Opportunities for Industrial Carbon Capture and Utilization

Statement of:

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Chairman Tonko, Ranking Member Shimkus, members of the committee, thank you for the opportunity to testify before you today on the USEIT Act, a bill that will advance capture and utilization of carbon into products that create value and economic opportunity. On behalf of LanzaTech, Inc., I welcome this chance to share our experience in developing and commercializing an industrial carbon capture and utilization (CCU) technology that is in commercial operation today. Industrial CCU represents an important new strategy for carbon mitigation that reduces emissions from manufacturing while substituting recycled carbon for fresh fossil resources in new products. I hope that our experience shines a light on both the opportunities and challenges for developing and scaling new CCU technologies and, in doing so, explains our support for the USEIT Act.

LanzaTech, Inc. is a biotechnology company, headquartered at the Illinois Science + Technology Park (ISTP) in Skokie, Illinois, where we employ a staff of nearly 130 highly trained scientists, engineers, and business professionals. We also have technology scale up operations at our Freedom Pines Biorefinery in Soperton, Georgia, where we have grown from a handful of staff to roughly 30. Additional staff are located at customer support offices in Europe, China, India.

The company is privately held and has to-date raised over $340 million dollars from a diverse global investor pool to develop, scale up, and commercialize a complete biological CCU platform based on the fermentation of gases. Our headquarters houses the world-leading laboratories and unique experimental capabilities necessary to continue developing and demonstrating the biological CCU technologies which we then license to customers for deployment. Our Freedom Pines Biorefinery in Georgia is the site of our field pilot units and will host the precommercial demonstration of a second technology that produces jet fuel from ethanol, in design today. The company is in an active growth phase in the process of doubling the size of our headquarters, where we have added nearly 25 full-time staff just over the past 6 months.

Although we do not necessarily think of it this way, nature actually provides role models for CCU in biology. After all, plants and trees constantly capture and reuse carbon to make biomass. However they take up carbon only in the form of CO_2 and only after the carbon has already been emitted to

the atmosphere. LanzaTech was founded to exploit a different form of biological CCU – gas fermentation. LanzaTech's gas fermentation platform harnesses biology to capture waste carbon from industry, before it is emitted to the atmosphere, and to make new products in addition to biomass.

At the heart of industrial gas fermentation is an ancient biological pathway that allows certain microbes to get all their carbon and energy from gases, rather than the sugars or starches used in conventional fermentation. This ancient biology allows microbes to live on gases containing carbon monoxide (CO) and carbon dioxide (CO_2) – collectively referred to as "carbon oxides". In fact, they can live on CO alone, which is a major component of industrial emissions, including steelmaking. By this means, gas fermentation enables the continuous production of fuels and chemicals from industrial waste gases, simultaneously mitigating carbon emissions and creating products.

As I will describe later, LanzaTech has taken the first instance of gas fermentation, ethanol production from steel mill emissions, through to commercialization. While this has established the viability and near-term potential of industrial CCU, it took nearly 14 years to achieve, with multiple stages of scale up from the lab through pre-commercial demonstrations and increasing capital requirements at each stage. Since the field overall is at a relatively early stage, major investments in research, development, scale up and deployment will be required to realize the full carbon mitigation benefits of industrial CCU. Therefore, we are tremendously pleased with the commitment to research and development on CCU technologies in the USEIT Act. We also advise that application of CCU to major emitters in the industrial sector, such as steelmaking, requires that the research and development provision of the USEIT Act encompass utilization of carbon oxides, consistent with the utilization component of 45Q, rather than CO_2 alone.

By way of background, the CO from steel mills is an unavoidable byproduct of steelmaking chemistry, in which carbon is used to reduce iron ore. Because this CO cannot be released directly into the atmosphere due to its toxicity, it is inevitably combusted and instead released as CO_2. Industrial CCU captures the CO before it is combusted, preventing its release (and reducing criteria pollutants). In our process, microbes then consume the CO, along with any hydrogen and CO_2 that may be present, and through their own metabolism synthesize ethanol or other products. The microbes performing carbon capture are themselves a valuable protein rich nutrient source and can be converted to nutritional feed once spent.

