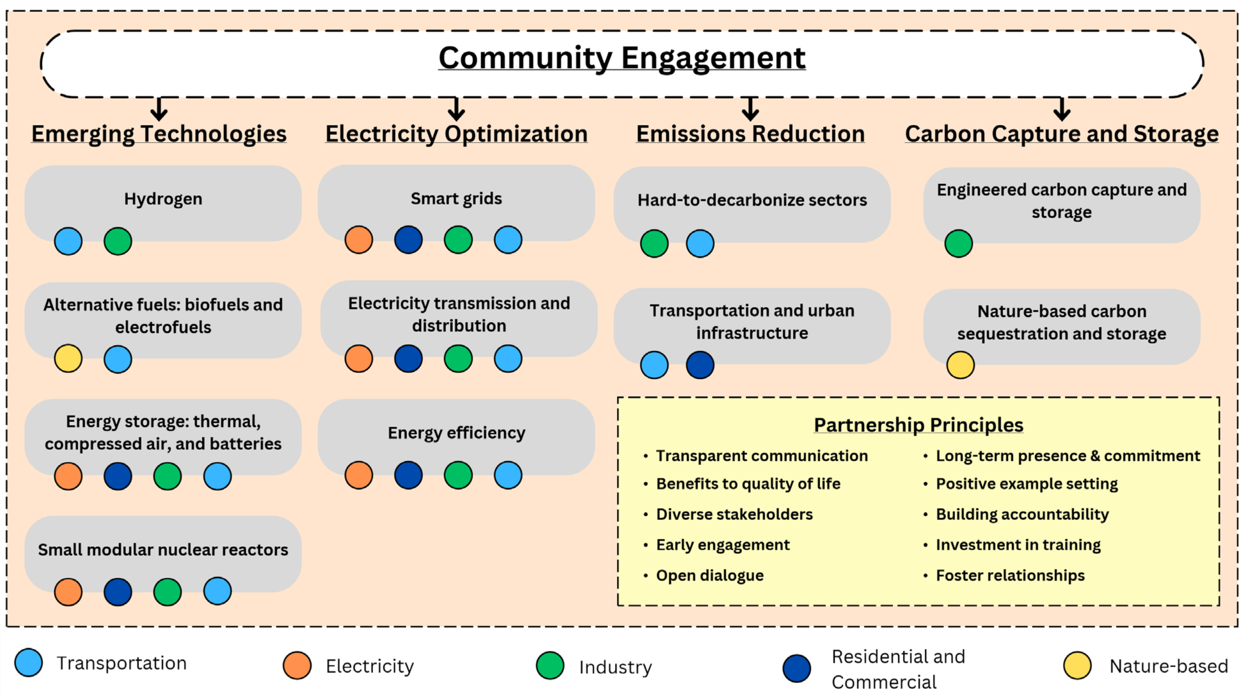
The notes taken during the Café Conversations and the feedback from participants revealed that the format cultivated an informal and relaxed atmosphere in which professionals and experts from a variety of backgrounds and specialties could have productive conversations about decarbonization and relevant solutions for the Southeast. Throughout the Workshop, principles of successful partnerships were discussed and are summarized in Figure S.1. Moving forward, these principles should guide community engagement and promote successful outcomes.

Figure S.1. Illustrative current initiatives and principles to guide future partnerships

Rather than focusing solely on *Technology Readiness Levels* (US DOE 2015), participants were generally more interested in discussing mechanisms that complement *Adoption Readiness Levels* (US DOE 2023). For example, Innovation and Demonstration are traditionally seen as stages that involve introducing and piloting the technical ability of a new technology, but participants focused instead on how these stages should incorporate social and financial criteria to confirm a technology's readiness. Suggested criteria include workforce development, social acceptance and rural adoption pathways, supply chain partnerships, and potential policy incentives. Participants focused on how these additional criteria can support the scaling of a decarbonization solution so that Deployment is less of a bottleneck, as well as how we can ensure equitable implementation of clean tech.

High-priority decarbonization solutions for future partnerships in the Southeast were identified by workshop participants. These and other solutions provide a wealth of opportunities for research partners to build on the momentum of our conversations and engage in the collaborative activities needed to accelerate the clean energy transition. Emerging technologies, electricity optimization, emissions reduction, and carbon capture and storage alike can be reinforced by community-engaged policy development that inspires place-based solutions, distributional equity, procedural equity, and the integrated deployment of decarbonization technology alongside communities instead of on their behalf. Figure S.2 summarizes key points discussed by participants about how the decarbonization pillars can be better supported by additional partnerships and better executed with strong partnership principles.

Figure S.2. Priority decarbonization solutions for future partnerships in the Southeast



Chapter 1. Motivation and Goals of the Workshop

In November 2023, Georgia Institute of Technology's (Georgia Tech's) Strategic Energy Institute and Oak Ridge National Laboratory's (ORNL's) Climate Change Science Institute hosted the Southeast (SE) Decarbonization Workshop. The event was motivated by the recognition that climate change is both a huge threat to the SE as well as a significant opportunity for the region. Climate extremes are intensifying, and the SE is particularly vulnerable to its consequences (National Climate Assessment 5 2023). At the same time, the SE is emerging as a major clean tech manufacturing hub in which significant investments are generating jobs and creating economic opportunities.

Against this backdrop, five goals were set for the Workshop:

- Strengthen our community of practice and build relationships
- Develop strategic prioritizations and partnerships
- Share timely decision support tools and data to decarbonize the SE
- Share essential information for public policy decision-makers
- Identify possible collective roles that we could play together following the workshop

These goals represent a recognition that an equitable transition to clean tech is crucial—one that brings benefits to historically underserved populations and regions. They also reflect the benefits of creating strong partnerships across the region.

Angel Cabrera, the President of Georgia Tech, offers a useful foundational perspective (Cabrera and Cutright 2023, p. 1):

> "The riches tapped by the industrial revolution have come at a dear price. We live longer, healthier, safer lives than any prior generation. Yet the innovations that made this possible also originated a set of complex challenges which threaten major human harm if not the very viability of our way of life."

Universities and research laboratories can play a major role in advancing decarbonization pathways to avoid future harm. To be sustainable, however, these solutions must also be equitable and inclusive. Effective partnerships are a means to this end, and they require a shared sense of purpose along with mutual trust and support—as well as a sharing of information and rewards (Butcher et al. 2011). Therefore, the theme of partnership principles pervaded the SE Decarbonization Workshop.

Recognizing the importance of SE decarbonization to both ORNL and Georgia Tech, leaders of both organizations helped to organize the Workshop and participated in it (Figure 1.1).

Figure 1.1. Leaders from Georgia Tech and ORNL at the SE Decarbonization Workshop

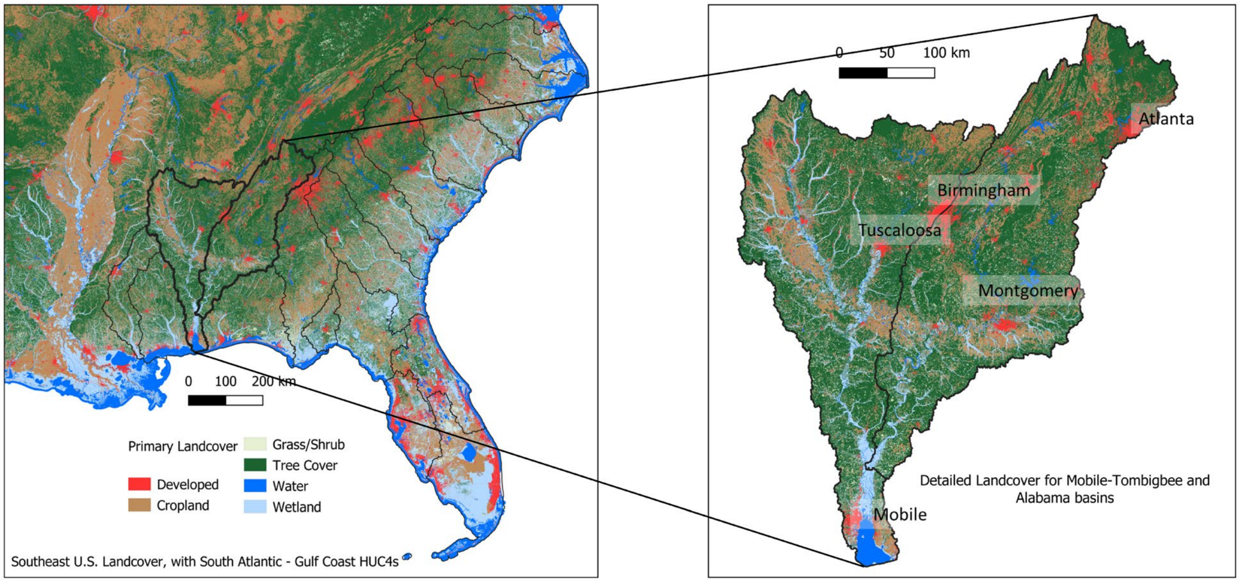
1.1 Why now, and why here?

Climate change represents both an existential threat and a monumental opportunity for the Southeast.

The ecological and human geography of the SE is distinctive: intensively managed agricultural and forestry production regions are interspersed with extensive inland and coastal wetlands, and both high-density urban and low-density rural populations are distributed across the region (Fig 1.2). The complex mixture of landcover and land uses creates opportunity for local-scale customization and optimization of decarbonization efforts.

Figure 1.2. Landcover and land use in the Southeast

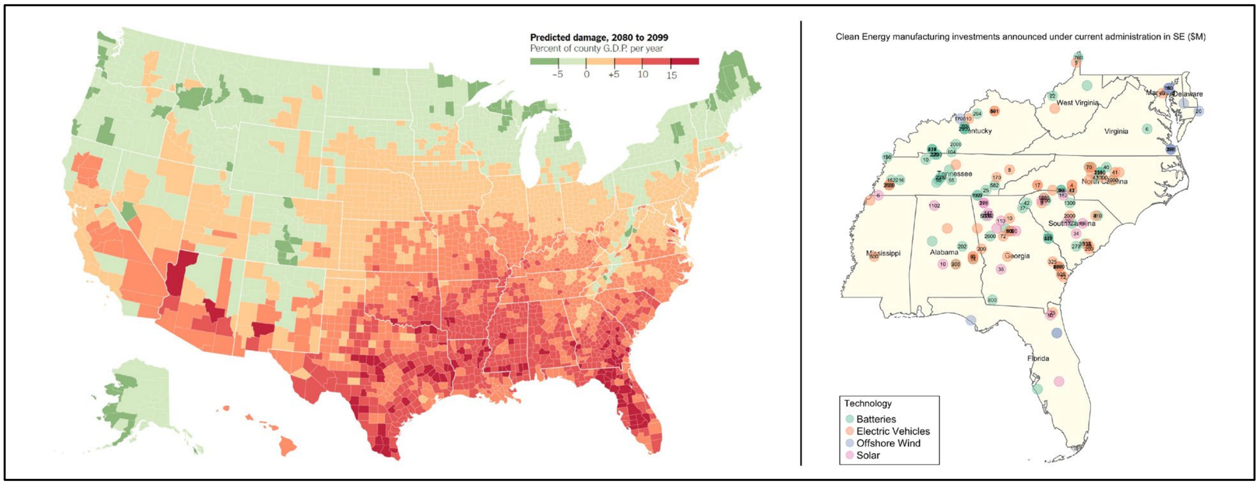
Forest cover, cropland, dense population centers, and inland and coastal wetlands are distributed across a fine-grained landscape mosaic in the SE. Watershed boundaries are used to show how similar biogeography and human geography patterns recur across the region. The detailed map to the right illustrates how landcover classes intermingle at fine spatial scales.



The threat of climate extremes is intensifying, and human systems are subject to increasing stresses; time is of the essence to reduce the world's and the region's risk of climate damages. The SE is particularly vulnerable to direct damages from climate change (Fig 1.3, left) as documented in the most recent U.S. National Climate Assessment (U.S. Global Change Research Program 2023). As a result, the SE's motivation to act is grounded in the recognition that the region has a great deal at stake.

Figure 1.3. Why now, and why the Southeast?

(Left): Estimated county-level damages quantified as percent of GDP per year for the period 2080–2099, under a high-emissions scenario (Adapted from Hsiang et al. 2017 as published by *The New York Times* June 29, 2017). (Right): Present-day clean energy manufacturing investments across the SE, as compiled by the authors of this report.



The SE is also emerging as a testbed for demonstration, deployment, and community engagement in a way that brings stakeholders together (Fig 1.3, right). Every dot in that figure represents at least $1 million of clean energy manufacturing investment announced in the SE under the current administration. The region is becoming a global hub for innovating and manufacturing the clean energy systems needed to address climate change.

At the same time, the US government will spend more than $500 billion on climate technology over the next decade, under three infrastructure laws passed since 2021:

- Infrastructure Investment and Jobs Act (also known as the Bipartisan Infrastructure Law, or BIL)
- Inflation Reduction Act (IRA)
- CHIPS and Science Act

Together, these resources will provide an unprecedented investment in strategic industries and tools designed to accelerate the production of clean technologies up and down the supply chain. These three programs have the potential to catapult decarbonization in the SE.

