New Carbon Economy Consortium:

Building Research Programs to Support 21st Century Economic Opportunity

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The Economic Opportunity of the 21st Century

Since the beginning of the industrial revolution, approximately 2 trillion metric tons of carbon dioxide have been added to the Earth’s atmosphere. If it can be removed and used, this excess CO₂ offers unprecedented economic opportunities that can catalyze innovation in agriculture, manufacturing, and other industries and spur the growth of new markets. The widespread use of carbon removal and conversion technologies can reduce climate risk, generate jobs, bring important environmental benefits, and create a wide range of opportunities for investors.

This innovation must happen fast, more quickly than technological advances of this scale have emerged in the past. An endeavor of this size—extracting an appreciable fraction of the excess CO₂, which is still increasing—will require a truly interdisciplinary science, engineering, and technology approach. It will also require a new generation of innovators focused on the challenges and opportunities of carbon removal and utilization.

Now is the time to map paths to the breakthrough research programs and forward-looking university-business partnerships that will serve as the hubs for this new carbon economy, an economy in which low-carbon industry and primary energy production are joined by industrial centers, agricultural regions, and food-producing ecosystems that turn excess CO₂ into consumer goods, fuels, building materials, and fertile soil. With deliberate but ambitious planning, the United States and collaborators in other countries can develop the knowledge, technologies, and human capital to catalyze the new carbon economy by 2040.

Launching the New Carbon Economy: A First Step

In June 2017, a one-day workshop was held at Arizona State University to begin to map out the work of a research consortium focused on creating a framework for the research programs necessary to support the new carbon economy. The workshop brought together experts from Arizona State University, the Center for Carbon Removal, Iowa State University, Lawrence Livermore National Laboratory, and Purdue University.

Participants agreed that now is the time to lay out a carefully considered, ambitious roadmap for building the new carbon economy. They discussed the long view as well as immediate actions in this effort to address countries’ environmental and economic concerns and restore the carbon balance for a prosperous future. Time is needed to develop and fortify the technical knowledge and human capital the new carbon economy will require. Time is also needed to establish the institutions that can cultivate and sustain the human capacity and capabilities. The first step is a roadmap that will guide research and capability development, which must extend beyond any single institution and demands a global, coordinating network of institutions.

The workshop’s key themes and the consortium’s next steps are summarized below. Following from these initial discussions, the consortium is expanding its partnerships to include people with diverse disciplinary
backgrounds in academia, visionary philanthropies, policymakers, and companies interested and able to pivot their agriculture, food production, and engineering expertise toward turning excess CO$_2$ in the atmosphere into valuable products and industries.

As new voices and expertise are incorporated into the consortium, it will redefine and re-prioritize the most promising avenues of action. Next steps are (1) to determine scientific and technical research programs most likely to yield immediate, actionable results; (2) to identify policies that can spur innovation and help create appropriate markets; and (3) to incorporate the sociopolitical dimensions of carbon removal and utilization into the consortium’s development. Once firmly established, this robust university-business consortium will advance the new carbon economy across the globe and across industries, including chemical products, farming, forestry, building materials, fuels, food production, and more.

**CO$_2$ as a Resource: A New Economic Engine**

Carbon removal and utilization represent trillions of dollars of potential new investment and the creation of major new industries on par with the scale of the oil and gas industry today. These technologies, once mature, will be a critical part of efforts to reduce climate risk and help to create a thriving economy around CO$_2$ recycling. Eventually, innovation in carbon removal and utilization should be stimulated by a price on fossil carbon, strict regulations on countries’ CO$_2$ emissions, or both. But beginning now, research programs and university-business partnerships can bring together forward-looking companies, policymakers, and researchers, taking the early steps necessary to prepare and stimulating this emerging market.

