Summary of Town Hall and Individual Input

Climate Change Solutions

Challenges

Carbon Management and Climate Change Mitigation

- **Carbon capture and sequestration**: Developing technologies and practices to capture and store carbon from the atmosphere.
- **Carbon dioxide removal**: Exploring methods for removing carbon dioxide from the atmosphere and sequestering it.
- **Increasing carbon sequestration in the soil**: Enhancing carbon storage in soils through agricultural practices and other strategies.
- **Soil carbon sequestration**: Monitoring, reporting, and validating soil carbon sequestration practices.
- **Developing seaweed culture**: Exploring the potential of seaweed cultivation for carbon sequestration, fodder, and food production.
- **Harnessing soil micro-organisms**: Exploring the potential of soil microorganisms to sequester carbon and enhance soil health.
- **Synthetic biology for carbon capture and storage**: Engineering biological systems to enhance carbon capture and sequestration.
- **Using microorganisms to convert CO2 into higher molecular weight compounds**: Exploring the potential of microorganisms in carbon capture and conversion.

Renewable Energy and Biofuels

- **Cellulosic biofuels**: Developing biofuels from non-food plant materials.
- **Energy feedstocks and fuels**: Developing renewable energy sources and fuels from biomass.

Ecosystem Conservation and Restoration

- **Biobanking threatened species**: Preserving and studying biological diversity.
- **Climate change impacts on ecosystem services**: Understanding and mitigating the effects of climate change on ecosystems and the services they provide.
- **Climate-smart restoration**: Restoring degraded ecosystems to enhance carbon sequestration and ecosystem services.
- **Natural climate solutions**: Exploring the role of natural ecosystems in mitigating climate change.

Industrial and Agricultural Decarbonization

- **Decarbonization and recovery**: Developing technologies for the decarbonization of industrial activities and the recovery of resources.
- **Industrial carbon emissions reduction**: Developing technologies and strategies to reduce carbon emissions from industrial processes.

Bioeconomy and Climate Change

- **Role of bioeconomy in climate change solutions**: Maximizing the potential of the bioeconomy in addressing climate change.

Microclimate and Agriculture

- **Microclimate effects on crop production**: Understanding the effects of localized weather patterns on crop production and disease.

Solutions

Microbial and Plant-based Innovations

- **Develop a better understanding of factors that limit maximum product concentration in microbial fermentations**: Aims at optimizing microbial processes for higher yields in bioproducts.
- **Use our knowledge of plant domestication and physiology to improve climate-resilient species**: Focuses on leveraging genetic and physiological insights to enhance plant resilience against climate variability.
- **Harness the natural process of photosynthesis to remove carbon dioxide from the atmosphere**: Proposes using enhanced photosynthesis as a natural method for carbon capture.

- **Cooperate between plants with high specialization in survival tasks**: Suggests promoting symbiotic relationships and cooperative mechanisms among plants to improve ecosystem resilience and productivity.
- **Capture more of the plant inputs in soils in more persistent forms**: Aims at increasing carbon sequestration in soil through the stabilization of organic inputs.
- **Enhance ability of soil microbes to convert carbon dioxide to useful products**: Focuses on leveraging soil microbiomes for carbon capture and conversion, enhancing soil health and carbon sequestration.

Renewable Energy Integration

- **Use wind, solar, and hydroelectric power as energy sources, and even hydrogen**: Proposes the adoption of a mix of renewable energy sources to power bioeconomy processes, reducing dependence on fossil fuels.
- **Develop integrated biorefining processes that are energy efficient**: Aims at creating biorefineries that efficiently utilize renewable energy sources for the production of bio-based products, minimizing energy consumption and waste.

Carbon Management Strategies

- **Identify and invest in novel and different important topics to decarbonize the bioeconomy**: Calls for targeted investment in innovative solutions that reduce the carbon footprint of bioeconomic activities, contributing to the overall decarbonization efforts.