1.2 Creating a signature partnership

Recognizing the synergy between the goals of (1) averting climate risk and damages and (2) deploying science to create solutions and economic opportunities, ORNL and Georgia Tech established a signature partnership focused on the SE. Because successful partnerships must be inclusive and provide shared rewards, we concluded that a regional workshop with broad participation could catapult us forward.

From the beginning, our workshop planning was always mindful of the need for equitable initiatives—those that would create jobs and economic benefits for historically underserved communities in the SE. We also were determined to build strong and inclusive partnerships across the region that would lead to enduring relationships. In doing this, we built on an earlier workshop at Georgia Tech focused on electrification that was facilitated by the Beneficial Electrification League. We also built on the multi-university collaboration that produced 20 high-impact solutions through the Drawdown Georgia research initiative. In addition, members from the Drawdown Georgia Business Compact participated in the workshop (Brown et al. 2023).

Chapter 2. Workshop Overview

2.1 Workshop organization and attendees

We adapted the three-fold technology action plan of the White House Office of Science and Technology (OSTP) (2023) to organize the Workshop. The first leg of the OSTP's action plan involves investing in R&D to deliver game-changing innovations to ensure an adequate suite of technologies to reliably, affordably, and equitably achieve net-zero emissions by 2050. Attention then turns to demonstration, which supports early deployment of emerging technologies. The third leg of this stool uses regulations and financial incentives to accelerate manufacturing, deployment, and adoption of technologies that are currently available.

The workshop attracted 157 invited participants from 8 southeastern states and included academics, national laboratory scientists, and employees of businesses, government agencies, and non-governmental organizations.

Table 2.1. Participant Count by State and Sector

State	Count	State	Count	Sector	Count
AL	1	LA	1	Academia	52
CA	1	MN	1	National Lab/Research Institute	31
DC	2	NC	5	Government/Regulation	15
GA	74	SC	1	Industry	10
KY	1	TN	34	Non-governmental organizations (NGOs)	14
				N/A	**35**
157 participants from 10 states					

2.2 Why Café conversations?

The best part of going to conferences is often the conversation afterward over dinner, at a beer garden, or at a cafe the next morning. We brought the cafe to the conference with so-called *Café Conversations*—casual but meaningful group discussion—thereby creating an event that was largely conversational. We still had a speaker or two, but they only spoke for 5–10 minutes, and they ended by posing 1–2 powerful questions. These big questions guided the conversations, as providing meaningful and actionable answers typically requires innovation, deliberation, and consultation.

Figure 2.1. Participants engaged in the Café Conversations

Innovation Session

Demonstration Session

Deployment Session

System Interactions Session

During our conversations, participants were encouraged to think about decarbonization in different ways—to think outside the box, go beyond standard scientific frameworks, beyond typical business concepts, and even perhaps develop a novel "napkin" drawing.

In these conversations, we encouraged the discussion of possible collective roles that we could play together to answer key questions following our workshop.

In a fast-changing, competitive world, the consequences of change are not always obvious, and one person rarely has all the insights. Our cafes were meant to bring diverse perspectives together, connect people, and build relationships. To further engage all participants, we used prompted polling via the online "Slido" application.

2.3 Speakers and Slido participation

Keynote Speakers

- Kelly Cummins (Office of Clean Energy Demonstrations, DOE)
- Mandy Mahoney (Director, Building Technologies Office, DOE)
- Nathaniel Smith (Chief Equity Officer, Partnership for Southern Equity)
- Tim Echols (Vice-Chairman, Georgia Public Service Commission)

Insight Speakers

State and Local Government Speakers

- Anna Aponte (Georgia Environmental Protection Division)
- Helen Hossley (Special Projects Manager, North Carolina Dept. of Environmental Quality)
- Jason Lanclos (Director, Technology Assessment Division, Louisiana Dept. of Natural Resources)

Science and Technology Speakers

- B. Andrew Campbell (Tennessee Valley Authority)
- James Marlow (Southface Institute)
- Ben Preston (RAND Corporation)
- Kumar Venayagamoorthy (Clemson University)

Student Speakers

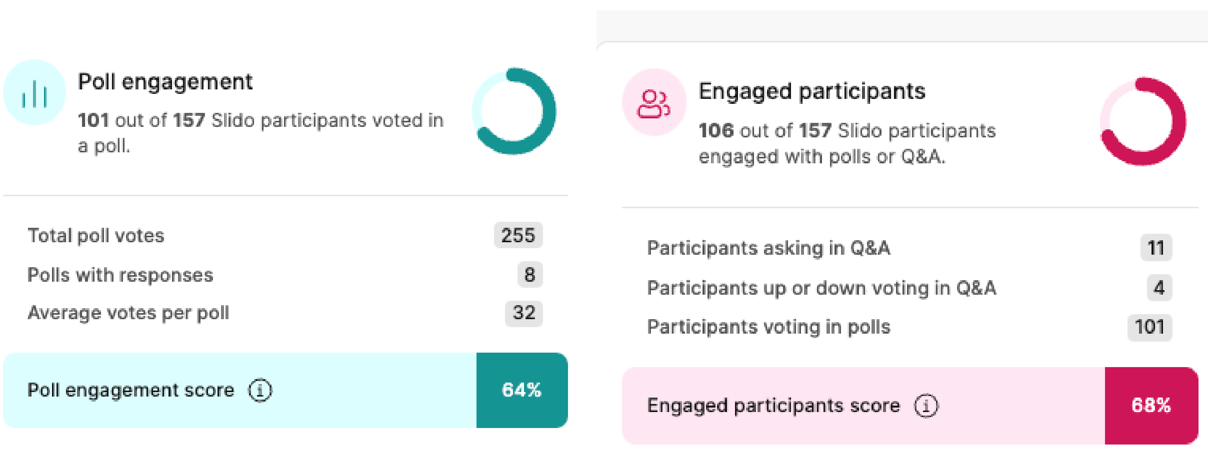
- Ryan Anthony (PhD Candidate, Georgia Tech – Climate and Energy Policy Lab)
- Oliver Chapman (PhD Candidate, Georgia Tech – Fellow, Brook Byers Institute for Sustainable Systems)
- Jack Churchill (MS Candidate, Georgia Tech – 2023 Spark Award Recipient)
- Azell Francis (PhD Candidate, Georgia Tech – Fellow, Graduate Sustainability)

Business Panelists

- Joanna Chavez (Global Sustainability Program Manager, Delta Air Lines)
- Burt Fealing (EVP, General Counsel and Chief Sustainability Officer, Southwire)
- Liz Minné (Global Sustainability Director, Interface)
- Ken Shiver (Chief Economist, Southern Company)

Figure 2.2. The CSO Business Panel

Figure 2.3. Slido Participation in the 2023 Southeast Decarbonization Workshop

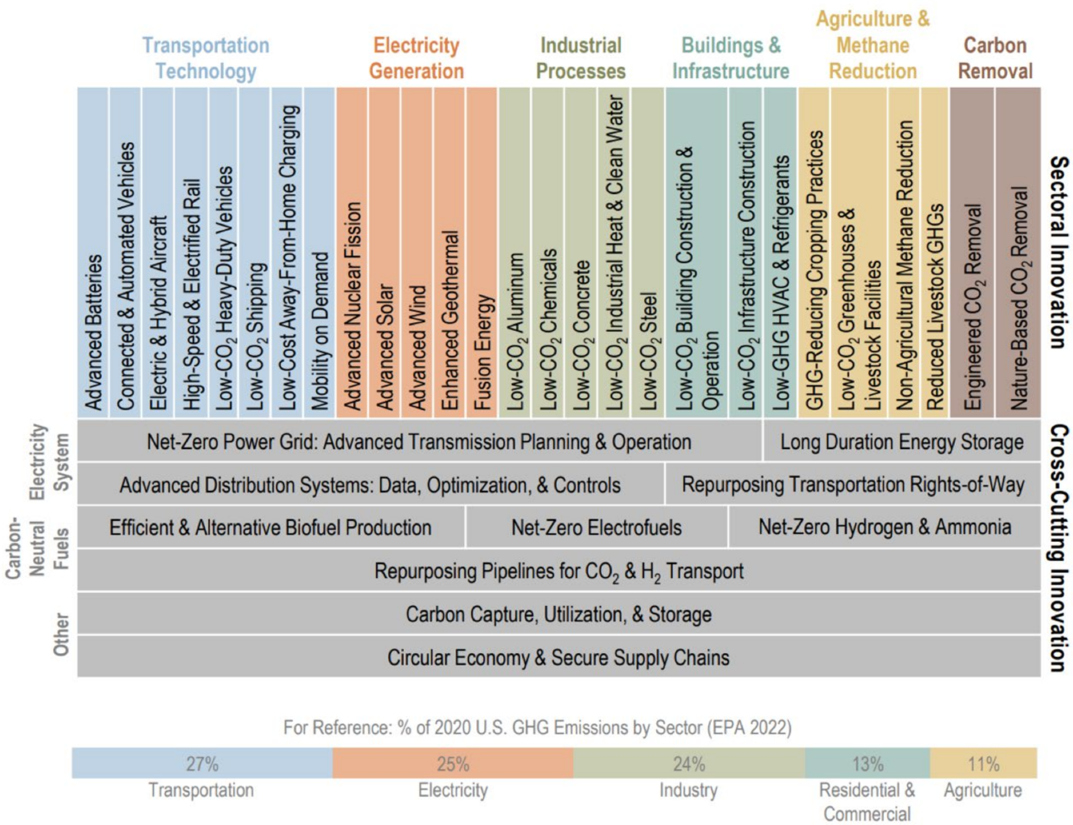


Chapter 3. Key Science and Technology Needs for Decarbonization in the SE

Going into the Workshop, the organizers considered the climate pollution sources and solutions prioritized by the White House OSTP (2023), as shown in Figure 3.1.

Figure 3.1. Decarbonization solutions prioritized by OSTP for the U.S.

(Sources: White House Office of Science and Technology Policy, 2023)

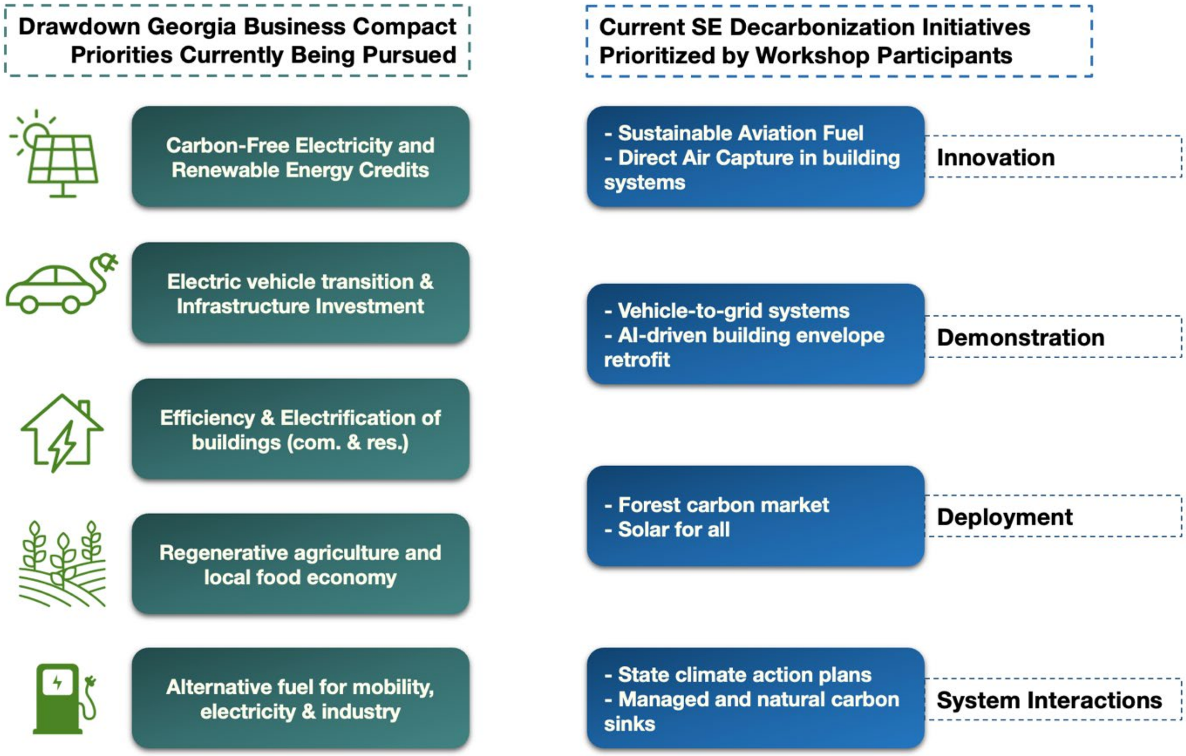


All together, these climate pollution solutions address "How we Get Around—How we Plug In—How we Make Things—How we Keep Cool and Stay Warm—and How we Grow Things."

