Engineering our way to a sustainable economy

Statement of :

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1. Please provide a brief overview of your company and its technologies.

LanzaTech Inc is a Chicago-based start-up company pioneering the commercialization of a complete process platform to allow the continuous production of sustainable fuels and an array of chemical intermediates from gases at scale. Using a proprietary biological conversion technique known as gas fermentation, the LanzaTech process leverages local, abundant, low-cost waste resources as feedstocks. The technology has been successfully demonstrated using a diverse range of feedstocks composed of carbon monoxide (CO), hydrogen (H2), carbon dioxide (CO2), or methane (CH4), including waste gases from industrial sources (e.g., steel mills, or refineries), syngas generated from any resource (e.g. unsorted and unrecyclable municipal solid waste or agricultural waste), or biogas. LanzaTech operates a licensing business model, offering customers a full process package having developed the process engineering, biology and chemistry of this waste valorization technology.

The first commercial plant demonstrating fuel ethanol production from gas residues produced by the steel industry was commissioned in China in May 2018.To date this plant has produced over 5 million gallons of low carbon ethanol from a waste stream from steel making. Further commercial plants are in design or under construction, including one in the US using biomass residues. To expand the product portfolio from these plants, LanzaTech has pioneered the development of synthetic biology techniques for genetic engineering of gas fermenting organisms. This capability has been reduced to practice by developing organisms capable of producing high value chemical intermediates such as acetone (used in in the manufacture of acrylic glass), isopropanol (used for the production of polypropylene plastics), and isoprene (used in the production of synthetic rubber). Indeed, LanzaTech has used its synthetic biology platform to produce improved industrial microbes and demonstrate the production of over 50 valuable chemical intermediates from the low value high volume gas streams that can be accessed by gas fermentation. The commercial deployment of bacteria able to produce different chemical intermediates from gases paves the way for the operation of “product flexible” conversion facilities that can switch between final products by deploying different bacterium in their bioreactors according to market dynamics.

2. Please describe your company’s history with federal funding, and any current partnerships with federal agencies, including through the National Laboratories.

LanzaTech has benefited from numerous partnerships with federal agencies since 2010. These have taken multiple forms: competitive grants and cooperative agreements awarded to LanzaTech or to our university and industry partners; direct funding to national lab partners for projects cost-shared by LanzaTech; and funding to consortia engaged in research relevant to our technology. Partnerships related to biological engineering have been funded by DARPA, DOE Bioenergy Technologies Office (BETO), DOE Office of Science, and ARPA-E. Example outcomes of these partnerships are fundamental knowledge of our microbe and the gas fermentation process, tools for high throughput genetic engineering of anaerobic bacteria, analytical and data mining methods and models to enable rapid development of pathways to new fermentation products, and demonstration of new processes such as acetone production from gases. Current partnerships include university-led research programs to develop new genetic modification tools and a Clostridia-based Biofoundry based on automation and cell-free tools, supported by BETO and DOE Office. Another group of partnerships is investigating ways to convert carbon dioxide into chemicals and fuels by combining electrochemistry with our gas fermentation. In more focused projects, we are optimizing the production of acetone and higher alcohols from gas streams.

Additional partnerships to develop bioreactor technology and catalytic processes that convert our direct fermentation products into downstream fuels and chemicals such as sustainable aviation fuel and butadiene have been supported by BETO, ARPA-E, DARPA, and FAA. In current partnerships, we are scaling up technology to produce sustainable aviation fuel from ethanol and supporting projects at Pacific Northwest National Lab to produce higher value products through catalytic conversion of ethanol.

3. What is the potential for engineering biology technologies across different sectors?

In every field in which biological processes are used, engineering can be used to improve these biological processes in terms of the efficiency of the process or the value of the outcome. Below we have provided a snapshot of engineered biology can play a role in various industry sectors:

- Transportation
    - Fuel Ethanol, Diesel, Jet, novel fuel blend components

- Materials (Commodity chemicals)
    - Textiles, Plastics, Rubber, Building materials, etc

- Household (Solvents, Specialty chemicals, Industrial Enzymes)
    - Detergents, Cleaners, Fragrances, Cosmetics, Coatings, Colors, Dyes, etc

- Nutrition (Proteins, Vitamins, Amino Acids)
    - synthetic meat and milk protein, Sweeteners, Vitamins, Amino acids, Omega-3’s, Flavors (e.g. Vanilla), Fish/Animal Feed

- Agriculture (Advanced crops, Natural products)
    - Advanced crops, Crop protectants, fertilizers, etc
- Medicine (pharmaceuticals, vaccines)
    - Antibiotics, drugs (e.g. Anti-Malaria), vaccines, antibodies
- Communication
    - Sensing/Detection/Memory, Communication/Electronics (e.g. Nanowires)

In manufacturing, biological processes can offer numerous advantages over traditional production strategies:

- More sustainable, fewer GHG emissions, using renewable and waste resources
- Avoiding hazardous effects on health and environment during production process
- Advanced properties, e.g. biodegradability, strength/durability (e.g. spidersilk)
- Potential for reduced production cost and security of supply

4. How can the federal government and universities best partner with the private sector to advance research and innovation in engineering biology?