Potential Milestones

Microbial Bioprocessing and Bioenergy

- **2-3 yrs. Develop a single demonstration of a natively-cellulolytic microbe that can produce products from cellulose at high yield and titer**. This solution targets the optimization of microbial processes for efficient bioconversion of cellulose into valuable products, focusing on the use of cellulolytic microbes.
- **3-5 yrs. Extend the previous demonstration to other organisms, pathways, and products**. Aims to broaden the application of microbial bioprocessing to a wider range of organisms and bioproducts, enhancing the versatility and efficiency of bio-based production systems.

Renewable Energy Integration in Biorefineries

- **2-3 yrs. Develop small-scale adoption of solar or wind energy by conventional biorefineries**. Focuses on incorporating renewable energy sources into existing biorefinery operations to reduce carbon footprint and improve sustainability.
- **5 yrs. Develop pilot-scale biorefineries operating on hydrogen fuel, and energy-efficient plant biomass fractionation and by-product valorization processes**. Targets the development of next-generation biorefineries that utilize clean hydrogen fuel and incorporate advanced technologies for biomass processing and by-product utilization, promoting energy efficiency and waste reduction.

Soil Science and Carbon Stability

- **2-5 yrs. Identify key plant/microbe/abiotic/chemistry factors driving soil C (carbon) stability and use this knowledge to predict plant/microbe interventions**. Aims at understanding the complex interactions in soil ecosystems that contribute to carbon stability. This knowledge could inform strategies to enhance soil carbon sequestration through targeted interventions involving plants and microbes.

Resources Required

Collaboration and Commercialization

- **Subsidized collaborations with industrial partners**: For characterizing engineered organisms in real-world conditions and demonstrating novel technologies like nitrous oxide recovery.
- **Collaborations with industrial partners in demonstrating novel technologies**: Including the commercialization potential of these technologies.

Policy and Public Awareness

- **Public policies that encourage investment in carbon dioxide removal**: Highlighting the need for policy frameworks that incentivize carbon management strategies.
- **Broad awareness of the importance of Bioeconomy R&D**: From both government and society, to foster a supportive environment for bioeconomy initiatives.

Research, Innovation, and Technology Development

- **Modeling studies for carbon sequestration**: Such as those indicating the scale of sequestration in oyster shells or the development of super carbonate sequesterers.
- **Economic sources of reactive hydrogen atoms**: Whose production does not contribute to CO2 emissions, and research on ecosystem carbon storage versus emissions.
- **Soil ecology and microbiome manipulations**: Understanding soil ecology, manipulating the soil microbiome for enhanced carbon sequestration, and overcoming challenges in transforming non-model microbes and plants.

Partnerships and Engagement

- **DOE--NSF--USDA partnerships**: To support interdisciplinary research and development efforts.
- **Direct engagement between companies and academics**: To bridge the gap between research and practical application.

Standardization and Data Management

- **Scaling and MRV (Monitoring, Reporting, and Verification)**: Addressing the need for standardization across industries and overcoming the lack of data and organization.
- **Over-arching barriers**: Such as quantifying carbon sequestration and transitioning entities into the bioeconomy, with a focus on both large and small businesses' understanding and utilization of carbon credits.

Societal and Regulatory Considerations

- **Time to understand the reality of managing public and private lands**: Including the economic, cultural, and regulatory challenges that impact the adoption of bioeconomy solutions.
- **Diverse research topics beyond crop plants**: Encouraging a broader range of research subjects to address over-specialization among scientists and promote a more inclusive bioeconomy.

Food and Agriculture Innovation

Challenges

Technology and Innovation in Agriculture

- **Alternative protein production**: Research and development of alternative protein sources, such as plant-based and fermentation-derived proteins.
- **Biomanufacturing alternative proteins**: Challenges in scaling up and optimizing biomanufacturing processes for alternative proteins.
- **Crop breeding and improvement**: Engineering crops for enhanced yield, resilience, and nutritional value.
- **Precision agriculture**: Utilizing data and technology to optimize agricultural practices and improve efficiency.
- **Valorization of waste and byproducts**: Utilizing agricultural waste and byproducts for value-added products and sustainable resource management.