Several illustrative current SE decarbonization initiatives were identified (Fig 3.2). Some of these emerged from the Café Conversations. Others were born of a multi-year prioritization process led by the Drawdown Georgia project and the 60+ members of its Business Compact.

Figure 3.2. Current decarbonization partnerships in the SE:

Representative list of topics prioritized by Drawdown Georgia and highlighted by workshop participants. A more comprehensive list of priorities emerging from the workshop is shown in Figure 3.3, and further details on topics prioritized during the workshop are provided in Sections 3.1–3.4.



Throughout the workshop and in follow-on discussions, participants described concrete examples of successful transitions of green solutions that progressed from the laboratory to the marketplace. These successes are highlighted in Boxes 1–4, which follow below.

Emerging from the SE Decarbonization Workshop, additional solutions were identified as important future priorities based on the notes taken during the four Café Conversations.

Box 1: Heat Pumps: From the Lab to the Marketplace

Scientists at ORNL played a pivotal role over multiple decades in bringing today's modern, high-efficiency and affordable heat pumps (HPs) into the marketplace. Their contributions include research on refrigerants to replace those with high global warming potential, materials and joining techniques to improve the efficiency and reduce the cost of heat exchangers, efficiency improvements through modeling and testing, improved mechanical designs to enable better air handling systems, and sensors and controls to promote reliability and interoperability. Numerous business and industry partnerships were keys to this success, including ASHRAE (headquartered in Atlanta) and Atlanta-based Rheem, which now manufactures the indoor heat exchange units used in the Fujitsu ductless mini split HP—the modern heat pump design that uses in-room "heads" to heat or cool zones in homes instead of ducted heat registers. ORNL and partners in Georgia are also working with Mitsubishi's ductless system, which will be featured in Mitsubishi's new $30 million U.S. headquarters for HVAC products being built in Atlanta.

Partnering with Georgia Power and the Southern Company, Rheem and ORNL collaborated to build a showcase residential development in Atlanta powered by rooftop solar systems and battery backup to provide reliable HP climate control and water heating, all managed in real time with advanced controls that respond to dynamic price signals. The market for HPs is relatively mature, but the technology is still rapidly evolving. Entering the mainstream in Europe in the late 1970s, the technology market share has slowly expanded, first in Europe and later in the U.S. and worldwide (Nyborgab & Røpke 2015). By 2020, Georgia was estimated to have approximately 1.14 million residential HPs, accounting for 29% of all primary occupied housing units in the state and the majority (55%) of units heated by electricity (EIA RECS 2020). Georgia has the eighth highest HP adoption rate in the U.S., though it ranks the lowest of four adjacent neighbors in the SE.

Research continues on cold climate HPs that will operate efficiently at low ambient temperatures in the Appalachian Mountains and in northern states.

Two targeted emissions reduction options:

- Hard to decarbonize sectors – aviation, maritime, manufacturing
  - Breakthroughs in aviation and maritime sectors, which currently lack clear decarbonization pathways. Sustainable aviation fuels (SAFs) need further development.
  - Breakthroughs in sectors such as steel, concrete, and glass manufacturing to reduce process emissions.
- Transportation and urban infrastructure
  - Innovations in urban design, transport, and infrastructure to reduce emissions from cities.
  - Data analysis and modeling.

Three electricity optimization solutions:

- Smart grids – load balancing and generation
  - Smart grid technologies to balance load and generation. Especially with increased electrification and distributed renewable generation.
- Electricity transmission and distribution
  - Energy transmission upgrades to support growth in renewables and electrification. Solving challenges of interstate transmission.
- Energy efficiency
  - Improvements in energy efficiency across sectors like buildings, manufacturing, and transportation. Developing new efficient appliances, processes, and automotive technologies.

Four emerging technologies:

- Small modular nuclear reactors
  - Small modular nuclear reactors to provide carbon-free baseload power.
  - Overcoming deployment barriers.
- Hydrogen
  - Infrastructure for hydrogen production, storage, and use. Plus demonstrating applications.
- Alternative fuels – biofuels and electro fuels
  - Next-generation biofuels and electro fuels that can provide low-carbon liquid fuels for sectors like long-distance transportation.
- Energy storage – thermal, compressed air, batteries
  - Advances in energy storage to support growth in renewables. This includes batteries, thermal storage, and technologies like compressed air storage.

Two approaches to carbon capture and storage:

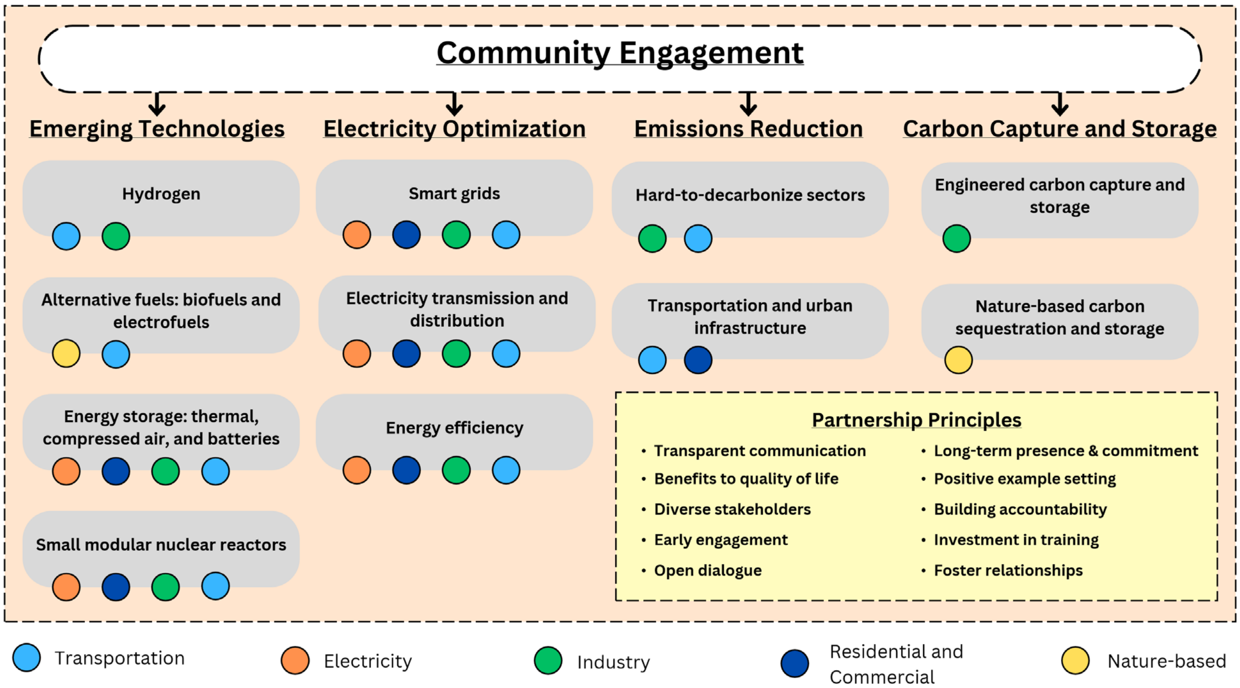
- Engineered carbon capture and storage
- Nature-based carbon sequestration and storage

Underlying all of these themes:

- Community-engaged policy development
  - Social science research to support community engagement, policy development, behavior change, and equitable outcomes.

These topics are summarized in Figure 3.3 and described in greater detail in Sections 3.1 to 3.4.

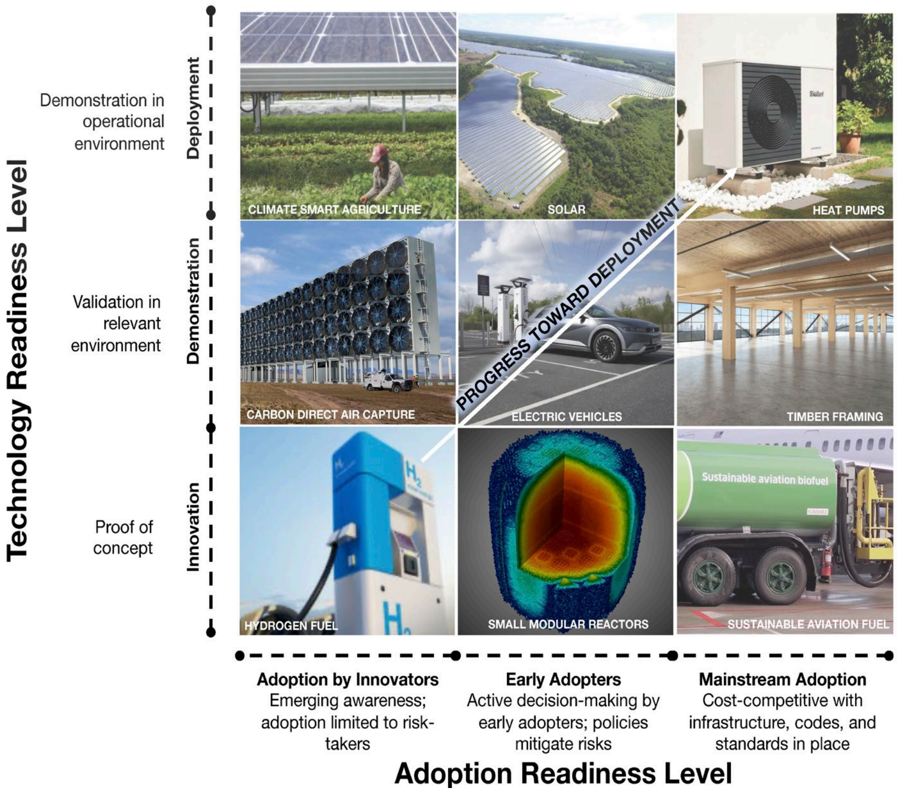
Figure 3.3. Priority decarbonization solutions for future partnerships in the SE



The timing and magnitude of decarbonization will depend on the technology and adoption readiness of the solutions (Figure 3.4). These two dimensions can be assessed using scales that reflect decades of experience and research.

Figure 3.4. Technology and Adoption Readiness Levels illustrated in the SE

(Adapted from DOE 2015 and DOE 2023)



Technology Readiness Level (TRL) documents the typical decadal transition of inventions into innovations during the discovery phase and subsequent R&D. The ensuing innovation typically requires further development to produce a final proof-of-concept that launches and enables deployment. During this transition, deep science proceeds to early stages of technology development. Laboratory and field demonstrations then ensue over additional years, followed by prototypes that operate in real-world settings. The final stage involves product proof-of-concept that could last several more years and typically includes pilot projects (Hughes, Yordi, and Besco 2020) and large-scale demonstrations (DOE 2015; Blackburn et al. 2020; Nemet, Zipperer, and Kraus 2018). These stages are displayed along the vertical axis of Figure 3.4.

Adoption Readiness Levels (DOE 2023) characterize decision-making and patterns of adoption from the perspective of those organizations and individuals that may deploy an innovation. Innovation diffusion theory presumes that new technologies and practices take hold partly as a result of a process of information diffusion and knowledge acquisition (Rogers 2003). Stages of adoption progress from knowledge/awareness (i.e., when firms and individuals are first exposed to the technology), persuasion (i.e., when information is being actively sought), decision-making (i.e., when the adoption decision is actively considered based on possible costs and benefits), implementation (i.e., when technology adoption occurs), and confirmation—which results in either continuation or retraction (Wolske et al. 2017).

This diffusion process is influenced by attributes of the innovation itself (i.e., its complexity and compatibility with current practices) (Wolske et al. 2020), the communication channels used to learn about it (e.g., via business affiliations or social relations, via in-person communications or mass media), and the policies and incentives implemented to direct investments toward social goods. Demand-pull and technology-push work simultaneously, but the balance between them can differ significantly (Nemet 2009). Communications track aspects of the business and social systems where prior adopters become opinion leaders fostering imitation. The adoption process involves moving from a state of awareness and attitude formation to decision, implementation, and confirmation or retraction. Organizations and people prefer to adopt technologies that are familiar to them and are less likely to adopt dramatically different energy technologies (Stern et al. 2016). Research on the technology adoption behaviors of firms and individuals often distinguishes them by the timing of their adoption decisions (innovators, early adopters, adopters, late majority, and laggards). Early and late adopters are driven by different values and have distinct characteristics: they are more or less innovative, educated, affluent, and able to motivate others to adopt (Brown and Sovacool 2018; Wolske et al. 2018). Relevant concepts include rational deliberation; expected gains and losses; utility; habit, lifestyle, communication, persuasion, and imitation as well as social norms, expectations, and institutions; community networks, stakeholder influence, copying, and conformity.

3.1 Session 1 – Innovation

The first Café Conversation focused on Innovation and began with three questions:

1. Which innovative solutions should be prioritized for demonstration?
2. Which new partnership and financing approaches would enable businesses to demonstrate these solutions?
3. What new research, white paper, or demonstration collaborations between industry and national laboratories/academics would help to move the needle?