Private companies can offer both a valuable commercial context and potential path to commercial application for innovative engineering biology technologies being developed in federal government laboratories and universities. Many technological developments in engineering biological systems have the potential to be applied in numerous industry sectors. This provides an opportunity for there to be multiple potential pathways to commercializing a mature technology development in this area of science. However, in the early stages of the development of such technologies, companies partnering with government or university research groups will necessarily take a significant up-front risk on the efficacy and value of a research project. Therefore, in-order to encourage the formation of these valuable early partnership events between companies and researchers in universities and the federal government, recognition should be made in terms of preferential or dedicated technology access rights within a given field of application.

5. How does LanzaTech integrate ethical and security considerations into your technology development plans?

Our company has developed and now commercialized a technology to biologically convert a range of gases into valuable fuel and chemical products. Workplace and environmental health and safety has been a priority for LanzaTech throughout our company's history. Not only do we follow and comply with all standard regulations and biosecurity rules from EPA, and OSHA, we also actively operate an in-house Health and Safety program / culture that places priority on early hazard identification and remedy as a strategy to mitigate the potential for more serious incidents to occur within the workplace.

The biological catalyst used in our gas conversion process is called *C. autoethanogenum (C. auto).* This biological catalyst has been well characterized on a physiological level and classified by the World Health organization (WHO) in the lowest risk group (WHO risk group 1), the same as Baker's yeast. *C. auto* is non-pathogenic and unlikely to cause human or animal disease. As a strict anaerobe, it is unable to survive in presence of oxygen or in air. The strain developed by LanzaTech has further been selected on the basis that it unable to sporulate.

In our lab we follow standard laboratory procedures in accordance to OSHA and EPA. We minimize release of organisms through sterilization and bleaching, and have stringent biowaste policies.

In a commercial setting, the bacterial culture would be contained in bioreactors that are designed to maintain a strict anaerobic (no oxygen) environment, which forms a primary, environmental containment for the organisms. In case of spills or leaks, process plants are designed with physical containment in the form of a dyke to contain any liquid spills in order that these can be properly treated before disposal. Waste treatment together with heat treatment are an integral part of the process, forming a third layer of containment.

We consistently and routinely screen all new genetic or other elements used in the development of our biological catalysts to ensure that they are in no way associated with or precursors to toxic or pathogenic agents. In this way we ensure that the products of our engineering biology program can be deployed without risk to humanity the environment or agriculture. To aid this screening the U.S. Department of Health and Human Services (HHS) issued the *Screening Framework Guidance for Providers of Synthetic Double-Stranded DNA*. This voluntary Guidance outlines the U.S. government's recommendations for screening double-stranded DNA to ensure that existing Select Agent Regulations (SAR) and Export Administration Regulations (EAR) are followed, to encourage best practices in addressing biosecurity concerns, and to reduce the risk that individuals with ill intent could exploit the application of DNA synthesis technology to obtain genetic material derived from or encoding Select Agents or Toxins, or agents on the EAR's Commerce Control List (CCL).

In accordance with the HHS guidance, the U.S. Department of Energy Joint Genome Institute (JGI) has developed a DNA screening pipeline (BLiSS – Black List Sequence Screening) to screen all sequences that it synthesizes through its DNA Synthesis Science program. LanzaTech has incorporated the BLiSS pipeline into its inhouse genetic research routines.

6. **What recommendations, if any, do you have for improvements to the *Engineering Biology Act*? What additional recommendations, if any, do you have for Congress or for federal science agencies that fund engineering biology research?**

We are very pleased to see that the Congress recognizes the importance of Engineering Biology, as reflected in the Act. Interagency cooperation will be a key to accelerating the development of this area. We have identified one area for improvement. New biological platforms, of which ours is just one example, can process a wide variety of wastes and residues into sustainable fuels, chemicals and materials. Not all of the wastes and residues derive from plants or algae, which are traditionally thought of as the basis for "biofuels" and "bioproducts". Therefore, we recommend that the Act include language that references all technologies that have a biological component, either though biologically-derived feedstocks or biological processing, including biological carbon capture and storage.

In terms of recommendations for agencies that are funding engineering biology research, we recommend that programs be designed to promote industrial partnerships at the earliest stages of research. The historical progression of research programs has been to perform basic research in research and national labs, which is then transitioned to industry for applications. Incorporating industry experience, expertise and awareness of applications needs into basic research projects will increase the effectiveness of the federal government's research investments and accelerate the uptake of research results. This will expand the benefits of these investments for the U.S. bioeconomy and increase U.S. leadership in biotechnology.