The full suite of carbon removal and utilization technologies and approaches discussed at the New Carbon Economy Consortium workshop offers business opportunities across economic sectors, for new businesses and existing ones that choose to retool, for large and small businesses in forestry, agriculture, energy, manufacturing, mining, and other industries. Developing clean energy, improving agriculture and land management, and securing environmental benefits, including climate mitigation, have broad political appeal. Workshop discussions ranged widely across elements integral to creating the new carbon economy, and those discussions led to first steps in identifying a research roadmap for the next two decades.

**Mapping Out Robust Research Programs in Carbon Removal and Utilization**

Creating the new carbon economy is a truly interdisciplinary endeavor. It pulls together economics with biology, agriculture, forestry, chemical and material sciences, and engineering. It requires complex systems engineering embodying all of these disciplines, lifecycle impact assessments, economic assessments, supply chain logistics, workforce training and development, and an understanding of socioeconomic and behavioral factors. Workshop participants discussed the options on the table today and identified knowledge gaps that the consortium will work to fill through interdisciplinary R&D.
Key Approaches to Carbon Removal and Utilization

Engineered Solutions
Engineered processes can be used to extract CO₂ from the environment and convert it into useful products. A number of engineering solutions offer opportunities for commercialization in the new carbon economy, ranging from reversible fuel cells and carbon-based fuels produced from electricity or directly from solar processes, to plastics, carbon electrodes, and carbon fibers produced from CO₂. Biological and chemical approaches can also be interleaved. Direct air capture (the capture of CO₂ directly from the atmosphere rather than from point sources such as power plants and industrial facilities) can link to algae production for a number of applications, or the CO₂ captured from biomass combustion for electricity generation can be stored underground to achieve negative emissions. Workshop participants discussed which approaches and products hold the most promise—both short and long term—the economic research needed for opportunity mapping, and scientific and technological research needed to push the technologies toward pilot projects and then widespread commercialization. Each potential CO₂-made product will require a full lifecycle impact assessment to account for carbon emissions and other environmental and societal impacts associated with each production step and to identify engineering configurations that lead to carbon-neutral or carbon-negative outcomes.

Ongoing research highlights that process energy in CO₂ conversion must originate from carbon-free primary energy. Hence, the new carbon economy is not a substitute for decarbonizing our primary energy system. For engineering approaches like direct air capture and conversion of CO₂ to succeed in the long term, both technically and economically, research will need to focus on scale up, improved efficiency, and lower costs.

Bioenergy with Carbon Capture and Storage
Biomass-fueled energy generation can be combined with carbon capture and storage to yield carbon-negative power. Participants discussed how short-term opportunities in bioenergy with carbon capture and storage (BECCS) include modular systems for biomass conversion to energy coupled with generation of co-products and co-services. Clearly identifiable co-products include nutrients (mainly nitrogen and phosphorus), clean water, and soil amendments that enhance carbon storage and the fertility of soils. Markets will need to be developed for these co-products. Co-services also result from BECCS, include minimizing water and air pollution and providing jobs in rural areas.

Adapted from the global greenhouse gas emissions under different scenarios and the emissions gap in 2030
For BECCS to succeed in the long term—technically and economically—research will need to focus on the use of biomass that is complex, is locally available, and does not compete with food production. Key biomass streams include forestry and crop residues, animal wastes, and food-processing wastes. Success also will depend on creating co-products that have market value.

Accelerated Weathering and Mineralization
On decadal time scales, weathering of most surface rocks pulls CO$_2$ from the air and forms new minerals and rocks. If this process of mineralization and rock weathering can be accelerated in engineered systems, in addition to taking up carbon it can also produce construction materials such as cement and aggregates. These technologies’ ability to compete with current technologies depends heavily on policy incentives. In the short-term, participants discussed how accelerated weathering could remediate active mines, where minor operational changes or retro-engineering can turn mines’ waste products into valuable resources, such as cement, metals, and construction aggregate. Longer term, other viable technologies could include in-situ mineralization and conversion to aggregate and cements, and low-cost, low-energy mineralization acceleration. Basic research on mineral reaction kinetics and applied research on novel ways to catalyze CO$_2$ reactions with rocks and minerals are both needed to make accelerated weathering and mineralization viable pathways to remove carbon from the air and to create a market for the materials they can produce.