Following the Café Conversation on Innovation, workshop participants analyzed their notes and determined that the following solutions should be prioritized. Innovation includes not only new and improved technologies, but also business models, policies, markets, and social change. Examples mentioned include the following:

- Key technology areas include carbon capture, energy storage, small modular nuclear reactors, biofuels, hydrogen, electric vehicles, and efficient building materials.
- Business model innovation, such as circular economy approaches and industrial partnerships, was discussed.
- Policy innovations like carbon pricing, incentives, and public–private partnerships can drive change.
- Market and workforce development includes advancements in market dynamics and workforce development that are essential for the growth and support of sustainable industries to create new opportunities in the green sector.
- Social innovation around behavior changes and education is important. Demonstrations can reveal potential and change perspectives.
- Innovation is needed in modeling interactions between systems and in projecting decarbonization pathways.
- Deploying existing innovations can be as important as new tech. However, barriers like high costs, policy constraints, and social factors slow adoption.
- Funding demonstrations to reduce risk, building markets, workforce training, streamlining deployment, and partnerships can accelerate innovation.
- Different innovations are required to accommodate regional differences—rural areas may have less access to new technology.
- Equity, affordability, and distributional impacts should be considered in innovating.

To illustrate these priorities, participants mentioned these particularly promising examples of innovation partnership opportunities:

- small modular nuclear reactors (these are Tennessee Valley Authority [TVA] and Southern Company priorities),
- biofuels (particularly SAFs), and
- hydrogen (to address the difficult-to-decarbonize industrial and heavy-duty transportation sectors).

Box 2: Hydrogen Partnerships are Critical

In 2020, global hydrogen demand stood at 90 Mt, practically all for refining and industrial applications and produced almost exclusively from fossil fuels, resulting in close to 900 Mt of CO_2 emissions (IEA 2021). In the IEA's Net Zero by 2050: A Roadmap for the Global Energy Sector, hydrogen use extends to several parts of the energy sector and grows sixfold from today's levels to meet 10% of total final energy consumption by 2050, with all hydrogen being supplied from low-carbon sources. Today, several governments have released hydrogen strategies, and numerous companies are seeking to tap into hydrogen business opportunities.

In June 2023, the Biden Administration released a U.S. National Clean Hydrogen Strategy and Roadmap to facilitate large-scale production, processing, delivery, storage, and use of clean hydrogen to help meet bold decarbonization goals. Key elements of this strategy include targeting high-impact uses of clean hydrogen in industrial applications, transportation, and the power sector, reducing the cost of clean hydrogen production to $1/kg by 2031, and focusing on establishing regional networks.

In 2023, Georgia Tech, ORNL, TVA, and the Southern Company joined the Southeast Hydrogen Hub Coalition, which submitted an application to DOE's Regional Clean Hydrogen Hub Demonstration Program to develop an energy ecosystem in the SE to deploy green hydrogen as a decarbonization solution, and to help bring robust economic development benefits and jobs to the region. Although the hub was not selected for federal funding, efforts to organize it by identifying and bringing together key stakeholders in the region will facilitate the establishment of partnerships for future demonstration and deployment opportunities.

To support the growth of hydrogen in the transportation sector for medium and heavy-duty freight transport, the Georgia Department of Transportation (GDOT) is supporting the expansion of hydrogen infrastructure in Georgia. This initiative aims to boost market confidence and attract private investment in the hydrogen-based transport sector. Building on that momentum, Chart Industries, Plug Power, Racetrac, Hyundai, and others in the private sector are proposing the build-out of additional hydrogen refueling stations across the state. This would not be a complete network but is intended to signal market confidence and stimulate additional private investment in hydrogen.

Georgia Tech, ORNL, and its many partner organizations in the SE are actively involved in hydrogen research, development and demonstration (RD&D) activities addressing technical and economic challenges associated with the production, storage, transport, and utilization of hydrogen, including the durability and recyclability of fuel cells and electrolyzers, the cost of hydrogen storage technologies, and the logistics of hydrogen utilization and transport. All of these efforts are centrally focused on creating the pathway to utilize hydrogen cost effectively to decarbonize our region, the nation, and the world.

Timely and sustainable progress toward decarbonization goals is likely to require financial incentives beyond the IRA and BIL. A carbon tax or cap-and-trade approach is one way to achieve those goals. There are difficult issues around acceptance, fairness, monitoring, and management for any such approach.

Multi-institution partnerships built around trust and shared objectives are needed to explore alternatives, to quantify their costs and benefits. Further partnership opportunity examples are synthesized in Chapter 5.

In summary, innovation in technology, policy, business models, and social factors is key, and regional differences must be considered and accounted for. Deployment and scaling of new and existing solutions also require innovation to overcome barriers.

3.2 Session 2 – Demonstration

The second Café Conversation focused on Demonstration and started with three questions:

1. What are some leading examples of great demonstrations that reveal the potential of decarbonization? What makes them great?
2. Given available (government and/or private sector) financing approaches, what actions can help accelerate the pace and impact for businesses that wish to demonstrate and deploy decarbonization solutions?
3. What new research, white paper, or demonstration collaborations between industry and national lab/academics would help to move the needle?

The following are some key points about demonstrations for decarbonization that were discussed:

- Demonstrations show real-world viability of innovations and reveal potential to change perspectives.
- They build familiarity and social acceptance of new solutions like EVs, efficient buildings, solar, etc.
- Effective demonstrations involve diverse stakeholders, establish metrics, have educational components, and share lessons learned.
- Demonstrations should be replicable and scalable to achieve broader impact. Modular and distributed projects may be easier to replicate.
- Community-level demonstrations can show localized benefits and engage residents.
- Partnerships among research institutions, government, industry and communities enable impactful demonstrations.
- Simply demonstrating a technology does not guarantee adoption. Other factors like policy, incentives, affordability, and equity matter.
- Financing through the government and private sector can offset high costs demonstration costs.
- Failed demonstrations also provide learnings if evaluated properly.

- Outcomes depend on how demonstrations are designed, targeted, and communicated to influence behaviors.

To illustrate, participants mentioned these examples of demonstration partnership opportunities.

- Power companies have concerns about how regulations aimed at decarbonization will impact grid reliability, which is central to their mission.
- Impartial and trusted partners are needed to perform assessments demonstrating impacts under different scenarios and timelines.
- Research partners could contribute to better understanding of both technical and social dimensions of new regulations through these demonstration projects, within the practical context of the SE grids. Further partnership opportunity examples are synthesized in Chapter 5.

In summary, well-designed demonstrations can reveal potential and accelerate deployment, but they require diverse partnerships, financing, and effective communication and evaluation to drive change.

3.3 Session 3 – Deployment

This session kicked off with a recap of the Drawdown Georgia 20-solution research and the formation of the 60+ companies that are engaged in the partnership known as the Drawdown Georgia Business Compact. The 20 solutions are deployment- and scale-ready, whereas the Business Compact is focused on leveraging these solutions and other initiatives.

Compact Mission: Leverage the collective impact of the Georgia business community to achieve net zero carbon emissions in the state through a just and sustainable transition.

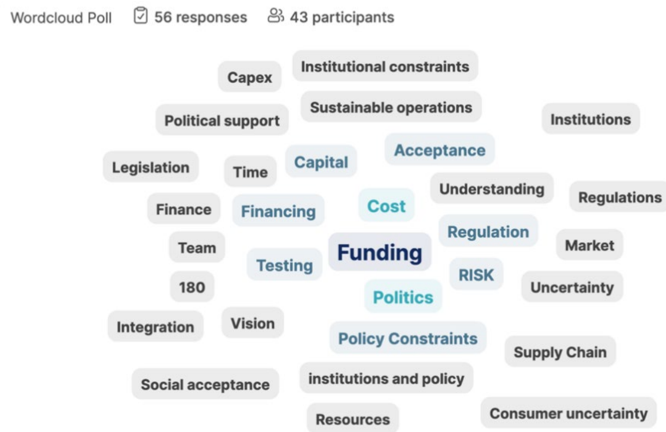
The third Café Conversation focused on Deployment and started with three questions:

1. If you had an ideal budget (please put in your number) what existing solutions would you prioritize to fund toward your organization's decarbonization goals?
2. Who are the partners you would like to have on your team for success, and what does that look like?
3. What are the key barriers or gaps that need to be addressed that these partners can help you overcome?

Workshop participants concluded that deploying existing solutions can drive significant emission reductions, even without major new technological breakthroughs. As shown in the word cloud (Figure 3.5), however, many barriers slow deployment. These obstacles include high costs, risk and uncertainty, financing and lack of political support and incentives, supply chain and policy constraints, workforce gaps, and understanding and social acceptance.

Rural areas face greater deployment barriers than urban areas and, as a result, may need greater assistance to accelerate the adoption of clean tech options. Urban areas therefore may offer more opportunities to scale rapidly and troubleshoot first-generation technology so that rural areas can be provided with more fail-safe and stress-tested solutions.

Figure 3.5. Word cloud in response to: "Based on your TRL, using one word, what is your largest barrier to deployment to scale?"



Partnerships between research institutions, government, utilities, and local communities can also enable deployment. Demonstrations are important to show real-world viability and to build familiarity and social acceptance. Workforce training and education are important to help deploy these market-ready innovations, especially in disadvantaged communities where there may be few existing adopters to show how the technology or practice can work.

An array of supportive activities is needed to accelerate the clean tech transition. Business models that involve public–private partnerships and circular economy approaches are valuable. In the policy arena, regulatory changes like standards and incentives as well as streamline permitting can accelerate deployment. Financing through bonds, rebates, and public funding can offset the high upfront costs that can stifle deployment.

Deployment strategies need to consider how the costs and benefits of deployment are distributed across different communities. Communications, outreach, and community engagement can build support for deployment, if there truly are shared benefits and honest engagement.

To illustrate, participants mentioned these examples of deployment partnership opportunities.

- A few deployment projects that ORNL is currently working on in the SE include direct air capture in building systems, vehicle-to-grid systems, and AI-driven building envelope retrofits.
- ORNL is partnered with several organizations on these projects, including TVA, EPRI, KUB, the University of Tennessee, and the Knoxville Community Development Corporation (KCDC). KCDC manages low-income housing for the City of Knoxville.
- Partnerships around workforce development could generate important benefits for the region but have long time horizons and require cooperation across multiple levels of government and across primary, secondary, and post-secondary education sectors, including trade schools and apprenticeship programs. Further partnership opportunity examples are synthesized in Chapter 5.

Other illustrative partnership initiatives currently underway within the Drawdown Georgia Business Compact include:

- Assessing potential unmet renewable energy demand among selected Compact companies.
- Exploring the creation of a voluntary carbon market for high-quality, high-integrity carbon credits through afforestation, reforestation, and revegetation and improved forest management, with a special focus on engaging small-acreage forest landowners.
- Exploring cost-effective ways to generate renewable natural gas to replace current natural gas use in industry, mobility, and electricity generation.

In summary, scaling up deployment requires overcoming many barriers through partnerships, financing, policy changes, equity, education, and community engagement. Demonstrations and supporting workforce development are also key.

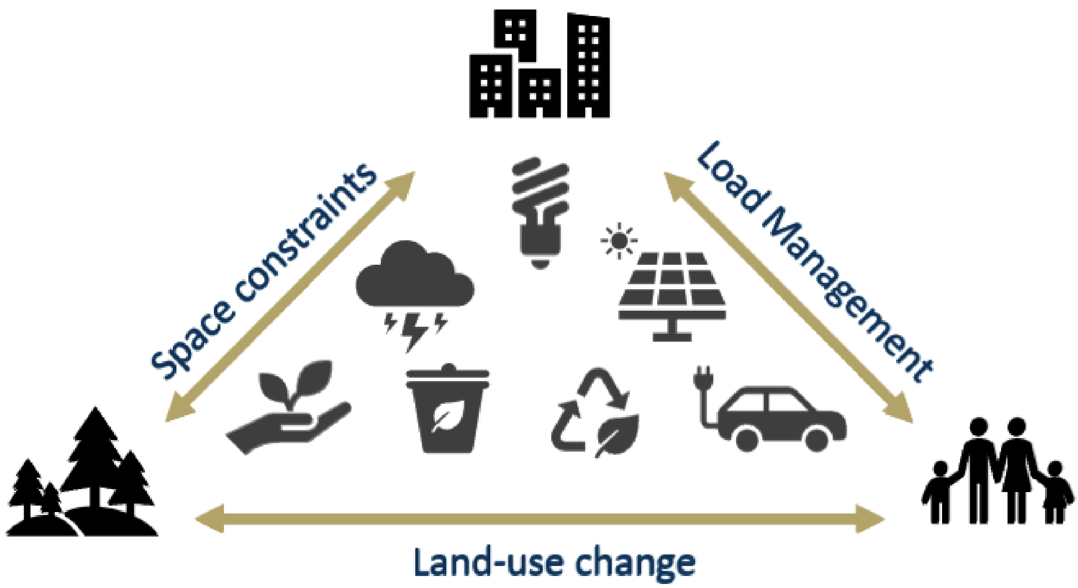
3.4 Session 4 – System Interactions and Equity

The fourth Café Conversation focused on System Interactions and equity, and it began with two questions:

1. What are the most important interactions between the built, natural, and social systems as we assess alternative pathways for decarbonization?
2. What are the equity considerations that need to be integrated with the transition to a decarbonized economy in the SE?