Environmental Sustainability

- **Carbon sequestration**: Enhancing carbon sequestration in agricultural soils and crops.
- **Closed-system agriculture**: Combining microbes and plants in closed-system agricultural environments.
- **Environmental sustainability**: Minimizing environmental impacts of agricultural practices, including water use, fertilizer application, and waste management.
- **Pesticide reduction**: Developing alternative pest management strategies to reduce pesticide use and environmental impacts.
- **Sustainable animal agriculture**: Enhancing sustainability in animal agriculture, including reducing environmental impacts and improving animal welfare.

Resilience

- **Disruption to food supply**: Preparedness for disruptions to the food supply due to environmental or geopolitical factors.
- **Resilient agriculture**: Developing agricultural practices that are resilient to climate change and other environmental challenges.

System Efficiency and Sustainability

- **Farm-to-fork systems**: Designing and implementing sustainable and efficient farm-to-fork systems for food security.
- **Food security**: Addressing the challenge of feeding a growing global population while ensuring equity and sustainability.
- **Life cycle assessment and techno-economic analyses:** Evaluating the environmental and economic impacts of food and agriculture innovation technologies to inform decision-making.

Solutions

Crop and Livestock Improvement

- **Develop structure-function relationships between the structural attributes of proteins and their functional performance**: Aims to enhance understanding and manipulation of protein functions for improved crop traits and food products.
- **Diversify food crops with more research on crop wild relatives and nascent food crops**: Focuses on expanding the genetic base of agriculture by incorporating wild relatives and underutilized crops, enhancing biodiversity and resilience.
- **Develop genomically optimized livestock farming systems**: Proposes the use of genomics to improve livestock breeds for better productivity, health, and sustainability.
- **Develop and breed existing and novel crops**: Involves genetic improvement and breeding strategies to enhance crop yields, resilience, and nutritional quality.
- **Develop immunostimulants and probiotics in aquaculture**: Aims to improve fish health and productivity in aquaculture through natural immune boosters and beneficial bacteria.

Waste Management and Sustainability

- **Accelerate the nutrients (fertilizers) recovery from Waste**: Focuses on recycling and recovering nutrients from waste

streams to create sustainable fertilizer alternatives.

- **Reduce our dependence on synthetic nitrogen fertilizers by improving associations between crops and nitrogen-fixing bacteria**: Proposes biological solutions to nitrogen fertilization, reducing reliance on synthetic inputs and enhancing soil health.

Technology Application and Integrated Research

- **Take a collaborative integrated research approach combining traditional agricultural research with genomics, biotechnology, and artificial intelligence**: Encourages interdisciplinary research that leverages advanced technologies for agricultural innovations.
- **Extend the industrial platforms of biorefineries**: Suggests expanding the capabilities and outputs of biorefineries to produce a wider range of bio-based products, contributing to the bioeconomy and reducing waste.

Potential Milestones

Crop Development and Genetic Research

- **2 yrs. Establish research institutes for developing nascent crops and crop wild relatives**: Aims at enhancing agricultural biodiversity and resilience through focused research on underutilized and wild crop species.
- **2-5 yrs. Develop novel insights into gene expression, genetic diversity, and Agrobacterium strains for crop improvement**: Focuses on genetic research to enhance crop yield, resistance, and nutritional value.

Carbon Capture and Bioproducts

- **2-3 yrs. Develop pilot-scale systems for harvesting carbon dioxide and hydrogen as feedstocks for gas fermentation and single-cell protein production**: Targets innovative approaches to utilize greenhouse gases for biofuel and bio-based product production.

Waste Management and Nutrient Recycling

- **5 yrs. Develop full treatment protocol for composting and nutrient recycling and improve compatibility and breeding efficiency for crop plants**: Aims at creating sustainable agricultural practices that close the loop on waste and nutrient cycles.
- **3-5 yrs. Develop nutrient recovery technologies for field demonstrations and establish a proof-of-concept for cutting-edge technologies for nutrient recovery**: Focuses on technologies to recover and reuse nutrients from agricultural and possibly other waste streams.