Direct Air Capture
In the new carbon economy, many processes that convert CO$_2$ into useful products start with pulling carbon from the air with technologies like direct air capture. In the short-term direct air capture remains expensive, but further developments show promise for making it cheaper and more widely deployed, including development of ultralow-energy capture systems with novel solvents, sorbents, and membranes or novel schemes for structuring/arranging these capture materials. Since a key challenge in direct air capture is the low concentration of CO$_2$ in air, maximizing the surface area of the capturing material that contacts CO$_2$ is essential and likely requires ultralow-capital techniques for commercial unit fabrication. Longer-term possibilities include the development of ultra-efficient recovery systems, integrated systems for CO$_2$ capture and conversion, and—as an alternative to direct air capture—direct
ocean capture systems. Tapping into the full potential of direct air capture will require foundational science, advances in materials science and chemistry, and technology innovation.

**CO₂ Conversion**

Participants discussed a number of promising CO₂ conversion opportunities, which, like the engineered solutions above, require value and market assessments to determine which ones show the greatest promise in the short and longer term and which can benefit from concerted R&D. Short-term opportunities include improvements in conventional CO₂ conversion approaches (such as reverse fuel-cells, electro-catalysts, and CO₂ polymerization). Over the longer term, reducing the energy penalties for conversions will be essential for commercial viability. Additional advancements can be made in the areas of thermochemical reactors, especially for thermal, biological, and photo-catalysis. Hybrid systems (e.g., photo-electro-chemical or plasma-based conversion systems) can provide breakthroughs in cost or performance, as can unconventional conversion systems including the discovery and development of novel conversion materials, reactors, and systems. Opportunities exist to integrate these systems with others—such as clean water or integrated CO₂/criteria pollutant capture systems—and to seek new product lines for applications of atmospheric carbon.

**Biological and Agricultural Solutions**

Conservation and stewardship ideals are central to the new carbon economy. Although a diversity of technological solutions are needed, biological means have a major role to play in closing the carbon cycle and restoring carbon balance. Workshop discussions explored the importance of biological solutions such as biochar, biomass conversion, the shifting of agricultural practices and crops to enhance soil health, modification of forest management practices, and restoration of ecosystems. As with engineered solutions, each of these approaches requires verifiable carbon accounting and lifecycle impact assessments; however, complex interactions and feedbacks inherent to biological systems may necessitate acceptance of a higher level of uncertainty than for engineered solutions.

**Grain Production Systems that Build Soil Fertility**

Workshop participants discussed the need to shift the management of crop production systems from systems that degrade soils to those that build soil health. Practices that build soils would also remove large amounts of carbon from the atmosphere and enhance the long-term sustainability of food production. For example, cropping systems that retain living biomass above ground also retain integrated root-fungal hyphae networks below ground and continue to add organic matter, increase water retention, and build up soil nutrients, bolstering system resilience. Two potential breakthroughs include the development of perennial grain crops and living mulch systems. In addition, restoring riparian areas can also help capture and store carbon in agricultural systems. Research on taking these to scale would be high risk, but, if successful, transformational. Crop breeding and genetics research are needed to develop high-yielding perennial grain crops and grain and living mulch cultivars that are synergistic rather than competitive. New agronomic management practices to support these systems are also needed.
Sculpted landscapes may also play an important role in the new carbon economy, in which grain is grown on prime agricultural land and perennial biomass crops are grown on more marginal and environmentally sensitive or degraded lands. Sculpted landscapes are achievable with a market for the biomass and the right economic and policy incentives. All of these systems would yield water quality, ecosystem, and soil health benefits in addition to substantial increases in carbon storage.