Interactions between built, natural, and social systems must be considered. Nature-based solutions include reforestation, climate-smart agriculture, bioenergy crops, and coastal restoration. Economies and impacts can be optimized by bundling complementary solutions while being attentive to equity issues. Modeling tools can help organize the understanding of these complex system interactions while considering space constraints, load management, and land use change (Figure 3.6).

Figure 3.6. Interactions between built, natural, and social systems



3.4.1 Scenarios of SE decarbonization pathways

The SE has had an intimate relationship with electrification since the 1930s, when the TVA was created by President Franklin D. Roosevelt. One of the purposes of the TVA Act of 1933 was to tackle flooding and other important problems facing the valley, while simultaneously bringing electricity to citizens in the seven-state region and raising their standard of living.

Since the construction of TVA's dams and the build-out of the electricity system across the SE, TVA and other electricity providers in the region have brought electricity to their citizens and businesses. Today, low-carbon renewable electricity is seen as a potential solution to the global climate crisis. It is therefore interesting to examine the readiness of the SE to use its existing electricity infrastructure as an asset to decarbonize its economy.

Scenarios of SE decarbonization pathways were created and presented to Workshop participants. We examined SE regional scenarios as well as state-by-state simulations using Princeton University's Net-Zero America Pathways (NZAP) (2021*)* and its supplemental tables. Additional calculations were needed to estimate state GHG emissions from fuel consumption, which drew on the GT-NEMS (the Georgia Tech National Energy Modeling System operated by the Climate and Energy Policy Lab) and other sources of data. Table 3.1 explains how these scenarios are defined, and Appendix A describes adjustments that were made to the NZAP scenarios to enable GHG emissions to be estimated.

Table 3.1. Assumptions of the reference case and E+ scenario

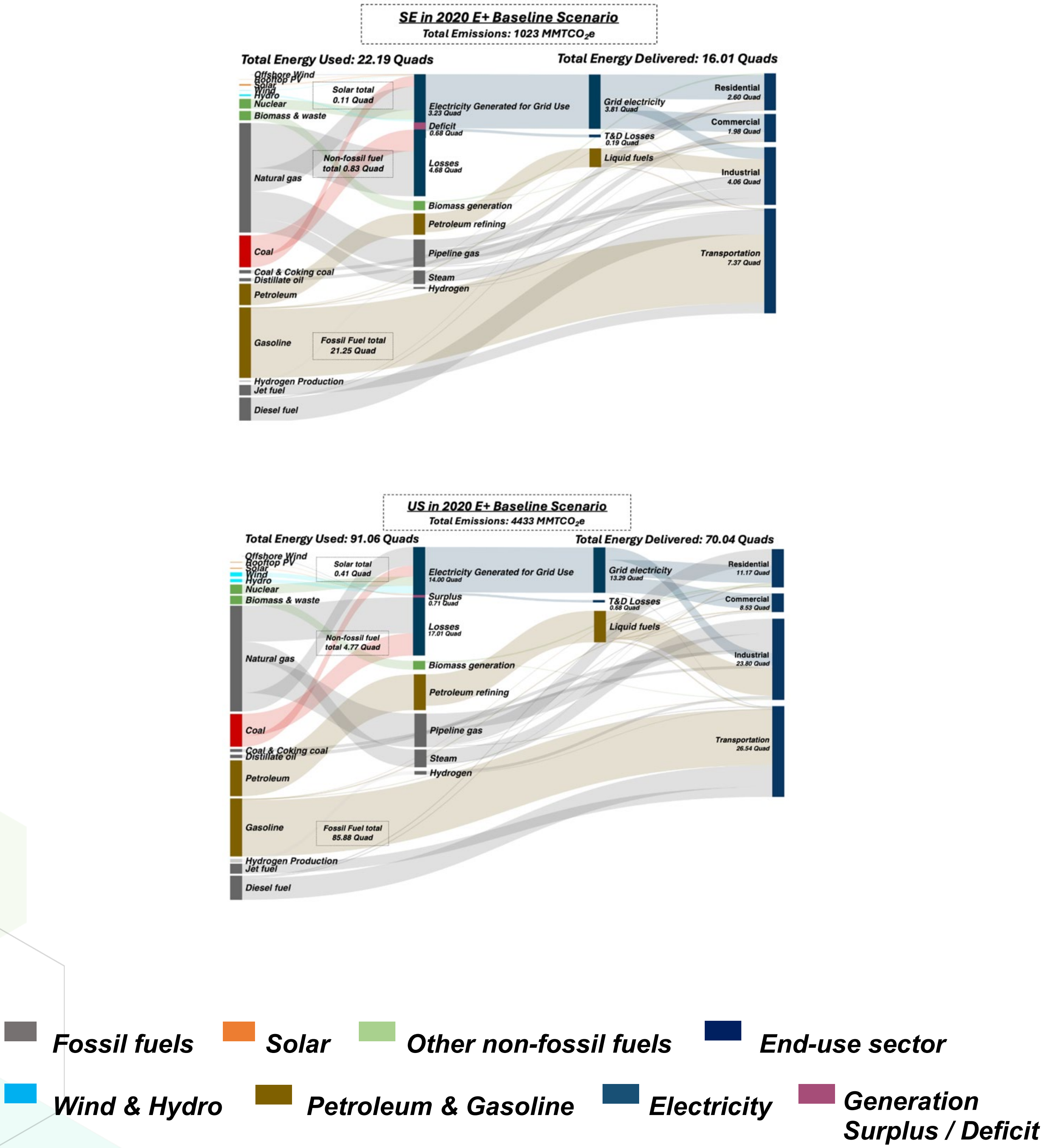
Reference case: IIJA, IRA, and CHIPs are not represented	Based on US EIA, Annual Energy Outlook 2019 (Reference case, no new policies)
Electrification E+: Aggressive end-use electrification; energy supply-side options relatively unconstrained (except biomass)	Nearly full electrification of transport and buildings by 2050 No land-use change for biomass supply allowed Achieves carbon neutrality in 2050 with the inclusion of carbon sinks

We begin by comparing the SE and U.S. energy systems, focusing first on 2020 and considering next the E+ scenarios for 2035 and 2050 (Figure 3.7), where E+ refers to the "high electrification" scenario described in Table 3.1. We then compare and contrast emissions for individual states in the SE in 2020 and scenarios for 2035 and 2050.

The SE has a distinct energy mix compared to the rest of the U.S. (Figure 3.7). Specifically, it has significantly greater reliance on electricity, and its electricity mix has more nuclear and less renewables. Overall, the reliance of the SE on fossil fuels and the carbon intensity of its energy consumption in 2020 were comparable to the U.S. (46.4 vs 46.2 $MMTCO_2e$/Quad and 95.2% vs. 94.3% fossil fuels). However, these similarities hide many differences. For example, compared with the U.S. at large, the SE is relatively more dependent on coal and jet fuel and less dependent on distillate oil, LPG, and steam.

Figure 3.7. Southeast and U.S. scenarios for 2020

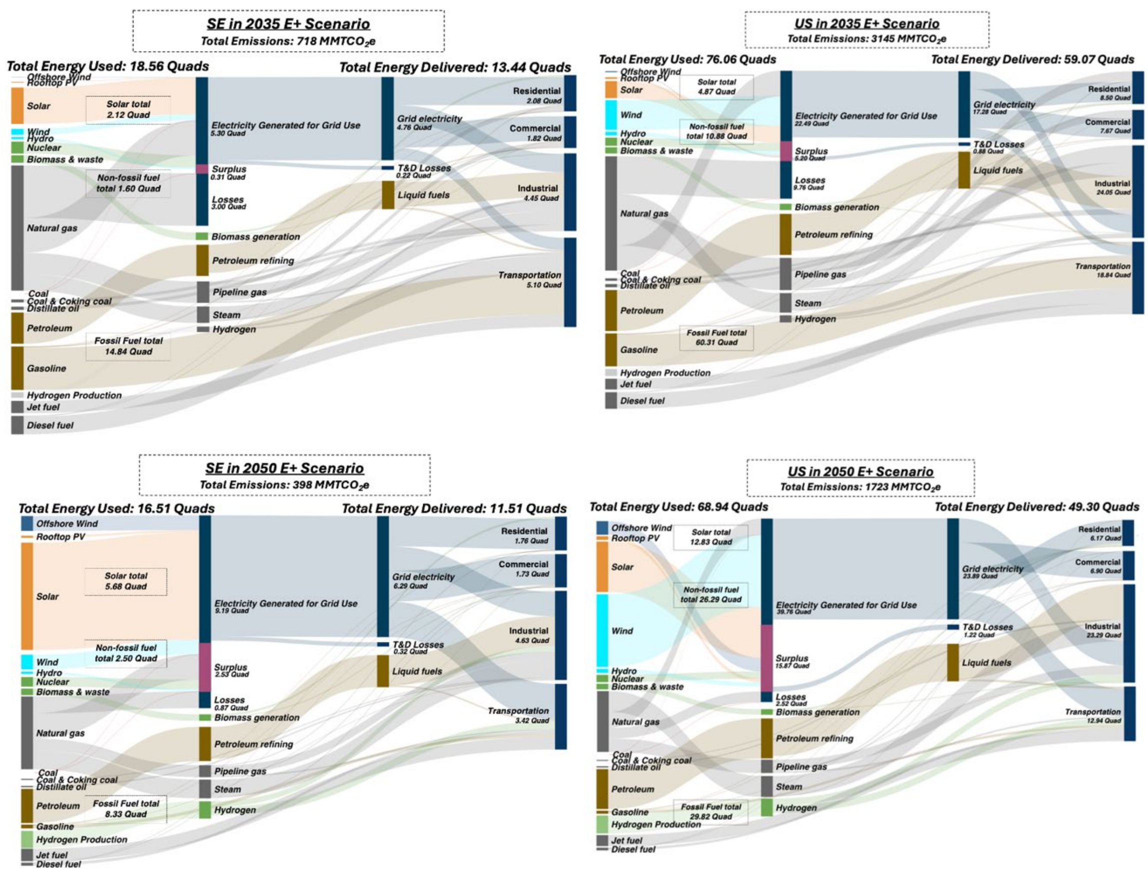
Note: Derived from Princeton E+ modeling of energy use and emissions; see Appendix A.



Scenarios for 2035 and 2050 are shown in Figure 3.8. In the Reference case scenario for the U.S. and the SE, emissions are expected to decrease by approximately 10% by 2035 compared to 2020 levels. Over time, however, the abatement slows, leading to only a 5% reduction in 2050 relative to 2020. This portends a plateauing, followed by a rebounding of emissions during 2035–2050. Across the SE, the major reductions come from the electricity sector, with a 16% decrease in emissions (31% per capita) between 2020 and 2050. Particularly notable is the rise in excess electricity generation by 2050, in both the U.S. and the SE. Such excesses are beginning to appear from renewable resources in California (from solar) and Texas (from wind and solar), leading to negative electricity prices. Investments in storage could reduce these excesses, but they are not explicitly modeled in NZAP.

Transport emissions, on the other hand, are reduced by only 12% (27% per capita). This highlights the significant role of electricity in overall emissions reduction efforts, along with the challenge of reducing emissions associated with mobility.

Figure 3.8. Southeast and U.S. decarbonization scenarios for 2035 and 2050 (derived from Princeton E+ modeling)



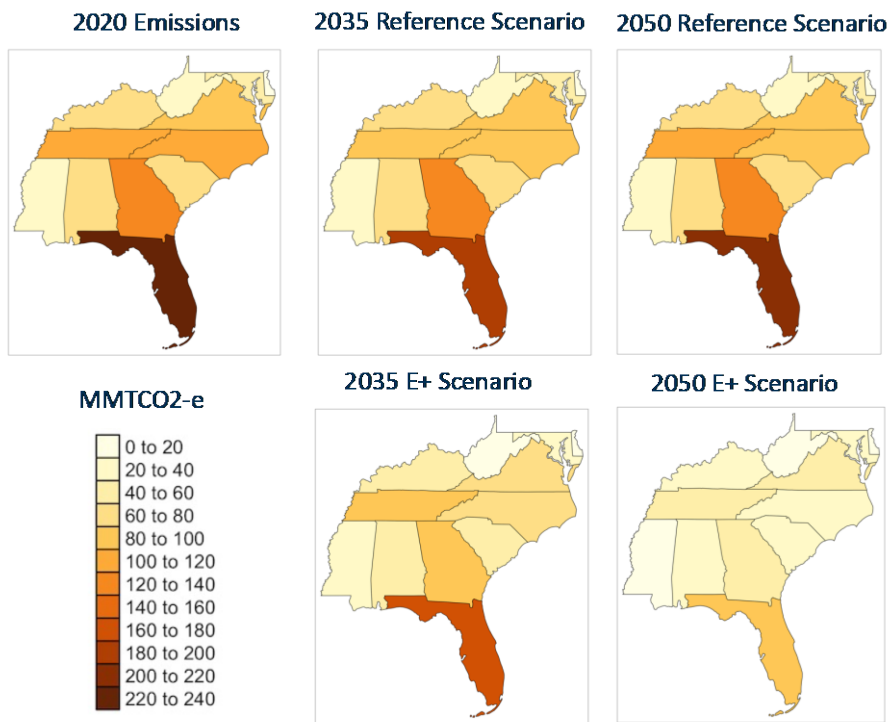
The E+ scenario also shows a steady and a common U.S. and SE pace of GHG emission reductions between 2020 and 2050. For instance, in 2035 emissions drop by 29.1% in the U.S. and 29.8% in the SE, relative to 2020; in 2050, they drop by 61.1% relative to 2020 in both the U.S. and SE. Moreover, the U.S. and the SE both experience a notable increase in electrification.