The initial application of LanzaTech's CCU technology is in the steel sector, producing ethanol from steel mill emissions. The first commercial plant was commissioned in China in 2018. To date this plant has produced over 12 million gallons of low carbon ethanol from steel mill waste gases, equivalent to avoiding emissions of 60,000 tons of CO_2. Further commercial plants are in design or under construction around the world, using gases from steel mills, ferroalloy plants, and refineries, as well as gasified biomass and municipal waste.

In addition to its use in road transport, ethanol from industrial CCU can be converted to plastics, or turned into jet fuel. These downstream markets enable continued growth of ethanol production from industrial CCU or other any other process, independent of future demand for cars and the "blend wall". LanzaTech is itself commercializing technology that converts ethanol to sustainable aviation fuel, which is of strategic importance to US airlines for meeting their commitments and international obligations to reduce emissions. This Alcohol-to-Jet technology originated in the Department of Energy's Pacific Northwest National Laboratory and was scaled up by LanzaTech at our Georgia facility, with support from the Department of Energy. LanzaTech has converted ethanol from steel mill emissions into aviation fuel that powered a commercial Boeing 747 flight from Florida to London in October of 2018, the first flight ever to use CCU fuel. Last October, the fuel was

used in the delivery flight of a brand new All Nippon Airways (ANA) Boeing 777-300ER commercial passenger aircraft from Boeing field in Everett, Washington to Japan.

In partnerships with other companies, LanzaTech is also investigating ways to convert CO_2 into chemicals and fuels by combining electrochemistry with our gas fermentation. Through electrochemistry, CO_2 can be converted to CO and fed into LanzaTech's existing gas fermentation process. This will broaden the commercial applications of gas fermentation to CO_2 sources that do not contain CO, such as waste gases from corn ethanol fermentation and, ultimately, CO_2 from Direct Air Capture.

Industrial CCU has the potential to create jobs and increase revenues in America's steel and other manufacturing sectors. Using industrial CCU to produce ethanol or sustainable aviation fuel can expand the pool of Advanced Biofuels or serve chemical and material markets, increasing energy security without additional pressure on land, water, or biodiversity. At least 33 ethanol plants, producing over 1 Billion gallons of Advanced Biofuel, could be built in states such as Indiana, Ohio, Illinois, Michigan, California, Texas, and Louisiana using only 60% of suitable waste gases. Each would create over 1000 jobs during construction and 240 during operation (direct, indirect and induced)[1]. Combined, these plants would add $660M annually to local economies. Productive utilization of steel waste gases also benefits the U.S. coal sector, which supplies metallurgical coke for steelmaking.

To expand our product portfolio, LanzaTech has pioneered the development of a full industrial microbiology capability for gas fermenting organisms, which enables production of high value chemical intermediates used to make materials such as acrylics, fibers, plastics, and synthetic rubber. In fact, LanzaTech has demonstrated the production of over 50 valuable chemical intermediates from gas streams in the laboratory. In the future, once fully developed, these new microbes can be dropped into an existing industrial gas fermentation facility to make a new product, in many cases leading to carbon capture and sequestration in durable goods.

In the future, industrial CCU has the potential to mitigate emissions across a wide range of sectors and produce low carbon products serving a wide range of markets. Examples of other products that will be accessible through industrial CCU include:

- Transportation
    - Fuel Ethanol, Diesel, Jet, novel fuel blend components
- Materials (Commodity chemicals)
    - Textiles, Plastics, Rubber
- Household (Solvents, Specialty chemicals, Industrial Enzymes)
    - Detergents, Cleaners, Fragrances, Cosmetics, Coatings, Colors, Dyes, etc
- Nutrition (Proteins, Vitamins, Amino Acids)
    - Synthetic proteins, Sweeteners, Amino acids, Omega-3's, Flavors (e.g. Vanilla), Fish/Animal Feed

In summary, LanzaTech represents only one of many potential platforms for industrial CCU, which can transform the way we think about industrial emissions. Instead of an environmental liability, they become resources for making valuable products, simultaneously preventing emissions from

[1] Jobs impact estimated using multipliers for construction and chemical manufacturing from https://www.epi.org/publication/updated-employment-multipliers-for-the-u-s-economy/.