**Crop Intensification**

Food security must be a top consideration in any proposed change to agronomic systems to avoid unintended consequences; for example, market incentives could inadvertently be created for farmers to convert rainforests or other formerly carbon-sequestering land into pasture if carbon removal initiatives take land out of food production and increased production is not created elsewhere. Therefore, steps must be taken to ensure food security by producing more food on existing crop lands and doing so more efficiently. The increase in crop intensity on existing crop land must not require higher energy inputs or increase carbon outputs. Participants discussed the need for research in crop breeding, genetics, efficiency of nutrient and water use, and crop and soil management systems.

**Biochar**

Biochar, char made from the partial combustion of plant mass, is a co-product of the pyrolysis-bioenergy-biochar-platform (PBBP), where locally harvested biomass undergoes pyrolysis or gasification processing to produce bioenergy and biochar co-products. Nutrients in the biomass feedstock are recovered with the biochar. The PBBP bioenergy products can displace fossil fuels, and biochar can be applied to soils to recycle nutrients and deliver direct soil quality benefits, including increased nutrient and water retention, increased soil porosity, and stabilization of carbon in the soil. Biochar carbon remains in soils for hundreds to thousands of years and will allow farmers to sustainably harvest a greater fraction of above-ground crop residues for use as feedstock in pyrolysis or gasification conversion systems.
Participants discussed the promise of PBBP systems, while recognizing that they are complex. Not all biochar is created equal. Biochar quality and stability in soils varies, and crop yield responses to biochar depend on complex interactions among biochar, soil, crop, climate, and management choices. Research is needed to understand and model these interactions so that agronomic and environmental outcomes can be predicted. Furthermore, to build a PBBP industry large enough to have a significant impact on the global carbon cycle will require substantial research: agronomic, engineering, macroeconomic (markets and policies), technoeconomic (costs and revenue for a specific plant design in a specific location), and that focused specifically on supply chains. Lifecycle assessments, which consider both direct effects (such as emissions due to harvest, storage, and transport of biomass; biochar carbon sequestered; and fossil fuel displaced) and indirect effects (such as positive or negative priming of soil organic matter mineralization and the impact on food security and land use) are needed to quantify the net impact of PBBP systems on greenhouse gas emissions.

In the near term, biochar can be used for a variety of non-agricultural purposes such as mine-land remediation, urban brownfield remediation, remediation of soils contaminated with heavy metals, anaerobic digester gas clean up, phosphate removal from water in anaerobic bioreactors, potable and effluent water treatment, gasifier feedstocks, and fertilizer formulations and stabilizers. Work on these non-agricultural applications can help address the current knowledge gaps and help develop familiarity with biochar as a treatment/supplement while building a more robust market.

**Forest and Aquatic Ecosystems**

Participants discussed other opportunities for carbon removal in biological systems that bring both economic and environmental benefits. For example, trees killed by bark beetles in the US west could be harvested and used as feedstock for biochar or bioenergy systems, simultaneously reducing the risk of wildfire. Reforestation of beetle-kill forests can take up more carbon from the atmosphere, and the entire process would likely be carbon-neutral or -negative. Sustainable forest practices and expanding forests onto marginal lands can help maximize carbon uptake.
Microalgae, a diverse group of aquatic photosynthesizing organisms that can convert solar energy into sugars, proteins, and chemicals, also garner considerable interest in discussions of carbon removal and utilization. The flexibility in application and relative ease of growing microalgae can provide a sustainable and dependable resource. Microalgae can be cultivated to produce bioethanol and biodiesel, grown as a source of animal feed, or produce pigments and pharmaceuticals. They do not grow in arable soil but rather in water slurries that can be placed in any sunny location that has relatively level ground, opening non-arable or marginal lands up for algae production and removing potential competition with food crops. They can be used in the photosynthetic treatment of municipal, agricultural, and industrial wastewaters, coupling an essential ecosystem service to CO$_2$ capture.

The biomass production rate of microalgae is significantly higher per unit area than for plants. Relative to terrestrial plants, microalgae require less feedstock and capture CO$_2$ more efficiently, and can be harvested all at once any time of the year, rather than seasonally. All parts of microalgae can be utilized for value: lipids can make fuel or chemical feedstocks, protein and carbohydrates can make animal and fish feed, and all of the biomass can also be used as a soil amendment.

