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The Future of Transportation and the Climate Change Industry

As the climate change industry enters 2023, what developments of 2020-2022 have changed the outlook for what we at CCBJ call the industry of the 21st century? **Global emissions** of greenhouse gases rebounded from the recession year of 2020 brought on by the coronavirus pandemic to reach historical highs in 2021 and 2022 (see pages 8-11). This result was not entirely unexpected, but is somewhat disappointing nonetheless to those hoping that global emissions would be closer to leveling off or even declining in the decade of the 2020s. Emissions from power generation have fallen in the greatest proportions due to the decline of coal and ascent of wind & solar, and notable progress is under way in industrial energy, but far too little progress has been made in buildings, land use and transport—the focus of this trend and data segment review in CCBJ.

In transport, using figures for the USA, the latest comprehensive data on vehicle-miles traveled for the year 2021 showed an obvious increase from the covid-restricted 2020 year, but only marginal increases and decreases in road travel modes, although still a notable decline in air miles from 2019. U.S. Dept. of Transportation data on U.S. Vehicle-Miles Traveled summarized by CCBJ on the table on page 4 makes it clear that moving people and freight around is not about to diminish.

But the future of modes of transport, their power sources, emissions profiles and lifecycle environmental footprints remain very much in question. Transportation is perhaps the most dynamic and multi-faceted major segment of the energy transition and the climate change industry.

Transportation & the Climate Change Industry in 2023

Climate Change Business Journal® assesses the trends shaping the $296-billion transportation segment of the U.S. climate change industry in 2023. Greenhouse gas emissions data is reviewed by region and sector, but trends in electric vehicles, the EV supply chain, EV charging infrastructure, biofuels, hydrogen and transit systems are only starting to show up in GHG figures. Private companies, investors and government agencies are all playing roles in technology and business.

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Visions of the Future of Transportation

Two of the most stirring images of the future of transportation come thanks to the glory of American television media. The iconic Hanna-Barbera cartoon of the 1960s entitled The Jetsons depicted a future of flying glass bubble cars with little platforms and feet that would pop out at your command allowing you to zip around in the air and stop wherever you wanted. But an even more signature form of transportation that was created by another glorious product of American television called Star Trek depicted human beings decomposed into fragments of light and being magically transmitted from ship to planet in a manner of seconds where they would recompose poised on the planet ready for action.

Today's American Consumer, however has no real short-term expectations of either of these contrived fictional futures. The open road and the gas powered engine cranking on 8 cylinders flying down the highway is a difficult ethos of Americana to threaten—and one day to top. Tesla set the EV bar early with improved performance in the all important category of zero-to-sixty, but electric vehicles still have a long way to go to capture the hearts and minds of middle America as inspired by Roger Miller's 'King of the Road' and Willie Nelson's 'On the Road Again' and other country music ballads celebrating the freedom of the open road.

The Specter of Socialized Transportation

On the other side of the coin of the open spaces of the open road, lies the specter of socialized transportation. If socialized medicine is the 'third rail of American politics', then socialized transportation faces similar resistance. American sociological and economic circumstances have created a still embedded resistance to the socialization of medicine. This concept is widely accepted in perhaps the United States of America's most neighborly nations, the United Kingdom and Canada. In each case both of these countries have national health service entities that have been both lauded and criticized—and will always be under scrutiny of the public that pays for its services with its taxes, and the professional medical establishment that needs a viable and sustainable economic model to provide incomes to their professionals.

What could be loosely described as socialized transportation can be examined in the history of public transport in the form of horse carriages, buses, street cars, and all forms of rail transportation. One could argue that these cannot really be called social transportation as most of the services have not been provided to the populace at no charge. Although almost universally subsidized, public transit usually demands a user fee from the consumer.

A few municipal jurisdictions have experimented with and continue to consider making public transit free to the entire populace—a recent example was proposed by a new mayor for the Los Angeles Metro. Many progressive leaders believe the social value of more engaged and consistently utilizing segments of the population will build a greater community foundation for supporting the infrastructure expansions required for more universally available public transport. Similar support and engagement will be required for the step further of a more radical transition to a networked transportation system, requiring individual vehicles that are integrated and networked into digital systems in urban areas for efficiency and safety. This also creates a need for greater uniformity in vehicle design, manufacturing and information technology — something not always consistent with the pursuit of innovation in American business, but some uniformity or compatibility is likely required for a truly networked transportation system.