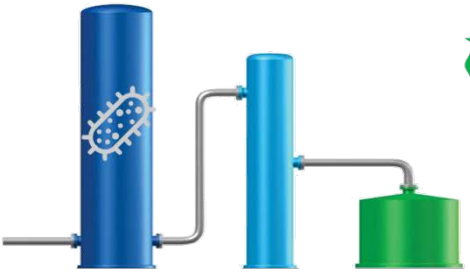
industry and reducing demand for fresh fossil feedstocks. The USEIT Act's investment in research and development that specifically focuses on carbon capture and utilization is a significant step in advancing this tremendously important avenue for mitigating carbon emissions from the industrial sector.

In closing, I would like also to acknowledge the many ways that LanzaTech has benefited from numerous partnerships with Federal agencies since 2010, including DOE, ARPA-E, DARPA and FAA. These partnerships have been instrumental in allowing us to develop the fundamental knowledge of our microbe and the gas fermentation process, tools for high throughput modification of our industrial microbe, and pathways to new products including the Alcohol to Jet technology.

Thank you again for the opportunity to testify today and for your kind attention.

Recycling Carbon

Industrial Off Gas
Biomass, MSW Syngas

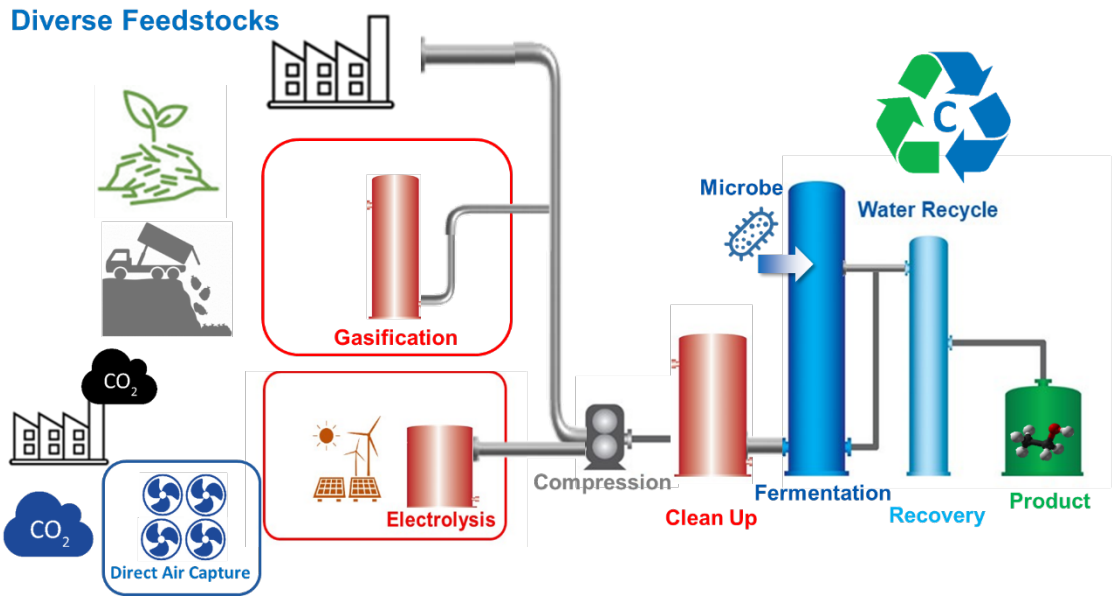


Fermentation

Product Tank

Recycling Gases: Environmental, Economic, Social Benefits


12 million gallons produced from CO waste gas
60,000 tonnes of CO_2 mitigated


Diverse Feedstocks
Gasification
CO_2
CO_2
Direct Air Capture
Electrolysis
Compression
Clean Up
Microbe
Fermentation
Water Recycle
Recovery
Product

Direct Production of Chemicals from Recycled Carbon

Direct Production Reduces Costs & Footprint

Putting Carbon in the Circular Economy