The high cost of nutrients, CO$_2$, and water, along with lack of favorable production locations are limiting where microalgae can be economical today. Research and development that target increasing biomass productivity per unit of surface area by optimizing delivery of light, CO$_2$, and macronutrients should be combined with efforts to improve the economics of microalgae by combining production with other CO$_2$-reuse opportunities.

**Economics of the New Carbon Economy**

The path to a thriving new carbon economy rests on sound economics and tapping into existing networks and industrial centers that offer a range of carbon-removal approaches today. Both macro- and microeconomic approaches will be needed to guide the scoping of different carbon economy pathways. Importantly, the first recommendation from the workshop participants was to bring economists into the roadmap discussion early on.

Current macro-economic models for negative emissions appear incomplete and narrow in scope. Research into new business models, hurdles to entrepreneurship, and existing and needed finance options would improve existing models. CO$_2$ product commercialization, supply chains, procurement practices, and purchasing behavior for new carbon economy goods and services must rest on a better understanding of all of the factors that influence the ultimate success of a given product or management
practice. The participants also agreed on the importance of research and modeling on both non-monetary and monetary valuation of carbon. For example, carbon removal in agricultural contexts can improve water quality and in the energy sector can increase domestic energy security, but how do we place value on these non-carbon benefits? And how do we account for changes in corporate decision-making processes in the new carbon economy? One way to monetize carbon removal is to create a carbon-negative certification program that highlights for consumers the climate benefit implicit in the product.

Longer term, macro- and micro-economic modeling of new carbon economy products and services needs to take into account transactions and validation for carbon exchanges and market valuation of carbon removal within a lifecycle analysis framework. This quantitative approach will be important for ensuring that the carbon benefits are properly accounted for and guided by the best available science (for example, impact of labeling on purchasing). Case studies will be important to detail the early adoption of new carbon economy activities in the United States, the European Union, and China markets.

Creation of Global Hot Spots
Participants discussed the emergence of locations with particularly rich opportunities around carbon products or carbon waste disposal. These industrial clusters and regional agricultural areas will have a strong impact on the development of the new carbon economy. The challenges and opportunities vary geographically, and the feasibility of carbon removal approaches depends on the specific traits of local, national, and international economies; the presence of innovative companies; and the availability of a trained workforce. Stimulating soil carbon storage, for example, requires a combination of the right biophysical environment (soil type, climate, etc.), the right economic opportunities and incentives, and a community of practitioners willing to change their practices to promote soil carbon uptake. The regions with the greatest potential for soil carbon storage are the very regions that have been the most environmentally degraded. Although the suite of practices that enhance soil carbon storage is known, and even though these practices bring other benefits that improve the entire agricultural operation, socio-economic challenges will be a deciding factor in whether certain practices are implemented. Economic incentives and social acceptance go hand in hand, and both must be in place for land managers to adopt new practices.

Supply Chains
Supply chains are key points of leverage in the new carbon economy, since vendors can work with their suppliers to develop new products and processes taking advantage of harvested carbon. To ensure that lifecycles improve or meet sales standards, accurate measurement and verification of carbon removal, transparency, and traceability must evolve. Workshop discussions included how accounting for carbon removal in natural systems (forests, agriculture) will be especially challenging. Carbon farming, for example, is not a simple accounting exercise: just as some farming methods can sequester carbon, others have the potential to release...
Accurate, robust, and accepted measurement and validation along supply chains will be critical for procurement and investment decisions. In the absence of an international governing body, nonprofits and other nonpartisan institutions can play an important role in creating and updating standards in collaboration with other organizations to drive supply chain innovations. Ultimately, such considerations are contingent upon the policy environment, including mechanisms such as the renewable fuel standard (e.g., California’s Low Carbon Fuel Standard or the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) fuel standards), carbon offsets, or a carbon tax, all of which have different impacts on supply chains.