Perhaps somewhat as fantastical as the futures of The Jetsons and Star Trek, depictions of what an autonomous vehicle

Direct Air Carbon Capture and Storage (DACCS) Garners Significant Scientific, Engineering and Commercial Interest

The **Boston University Institute for Global Sustainability** (IGS) pioneers research to advance a sustainable and equitable future. The IGS focuses on planetary and environmental health, climate governance, and energy systems and has replaced the The Boston University Institute for Sustainable Energy (ISE), expanding the ISE's mission beyond energy to a broader scope of interdisciplinary sustainability research. The mission of IGS is to translate sustainable energy research into urgent action. This university-wide center is dedicated to developing energy systems that will provide abundant, universally accessible and sustainable energy sources for emerging and advanced economies. The IGS approach combines interdisciplinary research, policy analysis and collaborative engagement with partners at every level—from individual energy and water utilities to cities, states and countries. Recent highlights include \$1.3 million in total funding, 63 affiliated faculty, 19 senior fellows and 11 published reports.

Respondents for the Institute for Global Sustainability, Boston University:
Cutler Cleveland, Associate Director, and Lucia Vilallonga, Graduate Research Assistant

CCBJ: Direct air carbon capture and storage (DACCS) has faced a pretty skeptical community of scientists and engineers. What recent breakthroughs have moved the needle of perception?

IGS: A 2018 paper by Carbon Engineering (Keith et al., 2018) in Joule provided detailed engineering and cost analyses for a 1 MtCO2/year capture plant, and was reportedly the first DAC paper to include a "commercial engineering cost breakdown." Since 2011, estimates of near- and long-term costs of DACCS have been decreasing, although the per-ton cost still remains high compared to other emissions reduction methods.

Furthermore, work by Jennifer Wilcox, Ben Kolosz, Jeremy Freeman, and their many colleagues on the Carbon Dioxide Removal Primer, an open-source digital textbook, has helped to democratize knowledge of CDR. The Primer includes a section dedicated to various methods of DAC, and also features discussions about geological storage of CO2, CO2 utilization (another possible destination of carbon captured through DAC), and the environmental, justice, and policy implications.

There have also been engineering innovations in the modular DAC space. For example, Carbon Reform, a Detroit-based company, has developed a method of small-scale DAC for use in buildings. The device, via absorption, captures CO2 in the building and transforms it into a limestone slurry, which can be solidified for use in green construction.

Finally, excitement has been brewing in the United States, thanks to increased funding opportunities through the Department of Energy and the Inflation Reduction Act of 2022.

CCBJ: What have been the most notable projects in DACCS, and what applications will have the most impact on future emissions?

IGS: The largest operational DAC plant is owned by Canada-based Carbon Engineering, which captures a net 1 MtCO2 annually. The largest DACCS project, which includes both capture and storage, is Orca, owned by the Swiss company Climeworks, which captures and stores 4 ktCO2 annually. Both projects use the absorption method of DAC, wherein the CO2 molecules are bound to chemical agents placed on a solid sorbent and then released as a relatively pure stream via a regeneration cycle, to finally be compressed and transported to a storage facility.

One of the challenges of this method of DAC is that the regeneration process requires a large amount of heat, typically supplied by natural gas or industrial waste heat. Thus, the net carbon benefit of a DAC plant using absorbent technologies must take into account the emissions from the heat source, in addition to emissions from other energy requirements and materials across the DACCS lifecycle. Sourcing the heat energy from low- or zero-carbon sources will have a profound impact on a DAC plant's net emissions, and help to ensure the efficacy of the project.

Innovations, policies, and investments that can scale DACCS to achieve gigatonne removal, the level reportedly required by the IPCC to either prevent a global increase of 2° or to return to below 1.5° after an overshoot, will have the most impact on global future emissions.

CCBJ: Is there a possibility of performance or technology criteria for DACCS similar to air pollution control measures such as best available or maximum available control technology?