However, the pace of electrification in the U.S. is more rapid than in the SE. Still, by mid-century, the E+ scenario has the SE remaining more reliant on electricity (at 54.6% of its energy) compared with the U.S. (at 48.4% of its energy).

E+ demonstrates how a sustained pace of emission reductions over three decades could propagate across the SE. In this E+ scenario, the transport sector leads the way with an 88% reduction in emissions, and the electricity sector also contributes significantly with a 56% decrease. This underlines the importance of electrifying transportation to meet science-based emissions reduction targets.

Across individual states in the SE, per capita emissions derived from the Princeton scenarios using the shared socioeconomic pathways and population forecasts from Hauer (2019) show interesting intra-regional variations (Figure 3.9). The results show great variation in current GHG emission totals as well as GHG emissions per capita across states in the SE. In 2020, Florida's emissions were nearly twice those of any other state in the SE. In contrast, Mississippi, West Virginia, and Delaware had the lowest emissions. On a per capita basis, however, the ranks are quite different. Per capita 2020 GHG emissions were highest in West Virginia, whereas Virginia, North Carolina, and Florida had relatively small carbon footprints.

Figure 3.9. Business-as-Usual and the Princeton E+ scenarios for individual SE states



Across the three maps at the top of Figure 3.9, Florida and Tennessee illustrate the possibility that today's business-as-usual case in the SE region could cause a plateauing of GHG emission reductions in the Reference case over the next decade—that is, by 2035. The scenario also suggests that this could be followed by a rebounding of emissions between 2035 and 2050.

In contrast, the 2035 and 2050 E+ scenarios shown in the bottom two maps are consistent with a slightly accelerated pace of decarbonization occurring in the E+ scenario for the SE as a whole and for the U.S., as well.

3.4.2 Engineered and natural carbon reduction and removal methods

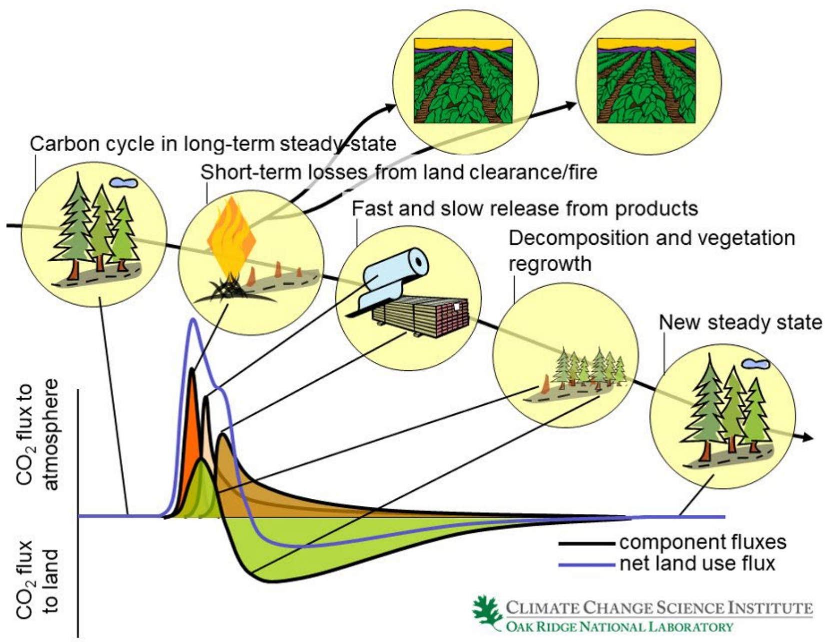
Because meeting national carbon goals will be challenging, both engineered and natural carbon reduction and CO_2 removal methods will be needed.

Several engineered innovations to enable carbon capture and storage solutions were emphasized by workshop participants. These include innovations in direct air capture to deal with hard-to-decarbonize sectors, improved absorbing materials to reduce costs, and underground storage options with enduring protection against leakage.

Several nature-based carbon sequestration and storage solutions were also discussed by workshop participants. These include advances in carbon sequestration in natural sinks like forests and soils. Monitoring technologies also need further development so that markets for such carbon management can be developed. Carbon storage in land ecosystems is dynamic and is influenced by human management as well as natural disturbance (Figure 3.10).

Figure 3.10. The dynamics of human and natural disturbance at a single location

Changes in carbon storage in land ecosystems over time depend greatly on the history of natural disturbances and management practices at each location in complex landscape mosaics. Carbon losses (i.e., flux to atmosphere) and gains (i.e., flux to land) are shown here as both the net flux (gray line) and some of the many contributing component fluxes (black lines). Hypothetical trajectories are shown for a plot of forested land, starting from a near–steady state. Land clearance and/or fire can cause large short-term losses of carbon (red shaded region). Decomposition of plant material remaining on the ground and losses of soil carbon can lead to losses of carbon early during the recovery of disturbed forest; later, as the new forest becomes well established, this can transition to an uptake of carbon in growing trees and in soil organic matter (green shaded region). Wood removed during harvest can return as carbon in the atmosphere as products decompose. That can happen quickly for products like paper (tan shaded region) or more slowly for solid or manufactured wood products (brown shaded region). Land area can also transition to other land uses, such as cropping or pasture, each of which will undergo its own further trajectory of complex carbon losses and gains (upper arrows).



Key illustrations of system interactions by technology and sector are summarized here:

- **Electricity Generation:**
  - Focus on carbon capture and storage, renewable energy integration, nuclear energy, hydrogen, and bioenergy
- **Electricity Infrastructure:**
  - Emphasis on improving grid capacity, transmission, distribution, energy storage, microgrids, and virtual power plants
- **Buildings:**
  - Energy efficiency via retrofits, weatherization, and building codes identified as priorities, along with efficient HVAC, materials, and smart controls
- **Transportation:**
  - Electric vehicles, charging infrastructure, biofuels, SAFs, medium- and heavy-duty vehicle electrification, public transit availability, and walking/cycling infrastructure

- **Manufacturing:**
  - Priorities include energy efficiency process improvements, carbon capture retrofits, waste heat recovery systems, and hydrogen use/storage
- **Equity:**
  - Key focuses are affordability, access, job impacts, procedural equity in planning, and distributional impact
- **Integrated Models:**
  - Models should link economic, environmental, and social factors and engage diverse stakeholders
- **Policy:**
  - Carbon pricing, incentives, standards highlighted as policy tools
- **Financing:**
  - Innovative financing and access to funding identified as critical needs
- **Supply Chains:**
  - Potential for improvements in manufacturing/energy supply chains discussed
- **Community Engagement:**
  - Social science, education, and outreach identified as important cross-cutting themes

Box 3: Mass Timber and Sustainable Construction as Growth Sectors

Georgia's standing as the top exporter of wood products and the second-largest consumer of wood for electricity in the U.S. underscores its potential in sustainable construction and energy production. Jamestown, a real estate investment and management firm part of the Drawdown Georgia Business Compact, exemplifies this potential with its latest project.

The project, an innovative mass timber construction known as 619 Ponce, will include 87,000 square feet of office space and 27,000 square feet of retail space, using locally sourced Georgia-grown timber and a regional supply chain. This approach not only bolsters the regional economy but also cuts transportation emissions, aligning with Jamestown's commitment to environmental stewardship.

Notably, this mass timber building is targeting net-zero carbon operations, with aspirations for LEEDv4 Core & Shell and Fitwel certifications. By sourcing materials within 100 miles and prioritizing human health through the minimization of harmful chemicals in construction materials, the project sets a benchmark for sustainable building practices.

Jamestown's president, Michael Phillips, emphasizes the speed and sustainability of mass timber construction, facilitated by off-site prefabrication. This method yields quicker construction times and fewer delivery trucks, reducing the environmental footprint.

Furthermore, ORNL's high-temperature materials program has been crucial in advancing the use of wood by-products for electricity generation, especially in the SE. The program's innovations in materials science have enhanced the durability and efficiency of burners at paper mills, allowing higher operating temperatures and better energy efficiency.

The following science and technology needs were identified as critical to decarbonization in the SE.

- Innovation in carbon capture technologies, such as direct air capture, to deal with hard-to-decarbonize sectors.
- Advances in carbon sequestration in natural sinks like forests and soils. These advances need to be coupled with improved monitoring technologies.
- In absorbing materials to reduce costs as well as underground storage, options are important.
- Marine and air transport as well as long-distance freight lack well-articulated decarbonization pathways. SAFs are a particular need going forward. Next-generation electrofuels can provide carbon liquid fuels for these sectors, allowing renewables from all sources to be stored conveniently as a liquid fuel.
- Advances in energy storage to support growth in renewables. This includes batteries, thermal storage, and technologies like compressed air storage.
- Improvements in energy efficiency across every sector of the economy—including energy supply and conversion, buildings, manufacturing, transportation, and agriculture. Developing new efficient appliances, processes, and automotive technologies.
- Smart grid technologies to balance load and generation. Especially with increased electrification and distributed renewable generation.
- Small modular nuclear reactors to provide carbon-free baseload power. Overcoming deployment and regulatory barriers.
- Energy transmission upgrades to support growth in renewables and electrification. Solving challenges of interstate transmission and grid interconnection backlogs.
- Infrastructure for hydrogen production, storage, and use. Plus demonstrating applications.
- Breakthroughs in sectors like steel, concrete, and glass manufacturing to reduce process emissions.
- Innovations in urban design, transport, and infrastructure to reduce emissions from cities.
- Data analytics and modeling.
- Social science research focused on supporting community engagement, policy development, and behavior change, explicitly incorporating elements of consumer adoption as well as institutional and regulatory change to achieve equitable outcomes.

Box 4: Sustainable Aviation Fuel from Bio-Based Resources

The SE is a center of excellence for fundamental R&D on bio-based alternative fuels and is an emerging producer of SAF.

ORNL's Center for Bioenergy Innovation (CBI) is pursuing high-impact scientific and technological innovations to create dedicated bioenergy crops (e.g., poplar and switchgrass) as a cost-efficient substitute for petroleum-based fuels and products (Stone et al. 2022). Through basic science research on dedicated bioenergy crops and a suite of engineered microbes, CBI researchers are developing high-yielding, process-advantaged, sustainable plant biofeedstocks and designing economic and efficient bioprocessing approaches using microbes that produce biofuels and bioproducts, including hydrocarbons for jet fuel. CBI aims to reduce the cost of converting carbohydrates to fermentation intermediates that can be catalytically upgraded to SAFs.

ORNL's patented processes to convert ethanol into jet fuel blendstock have the benefit of lower energy inputs for conversion and the ability to use hydrous forms of ethanol, which lower costs and decrease overall carbon intensity. Since the processes use ethanol, they can be combined with corn ethanol production or with future sources of cellulosic ethanol. ORNL is in the process of scaling up this conversion process through a CRADA with Gevo, Inc., a leading national producer of SAF, which is also licensing the underlying technology.

In Jessup, GA, RYAM is building a new plant to produce 60–70 million gallons of SAF and renewable diesel annually. The Freedom Pines LanzaJet SAF facility in Soperton, GA, is operational, contributing 10 million gallons per year. GranBio (in Thomaston, GA) hopes to grow its production from 1 million gallons to nearly 120 million gallons in the next six years. These developments are crucial for meeting the increasing SAF demands from entities like Hartsfield-Jackson International Airport and Delta Air Lines, which have set significant SAF consumption goals.

Success in the SE involves leveraging its natural assets like woody biomass and agricultural feedstocks, along with existing infrastructure and the latest research, to increase SAF production to 120 million gallons by 2030. Hartsfield-Jackson consumed over 1 billion gallons of conventional aviation fuel (CAF) in 2022 and is projected to consume nearly 1.2 billion gallons of fuel by 2030. To meet federal policy objectives and industry aspirations for 10% of total consumption from SAF by 2030, and to prevent Atlanta from risking non-attainment status, these partnerships are essential.

Workshop participants also mentioned the following examples of system interaction partnership opportunities, where manufacturers and financing institutions need full cost accounting, life cycle analysis, and cost–benefit analysis for decarbonization transitions. These include

- expansion of EV infrastructure,
- weatherization and electrification of buildings,
- autonomous transport, and
- hydrogen production and transport.