Bioreactor Development and Industrial Production

- **2-3 yrs. Develop proof-of-concept bioreactors for small-scale industry production**: Aims at designing and testing bioreactors that could enable sustainable production processes in various industries, particularly for small-scale operations.

Resources Required

Innovation and Sustainable Production

- **Greater recognition of the benefits of using single-cell protein production from waste carbon dioxide and renewable energy**: Advocates for increased awareness and support for innovative methods that use waste CO2 and renewable energy to produce proteins, offering an alternative to conventional agriculture.
- **Funding and incentives for gas cultivation and electrolyzer technologies to establish electricity to food protein value chains**: Focuses on developing technologies that convert electricity into food proteins without traditional agricultural inputs, emphasizing sustainable production methods.

Public Engagement and Knowledge Transfer

- **Communication with the public on how specialty tree crops can help solve real-world problems**: Highlights the importance of educating the public on the role of specialty crops in addressing environmental and sustainability challenges.
- **Public funding and open access research that's available for the industry**: Points to the need for publicly funded research to be

openly accessible, facilitating knowledge transfer and industry application.

Agricultural Innovation and Business Expertise

- **Access to breeding and business experts from agriculture firms and labs**: Emphasizes the importance of collaboration between researchers and industry experts to drive innovation in crop breeding and agricultural business models.

Research and Development Funding

- **Funding for research on practical application of probiotics and prebiotic in agriculture and aquaculture industries**: Supports the development of beneficial microbial applications in agriculture and aquaculture for improved health and productivity.
- **Funding for research on technologies to identify, extract, and evaluate compounds and develop bioplastics and edible films**: Aims at advancing research in bioplastics and edible films for both food and non-food uses, highlighting the need for sustainable materials.
- **Funding for research on disease biomarkers and biosensor technologies**: Focuses on developing technologies for early disease detection and engineering more resilient plants, addressing challenges in agriculture and health.
- **Funding to develop evolutionary data, and development of methods to process and interpret it at scale**: Supports research in evolutionary biology, providing insights into genetic diversity and adaptation, with applications in agriculture, conservation, and biotechnology.

Collaborative Opportunities and Infrastructure

- **Funding for research on building collaborations through engaging opportunities of researchers**: Encourages the creation of platforms for collaboration, such as planning grants and conference grants, to foster a community of researchers working towards shared goals in the bioeconomy sector.

Supply Chain Resilience

Challenges

Bio-Based Production and Innovation

- **Bioproducts and biochemicals production**: Focusing on the scaling up and optimization of bio-based production of chemicals and materials, highlighting the need for efficient bioprocessing technologies.
- **Hemp innovations and regenerative economies**: Exploring the sustainability and versatility of hemp as a resource, reflecting a growing interest in crop diversification and the development of regenerative economic models.

Supply Chain Resilience and Optimization

- **Diversification and redundancy**: Emphasizing the importance of diversifying sources and building redundancy within supply chains to enhance resilience against disruptions.
- **Localization and regional cooperation**: Fostering closer collaboration at local and regional levels to strengthen supply chain networks and ensure more sustainable and resilient supply chains.
- **Scalability and efficiency**: Addressing the need for developing processes that are not only scalable but also efficient, to accommodate the growing demand for bio-based products.
- **Supply chain optimization**: Seeking ways to streamline supply chains for better cost-efficiency, performance, and resilience, which is crucial for the competitive edge of the bioeconomy.

Sustainability and Resource Management

- **Waste reduction and resource recovery**: Focusing on minimizing waste generation and enhancing the recovery of valuable resources, aligning with circular economy principles and sustainable resource management.

Advocacy and Economic Development

- **Importance of bioeconomy**: Highlighting efforts to demonstrate the value and potential benefits of the bioeconomy, aiming to garner public support and attract investment into this sector.

Solutions

Supply Chain Optimization

- **Invest in feedstock supply chain research**: This solution emphasizes the need to improve the efficiency, sustainability, and resilience of the supply chains that provide raw materials (feedstock) for bio-based products. Research could focus on reducing costs, minimizing environmental impacts, and ensuring a reliable supply of diverse feedstocks.