IGS: One of the key findings of our research is that regulations for DACCS as an emissions reduction method largely do not exist yet. Although other carbon removal methods are included in some legislation, critical monitoring, reporting, and verification infrastructure and standards are lagging behind the pace of innovation and deployment. Some proposed regulatory methods include:

1. Treating carbon as a pollutant, such that its removal from the atmosphere (and prevention of its emission, where possible) is treated as a public good
2. Municipally owned DACCS systems.
3. Carbon taxes and/or cap-and-trade policies placed on emitting corporations, which may fund and/or contract DACCS projects as a means of compliance

Regardless of the means of regulation,

it is clear that rigorous and transparent monitoring, reporting, and verification standards along all stages of the DACCS process will be critical to ensuring that a certain amount of CO_2 is captured and safely stored for the long-term. Policies must also seek to prevent exacerbating existing energy, climate, and environmental inequities in vulnerable and marginalized communities.

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CCBJ: How does your analysis in Boston serve as a microcosm for a national or global picture?

IGS: Many regulatory entities use emissions ordinances and compliance pathways to address emissions, such as the City of Boston's BERDO 2.0 regulation. The challenges of incorporating DACCS into BERDO are not unlike those faced by regional, national, and international governments. Governments in the European Union, such as Germany and Norway, are currently discussing whether and how to incorporate DACCS into their climate action plans, and how to coordinate the sourcing and construction of materials, the transportation and storage of CO_2, and the associated costs among several interconnected but discrete countries, each with their own motives and policies. ☼

DACCS "Market Scan" Provides Overview of Emerging Market and Technologies

Produced for the Boston Green Ribbon Commission by the Boston University Institute for Global Sustainability, the Executive Summary is excerpted below.

Global consensus among climate scientists is that future temperature increases must be limited to 1.5° to 2°C above pre-industrial levels to avoid the most severe consequences of climate change. Most scenarios of future emissions assign a critical role to so-called "negative emissions." These refer to a range of technologies that actively remove carbon dioxide (CO_2) from the atmosphere and permanently store ("sequester") that carbon.

Direct air carbon capture and storage (DACCS) is a negative emissions technology that has garnered significant scientific, engineering, and commercial interest. A complete DACCS system includes the capture of CO_2, its compression and transport, and storage deep underground. Some components of a DACCS system are mature technologies. For example, companies have for decades captured CO_2 from oil and gas processing (and other industrial sources), transported it via pipeline, and injected it into oil and gas reservoirs to boost production. However, a complete DACCS system has yet to be demonstrated as a commercially viable technology that can be deployed at scale to yield large net reductions in atmospheric CO_2 concentrations.

Many states, cities, companies, and other regulated entities use approved "compliance pathways" to meet emissions reductions targets. Compliance typically comes through direct emissions reductions via fuel switching and energy efficiency, power purchase agreements, and renewable energy credits. In principle, the deployment of DACCS can be accelerated if it is a feasible and cost competitive means of reducing CO_2 from the atmosphere. DACCS must therefore compete with existing compliance mechanisms.

Cost estimates for DACCS ($/tCO2) are based on assumed design and performance attributes. Current estimates range from 100 to 1,000 $/tCO2 captured over a wide range of assumptions regarding technological readiness and scale of deployment. It is important to note that most estimates are for capture only; they exclude the cost of transport and storage. For context, consider the City of Boston's 2021 revision of its Building Emissions Reduction and Disclosure Ordinance (BERDO) that requires owners of buildings larger than 20,000 square feet to demonstrate emissions reductions.

Current options and approximate associated costs for Boston building owners are power purchase agreements ($12/ tCO2), Class I renewable energy credits ($10.50/ tCO2), and an "alternative compliance pathway" ($234/ tCO2). Thus, even if one assumes technical viability, in its current state DACCS is not economically viable as a compliance pathway. This could change because many new energy technologies exhibit rapidly falling unit costs as deployment scales. Economic viability goes hand in hand with the need to rapidly scale: thousands of complete DACCS systems are required to yield a sizable reduction in atmospheric CO_2. ☼