Further partnership opportunity examples are synthesized in Chapter 5.

Chapter 4. Addressing Equity and Inclusion

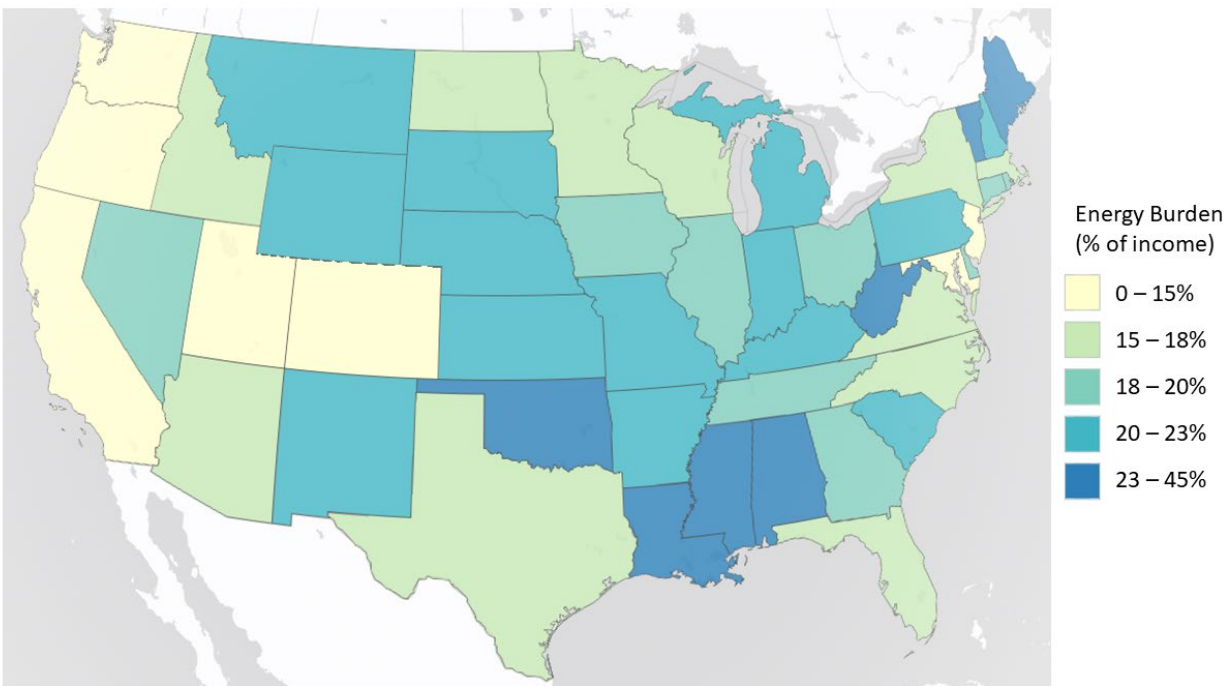
The equity and inclusion issues that challenge the SE are multifaceted. Workshop participants expanded on these issues as they relate to energy affordability and energy pollution leading to issues of environmental justice.

4.1 The Southeast's energy affordability and environmental justice challenges

The SE has high levels of energy poverty and rates poorly on energy affordability (Figure 4.1).

Figure 4.1. Low-income energy affordability

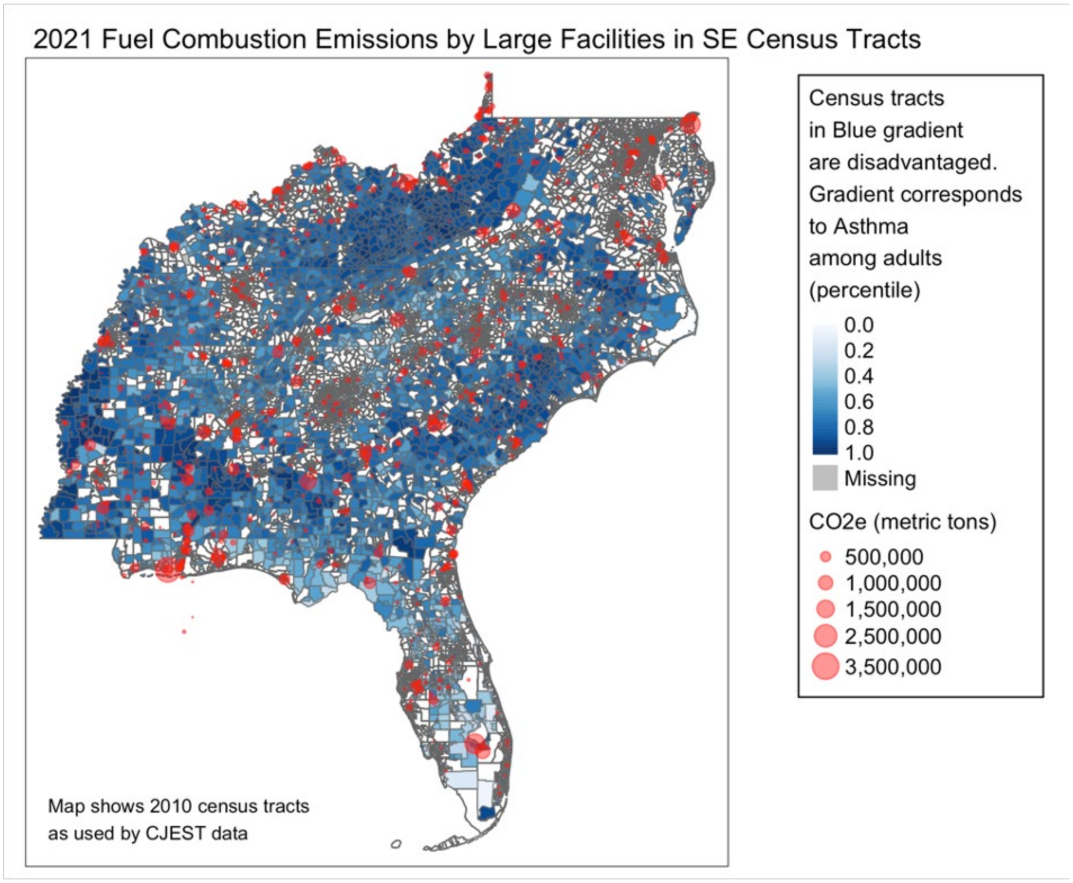
The affordability of household energy expressed as a percentage of income (energy burden), is higher across the SE than in many other regions. Shown here is the energy burden by state for all households earning 30% or less of the national median income. Data from the Low-Income Energy Affordability Data (LEAD) Tool, State and Community Energy Programs, US Department of Energy.



Across the SE, large polluting facilities are often co-located near low-income and disadvantaged communities. A significant number of industrial facilities in the SE that are extremely high GHG emitters (500,000–3,500,000 CO_2e in 2021) lie in disadvantaged communities, indicated by blue. In fact, for Georgia, practically all high emitters lie in disadvantaged communities.

As additionally indicated by the gradient of the blue color in Figure 4.2, many facilities across the SE lie in communities that have a relatively moderate-to-high share (0.6 percentile and above) of asthma among adults. In Georgia, the severity of this vulnerability is increased because most industrial facilities lie in disadvantaged communities in which the asthma percentile is 0.8 and above.

Figure 4.2. Large polluting facilities in disadvantaged communities

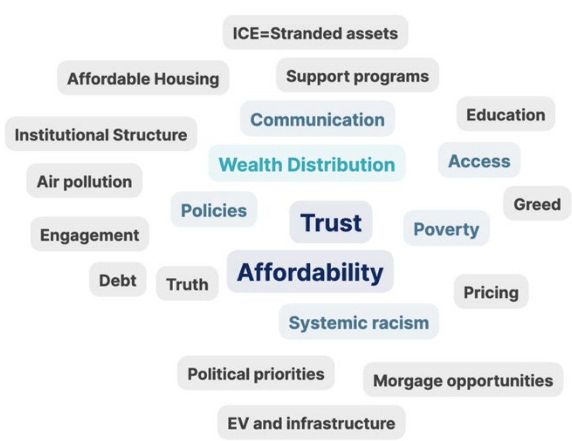


In 2022 the federal Government set a Justice40 goal, to meet which 40% of the overall benefits of certain federal investments must flow to disadvantaged communities that are marginalized, underserved, and overburdened by pollution.

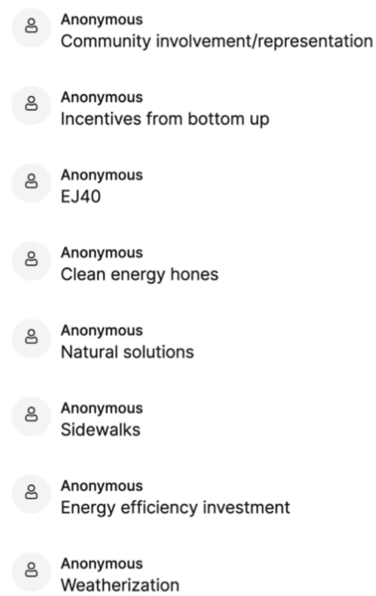
4.2 Café Conversations about equity

Figure 4.3. Word clouds and lists in response to equity Slido questions

"What equity issue is the most challenging for the decarbonization transition in the SE?" (45 responses)



"What are some equitable pathways for decarbonization?" (28 responses)



Addressing equity and inclusion, workshop participants offered the following reflections:

- Equity has procedural dimensions—inclusive decision-making processes and transparency—as well as distributional impacts on access to benefits.
- Rural communities face gaps in infrastructure, funding sources, and workforce skills to adopt new solutions.
- Low-income urban residents encounter higher energy burdens and limitations on housing upgrades needed for electrification.
- Affordability of electricity, housing and transportation for disadvantaged groups is a major issue with rising costs.
- Outreach and incentives should target marginalized communities to improve access to programs and technologies.
- Workforce development programs in renewable energy sectors can open up opportunities.
- Stranded asset risks of transitioning from fossil fuels should be mitigated for impacted workers.

- Policymakers must weigh tradeoffs between low-cost decarbonization options that may exacerbate inequities versus more equitable paths.
- Partnerships between community organizations, government, business, and philanthropic organizations can channel investment and opportunities to disadvantaged areas.
- Solutions should be tailored to local contexts, with community input, and avoid a one-size-fits-all approach.
- More data collection on the impacts of decarbonization efforts is needed to inform evidence-based policy.

In summary, procedural inclusion and equitable distribution of costs and benefits across communities should be considered, with localized engagement from disadvantaged groups.

4.3 Equity summary

Expanding on the long-standing focus of the Drawdown Georgia project on equity, inclusion, engagement, fairness, and justice (Brown et al. 2023), along with the commitment of ORNL to such principles, these topics were explicitly included in the presentations and questions that set the stage for our Café Conversations.

Workshop materials emphasized the need to incorporate equity considerations in the transition to a decarbonized economy in the SE, with a focus on distributional equity in allocating resources and benefits as well as procedural equity in ensuring transparency and community engagement. There was an explicit recognition of the diversity of the region spanning urban, rural, disadvantaged communities with considerations for affordability, quality of life, workforce transitions, and accessibility of new technologies.

Partnerships should engage diverse stakeholders from government agencies, businesses, community organizations, academia, and financing groups to co-develop place-based solutions, gathering socioeconomic data to inform eligibility for programs. Outreach through trusted communicators and respect for community knowledge is vital.

Solutions should create local economic opportunities and environmental benefits equitably. Key barriers to address include information gaps, funding limitations, and building understanding and buy-in across groups.

Chapter 5. Synthesis of Partnership Opportunities

Workshop participants were asked to identify and articulate partnerships that could produce useful outcomes for regional decarbonization. The goals were to generate new ideas, to stimulate collaboration, and to prioritize and leverage multi-institutional investments. Partnership opportunities were addressed in each of the four working sessions. Notes from across those sessions are synthesized here, and common themes are identified here.

Figure 5.1. Principles for SE decarbonization partnerships

5.1 Partnership principles focused on building trust, communication, and community engagement

The workshop participants identified best practices and general guidance for building relationships based on trust and for community engagement on decarbonization. These principles provide a foundation for successful partnership and collaboration across the full spectrum of technical and adoption readiness levels.

- Engage communities early and listen first. Build relationships with local leaders and community organizations. Take time to understand priorities and build trust.
- Convene diverse regional stakeholders from government, industry, academia, non-profits, and communities. Bring different perspectives together for open dialogue.
- Communicate benefits clearly. Demonstrate how solutions can improve quality of life. Frame around health, jobs, resilience etc. rather than just environmental benefits.
- Ensure representation. Partner with trusted communicators and involve stakeholders affected by changes. Account for biases.
- Share information transparently. Communicate facts openly, combat misinformation, and admit uncertainties.
- Deliver community benefits. Ensure that solutions address local needs and priorities. Invest in workforce development and training.
- Build in accountability. Use data and metrics openly. Report on progress and impact.
- Allow time. Move at the pace of trust. Build relationships first before pushing solutions. Phase funding and projects.
- Start small. Pilot solutions with individual communities. Create positive examples. Then replicate and scale.
- Show up. Maintain long-term commitments and presence in communities beyond individual projects.