**Workforce Development**

Workshop participants agreed that we need now to cast an eye on developing an educated workforce that can support the new carbon economy. One of the most important non-technical challenges is anticipating and meeting the need for a significantly expanded workforce trained in the various specialties that will be required. This workforce will need to be interdisciplinary and flexible to new skills as the new carbon economy takes off, in likely unpredictable ways. They will require specific training in the new carbon economy’s practice and flows, technology options, economic methods, and more. The figure below shows some key workforce needs by a robust suite of companies underpinning the new carbon economy.
For the new carbon economy to succeed, students need to be educated across disciplines with an entrepreneurial and innovation mindset. Academic institutions will need to revise, retool, and develop curricula and certification programs focused on new and emerging sensibilities and practices of the new carbon economy, and they will need to provide training and support for workforce development through both formal education and apprenticeship programs. Where possible, these programs should partner and work directly with companies and agencies that will operate the new carbon economy. Coordination, communication, and proficiency on the educational side are key to positioning the United States as a worldwide leader in commercializing and deploying CO$_2$-based technologies.

The consortium’s next steps include identifying science, engineering, and technology knowledge and capabilities required to advance CO$_2$ technologies, determining scalable and effective methods for training the workforce, sharing lessons learned, creating opportunities for students and faculty to engage in entrepreneurial activities and internships, and leveraging the contributions from a newly trained or a re-trained workforce for the success of the new carbon economy.

Key educational topics include simulation, risk assessment, and risk mitigation; carbon removal monitoring, verification, and accounting; geology-related analytical tools; site characterization; methods to interpret geophysical models for storage; methods for designing and completing CO$_2$-related extraction and product development technologies; and methods for public outreach and engagement.

A key early step will be to create a Workforce Advisory Board. The consortium will work with educational institutions and workforce development organizations and facilitate the time-phased creation of training programs to prepare workers for careers in the new carbon economy.

**Data and Modeling**

Businesses, policymakers, and local and state governments need accurate and transparent data on the reliability and permanence (or degradation pathways) of the carbon removal and carbon-based products afforded by a given practice or technology. They will use this information to make decisions about procurement practices, local and regional economic investments, and the education and training programs that must be developed according to the region’s specific opportunities for carbon removal and utilization and its competitive advantages.

Modeling needs, which are somewhat generic, include thermodynamics, techno-economics, and dynamics of market penetration. Each specific carbon removal approach will also have various and potentially multi-scale modeling needs—from atomistic and first principles models of materials in real-world conditions, computational fluid dynamics, and quasi-static to dynamic models of components, to full system models. Accompanying computational modeling and experiments is the generation of potentially massive amounts of heterogeneous data. Researchers across all carbon removal and utilization approaches would benefit from having common access to usable data on
such things as soil carbon measurements; geospatial measurements on carbon storage and biomass cover; and lifecycle assessments of specific low-carbon, carbon-neutral, and carbon-negative products or of modular system components for new system designs.

Today’s data needs for atmospheric carbon removal have similarities with the data needs for informatics in genomics and physics during the last two decades. Workshop participants discussed how researchers in carbon removal and utilization technologies can learn from these researchers’ foresight. In these fields, researchers attended early on to the challenge of shifting the field from generating disparate types of data to the creation of a common data informatics interface that, once built, accelerated research advances by orders of magnitude.

A Carbon Economy Data Hub would combine non-proprietary experimental and computational data on carbon removal and utilization in a searchable data infrastructure. A goal would be to capture experimental and computational results, tools, and expertise. This would include establishing data repositories and, where appropriate, distributing data to the scientific community, business community, government officials, and the public. The consortium will consider developing the Carbon Economy Data Hub as a searchable data infrastructure (materials, components, thermodynamics, lifecycle, technoeconomics) and encourage researchers to make their data available to others. The data infrastructure would be built using standardized, open source tools and enable the capture, storage, curation, analysis, and visualization of experimental, computational, demonstration-scale and pilot-scale results that are generated in the consortium or from associates willing to share. Arizona State University would host the Carbon Economy Data Hub.