To summarize, the keys to success are maintaining meaningful engagement, practicing open communication, delivering mutual benefits, and building strong relationships over time. Using these keys can establish the trust needed to advance decarbonization solutions. With that principle as a foundation, the participants discussed some specific community engagement partnerships.

These principles can be challenging to implement because there is no substitute for time and engagement, for listening and understanding. One approach could be to identify a small number of communities and begin developing these relationships through listening sessions supported by trusted community leaders. A few examples of this kind of partnering to build trusting relationships were discussed, and they are given below:

- We could support a compact of non-profit and community organizations, like the Drawdown Georgia Business Compact, to help those organizations leverage their individual efforts. Many such coalitions already exist, and we would need to be thoughtful about what new partnering services might be useful across the region.

- There is some hesitancy on the part of the states to gather information on equity, for fear of damaging existing trust. Research partners could use existing information to develop detailed estimates of equity and need across the decarbonization spectrum and then assess these findings through focused community engagements.
- Research partners could use technology and information resources to develop hands-on demonstrations of the needs for and benefits of decarbonization. Such demonstrations could be in the form of a traveling exhibit (trailer) that could serve as a fun foundation for community discussions.

5.2 Partnerships driven by recognized stakeholder needs

Regional stakeholders have already identified and prioritized important needs, and academic and national lab partners have an opportunity to connect with these stakeholders to understand how those needs could be addressed through collaboration and cooperation.

- Rural Electric Cooperatives have formed national consortia around topics such as EVs, microgrids, natural hazards, grid data, and security. These consortia are motivated in part by new funding opportunities like the IRA and BIL. Academic and national lab partnerships could immediately engage with the NRECA and member organizations to provide technical and research support, improving the competitiveness of SE rural electric cooperatives for new federal funds. In other regions these partnerships are already being developed, such as with Idaho National Laboratory and their Caldera project, which is being used to evaluate the impact of increased electrification on grids.
- Power companies have concerns about how regulations aimed at decarbonization will impact grid reliability and rates, as “reliability at the best cost” anchors their mission. Impartial and trusted partners are needed to perform assessments of these impacts under different scenarios and timelines. Research partners could contribute to better understanding of both technical and social dimensions of new regulations, within the practical context of the SE grids.
- Providers such as Waymo (autonomous mobility) will need integrated analysis of urban infrastructure and customer behavior as they attempt to scale their ride volume and service areas. This creates opportunities for high-resolution urban system modeling, including social systems.
- There are examples of private sector organizations that are already providing some of these analysis and assessment services. We need to be cautious not to replicate existing capability. It may be useful to open discussions with service providers like BlocPower, which serves needs for electric heating and cooling for older buildings in low-income areas, to see if there are private-public partnering opportunities that could help serve communities in the SE that might now be overlooked. For example, building inventories at Census tract levels can help explore compatibility for heat pumps in low-income homes, given fuel use and ducting.
- Manufacturers and financing institutions need full cost accounting, life cycle analysis, and cost–benefit analysis for decarbonization transitions, including expansion of EV

infrastructure, weatherization and electrification of buildings, autonomous transport, and hydrogen production and transport. Research partners can provide robust, flexible, and comprehensive platforms for such assessments.

- State governments managing the Carbon Pollution Reduction Grants (CPRGs) and Climate Action Plants (CAPs) have partnership needs. Research partners can bring value by offering a common set of data and analysis across the multi-state region, which would improve the competitiveness of all the partner states. This process is already well advanced, so partnering here needs to be tackled quickly and efficiently.

5.3 Partnerships driven by emergent or systemic needs

We identified some areas of emerging need for partnership across business, non-profit, government, education, and research organizations. Further engagement is needed to fully articulate these needs.

- Timely and sustainable progress toward decarbonization goals is likely to require financial incentives beyond the IRA and BIL. A carbon tax or cap-and-trade approach is one way to achieve those goals. There are difficult issues around acceptance, fairness, monitoring, and management for any such approach. Multi-institution partnerships built around trust and shared objectives are needed to explore alternatives, to quantify their costs and benefits.
- Partnerships around workforce development could have important benefits for the region but have long time horizons and require cooperation across multiple levels of government and across primary, secondary, and post-secondary education sectors, including trade schools and apprenticeship programs.
- More broadly, partnerships are required to communicate to people across the region the message about decarbonization's importance. This involves development of new curricula, partnership with individual schools where new teaching materials and approaches can be evaluated and improved, and adoption of meaningful standards at the district and state levels.
- There may be need for a comprehensive and high-resolution mapping of potential distributed energy resources, including solar, wind, and local energy storage. This should also engage the extensive modeling capability for biomass energy and emerging capabilities for assessing potential for sustainable liquid fuels.

Chapter 6. Conclusions

Workshop participants identified best practices and general guidance for building trust-driven relationships and community engagement around decarbonization. The workshop's four decarbonization pillars provide a framework for recommending partnership opportunities that illustrate the principles emphasized by the attendees.

The keys to success are maintaining meaningful engagement, practicing open communication, delivering mutual benefits, and building strong relationships over time. There is no substitute for time and engagement, for listening and understanding. This can establish the trust needed to advance decarbonization solutions.

With these principles as a foundation, the participants discussed some specific community engagement partnerships.

- One approach could be to identify a small number of communities and begin developing these relationships through listening sessions supported by trusted community leaders.
- We could support a compact of non-profit and community organizations, like the Drawdown Georgia Business Compact, to help the organizations leverage their individual efforts. Many such coalitions already exist, and we would need to be thoughtful about what new partnering services might be useful across the region.
- There is some hesitancy on the part of the states to gather information on equity, for fear of damaging existing trust. Is it possible to use existing information to develop detailed estimates of equity and need across the decarbonization spectrum, and then assess that approach through focused community engagements?
- We could use the technology and information resources of the universities and national labs to develop hands-on demonstrations of the needs for and benefits of decarbonization. This could be in the form of a traveling exhibit (trailer) that could serve as a fun foundation for community discussions.
- Public–private partnerships could be established between government agencies, research institutions, utilities, and private companies to demonstrate and deploy solutions. These could help fund pilots and share costs and risks.
- Partnerships between academic researchers and industry could be established to collaborate on new innovations and translate research into real-world applications.
- Community partnerships could be established with local governments, community organizations, and leaders to engage and educate on decarbonization solutions. This can build trust and tailor approaches.
- Partnerships across states and jurisdictions could be established to share best practices and policies, coordinate on grid and infrastructure planning, and attract funding.

- Partnerships between utilities, regulators, and consumers/businesses could be established to align incentives and accelerate adoption of solutions like renewable energy, EVs, and efficiency upgrades.
- Workforce development partnerships could be established between educators, training providers, and employers to build a pipeline for jobs in new decarbonization industries.
- Supply chain partnerships between manufacturers, suppliers, logistics providers could be established to share data, optimize processes, and reduce carbon footprints.
- Financing partnerships between governments, philanthropies, and businesses could be established to increase funding available for decarbonization projects.
- Modeling partnerships between research institutions, policymakers, and community groups could be established to improve integrated assessments and inform decision-making.
- Partnerships across disciplines and sectors could be established to take a systems approach and share knowledge and perspectives.

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- Sessions leads and major contributors of the café conversations were:
- Innovation: Richard Gruber (Georgia Tech) and David McCollum (ORNL)
- Demonstration: Edgar Lara-Curzio (ORNL) and Richard Simmons (Georgia Tech)
- Deployment: Michael Oxman (Georgia Tech), Melissa Lapsa (ORNL), Robert Wagner (ORNL), and Michael Twardy (ORNL)
- Systems Interactions: Marilyn Brown (Georgia Tech) and Peter Thornton (ORNL)

Several graduate students in Georgia Tech's School of Public Policy contributed to this analysis. Niraj Palsule (Georgia Tech PhD student) led the production of several key figures, and assistance was also provided by Urvashi Betarbet, Suprita Chakravarthy, Taylor Clark, and Tim Sterling (Georgia Tech MSEEM students).

Appendix A. Adjustments to the Princeton Net Zero America Project (NZAP) Analysis

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June 3, 2024

This memo describes several alterations that were made to the Princeton NZAP data to enable defensible estimates and scenarios of U.S. and state-level energy production, consumption, and CO_2e emissions. The adjustments are made to calculations for the entire U.S. and for individual southeastern states to create estimates for the Southeast (SE) region as a whole. The analysis was conducted in conjunction with the November 2023 Southeast Decarbonization Workshop on activating science, business and community partnerships. Preliminary results were presented at the workshop and updated results are included in the final workshop report (Brown, Thornton, et al. 2024) published by Oak Ridge National Laboratory.

We generate GHG emissions estimates for 2020, 2035, and 2050 for the U.S. and the SE by starting with state-by-state final (i.e., delivered) energy-use values published by the Princeton Net-Zero America Project (NZAP). Specifically, we use the NZAP results for two scenarios: the Reference case and High Electrification (E+) scenario. The following adjustments are made to derive estimates of CO_2-e emissions.

- NZAP's state-level estimates of delivered energy do not specify the energy losses during electricity generation and T&D, and during the refining of fuels. We estimate emissions from delivered energy using the emission factors provided in Table 1.
- For hydrogen production, the Princeton NZAP assumes multiple methods of production including pyrolysis of biomass. In our estimates, hydrogen in the Reference scenario is assumed to be produced entirely by Steam Methane Reforming (SMR). (Table 2 provides emission factors used for SMR hydrogen production.) In the E+ scenario we assume:
    - 2020 – 100% production by SMR
    - 2035 – 50% production by SMR + 50% production by electrolysis
    - 2050 – 100% production by electrolysis
- For the electricity sector, the Princeton NZAP database provides data only for installed capacity on a state level. We convert these estimates of capacity to estimates of electricity generation using capacity factors provided in Table 3.
- We generate primary and secondary energy-use estimates for Sankey charts based on energy end-use values (i.e., delivered energy) provided by Princeton NZAP. We estimate

and include energy losses during electricity generation and refining of fuels based on efficiency assumptions provided in Table 4.

- The Princeton NZAP database includes hydroelectricity generation only on a national scale. We borrow values on a regional scale from EIA for the year 2022 (U.S. Energy Information Administration, Electric Power Monthly, Table 1.10.B, February 2023, preliminary data) and assume that hydroelectric generation stays constant across the three time periods: 2020, 2035, and 2050.
- We estimate transmission and distribution energy losses across cables, wires, transformers, and all intermediate devices to be 5.1%, based on estimates of the Gross Grid Loss (GGL), which encompasses all possible T&D losses.
- We use SSP 2 population estimates prepared by Mathew E. Hauer of Florida State University (Hauer 2019) at in 2019, for the U.S. and each SE state through 2050. The spreadsheet with the state-by-state calculations of estimated populations can be found here. They were provided by Jeffrey Hubbs.

Table A.1 presents key estimates from our analysis of GHG emissions in the SE and the U.S.

Table A.1. Estimates and scenarios of GHG emissions in the Southeast and the U.S.: 2020–2050

SE Total (MMT CO_2e)	**2020**	**2035**	**2050**	**Percent Reduction in 2035 relative to 2020**	**Percent Reduction in 2050 relative to 2020**
Reference	1023.30	917.43	975.44	10%	5%
E+	1022.86	717.97	398.12	30%	61%
SE Total Per Capita (MT CO_2e)	2020	2035	2050	Percent Reduction in 2035 relative to 2020	Percent Reduction in 2050 relative to 2020
Reference	2.44	1.96	1.92	19%	21%
E+	2.44	1.54	0.79	37%	68%

Table A.1. Estimates and scenarios of GHG emissions in the Southeast and the U.S.: 2020–2050 (continued)

SE Total (MMT CO_2e)	2020	2035	2050	Percent Reduction in 2035 relative to 2020	Percent Reduction in 2050 relative to 2020
SE Transport	2020	2035	2050	Percent Reduction in 2035 relative to 2020	Percent Reduction in 2050 relative to 2020
Reference	547.42	455.69	482.94	17%	12%
E+	547.03	317.83	78.06	42%	86%
SE Transport Per Capita	2020	2035	2050	Percent Reduction in 2035 relative to 2020	Percent Reduction in 2050 relative to 2020
Reference	1.30	0.98	0.95	25%	27%
E+	1.30	0.68	0.15	48%	88%
SE Electricity	2020	2035	2050	Percent Reduction in 2035 relative to 2020	Percent Reduction in 2050 relative to 2020
Reference	187.42	150.18	157.05	20%	16%
E+	187.46	126.38	82.08	33%	56%
SE Electricity Per Capita	2020	2035	2050	Percent Reduction in 2035 relative to 2020	Percent Reduction in 2050 relative to 2020
Reference	0.45	0.32	0.31	28%	31%
E+	0.45	0.27	0.16	39%	64%

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