Features of the Carbon Economy Data Hub could include:
- A user-friendly web interface for researchers
- A user-friendly search interface
- A data portal for carbon economy data for businesses and governments
- Host structured, semi-structured, imaging, and experimental or modeling data
- Secure compartmentalization of data within organizations to protect proprietary interests
- The ability to publish certain datasets for public access, when appropriate
- Standardized metadata formats to facilitate data processing and searching
The Human Element

Public Attitudes
Even the technically “best” options require human buy-in, a validated value proposition, adoption, and the ability to scale up. The need for assessment and understanding of the public’s views on and knowledge about carbon removal and utilization was articulated multiple times during the workshop. For example, the success of carbon removal and utilization strategies depends upon the awareness and attitudes of the public (farmers, officials, and otherwise), environmentalists, policymakers, manufacturers, investors, and corporations, as does, ultimately, the viability of the new carbon economy itself. Participants agreed on the clear need to fold social science expertise into the consortium early on.

Several key questions require social science expertise: what motivates farmers to adopt different agricultural practices? What are consumers’ perceptions and preferences regarding added value pertaining to carbon-neutral or carbon-negative purchases? What knowledge do elected officials and other decision-makers have of the new carbon economy? What role do investors and corporations see for carbon removal and utilization? Do all of these groups, as well as researchers, understand the potential for risk and opportunities related to the new carbon economy? What are the governance issues in mining the sky?

Political Science and Governance
Workshop participants discussed how elements of the new carbon economy may help to transform our nation’s political dialogue, where issues that shouldn’t be politicized are. Participants see an opportunity for a nonpartisan conversation, one that brings people from different walks of life together to participate in this crucial economic shift. Workshop participants view the new carbon economy as an opportunity for economic value and jobs, while also addressing climate change risk through new businesses and new industries, through consumer choice, and by building awareness and engaging the public about the economic opportunities associated with carbon removal and utilization. A number of political dimensions of a “circular” carbon economy are ripe for exploration, including identifying the political economy theories
most relevant for the key participants in this new economy and analyzing the ways in which existing policies inhibit or enable the new carbon economy’s development and deployment. Longer term, participants discussed the need for research on the coupling/decoupling of the new carbon economy from climate and carbon regulation in politics and policy, and explored the extent to which policies could be driven by carbon value versus of carbon removal and utilization strategies’ co-benefits.

Research Roadmap Under Construction: Calling Collaborators

The new carbon economy will require building expertise, sparking enthusiasm, spurring innovation, and securing financial support, and it will need these from a wide range of individuals, governments, and organizations. These elements need to come together now and endure for decades. Workshop participants began to identify people and organizations who need to come to the table as the New Carbon Economy Consortium evolves. A diversity of voices will be critical for shaping a more detailed, imminently actionable roadmap that outlines the research, modeling, and prototypes needed to give a solid foundation to the new carbon economy and propel it into the market place and ultimately to scale.

This roadmap will identify immediate next steps and an end goal, while allowing the path between the two to remain flexible. Importantly, the roadmap will outline the new carbon economy’s investment needs. Workshop participants discussed the value of treating carbon removal and utilization investment opportunities as a broad portfolio, similar to a strategy of investing in venture capitalist funds rather than in startups directly. The price tag of developing the new carbon economy has been estimated to be similar to that of replacing high-carbon with low-carbon fuels. Workshop participants discussed the diversity of investment needs in the short term and over the long haul—drawing from philanthropies, governments, and the segments of the private sector that stand to reap direct benefits in the new economy.

Organizations and individuals interested in more information or getting involved—foundations, universities, companies, nongovernmental organizations, governments, international organizations, researchers, venture capitalists—may contact Noah Deich, Executive Director, Center for Carbon Removal, noah.deich@centerforcarbonremoval.org.