Societal Impact and Community Engagement

- **Understand the societal impact and promote community engagement**: This approach highlights the importance of assessing how bioeconomy initiatives affect communities and the environment. It also stresses the need for actively engaging communities in the development and implementation of bioeconomy projects to ensure they are inclusive, equitable, and beneficial to all stakeholders.

Rural Economic Development and Sustainability

- **Prioritizing Rural Economic Development and the dairy industry to recycle by-products into green chemicals**: Focuses on leveraging the potential of rural areas and agricultural sectors, such as the dairy industry, to contribute to the bioeconomy. This solution suggests recycling agricultural by-products into value-added green chemicals, promoting sustainability, reducing waste, and enhancing rural economies.

Potential Milestones

- 2 years: Grow trials to understand environmental constraints and opportunities for supply chain expansion.

- 5+ years: Breed for robustness in broader climates.

Resources Required

Collaboration and Infrastructure

- **Capacity, collaborations, novel biotechnologies, scale-up facilities**: Underlines the need for developing infrastructure that supports large-scale production and facilitates collaborations among stakeholders to leverage novel biotechnologies.
- **A governing agency to support regular collaboration**: Suggests the establishment of an organizational body dedicated to fostering regular interactions and partnerships within the bioindustry.
- **Collaborations and a legal framework for knowledge sharing**: Emphasizes the importance of not only fostering collaborations but also developing clear legal guidelines that facilitate the effective and equitable sharing of knowledge and resources.

Economic Development and Market Creation

- **End markets for co-products to enhance economic outcomes**: Points to the need for identifying or creating markets for by-products of biomanufacturing processes, thereby improving the economic viability of biotechnologies.
- **Ability to incentivize biotech companies to establish biomanufacturing facilities in rural communities**: Highlights the potential for biomanufacturing to drive economic development in rural areas, leveraging local workforces and resources.

Funding and Resources

- **Funding for a collaborative R&D and commercialization team**: Indicates the necessity of financial support for teams that bridge the gap between research and market-ready technologies.
- **Funding mechanism for collaborative projects**: Suggests the development of specific financial structures or programs designed to support collaborative biotech projects.

Supply Chain and Material Sourcing

- **Ability to get raw materials to be used in biomanufacturing facilities**: Emphasizes the importance of reliable supply chains for raw materials, crucial for the success of biomanufacturing endeavors and their commercialization prospects.

Technology Development and Implementation

- **High level of isolation, purification, and characterization methods**: Points to the need for advanced methodologies in the processing and analysis of bioproducts, ensuring their quality and efficacy.
- **Scale-up facilities**: Focuses on the necessity of facilities capable of scaling biotechnological processes from lab to commercial scale, a critical step towards successful commercialization.

Human Health

Challenges

Therapeutic Development and Research

- **Cell therapies**: Focused on the development and scale-up of cell therapies for regenerative medicine, highlighting innovations in treatment modalities.
- **DNA/RNA research for disease prevention and treatment**: Enhancing understanding and therapeutic approaches for genetic diseases, emphasizing the role of genetic research in healthcare.
- **Next-generation diagnostics and therapeutics**: Developing innovative solutions for personalized and precision medicine, including new diagnostics and therapeutic approaches.

Healthcare Workforce and Translation

- **Healthcare workforce development**: Addressing the need for training and development of a skilled healthcare workforce tailored to the evolving demands of the bioeconomy.
- **Human health research translation**: Bridging fundamental research with practical healthcare applications, focusing on the translational aspect of healthcare innovations.

Disease Management and Longevity

- **Infectious disease monitoring and prevention**: Developing strategies for early detection and prevention of emerging infectious diseases, reflecting the importance of preparedness and response.
- **Longevity and well-being**: Exploring how the bioeconomy can contribute to healthy aging and longevity, indicating a broader focus on improving life quality.

Public Engagement and Trust

- **Public trust and engagement**: Building trust and fostering public engagement in bioeconomy-related research and decision-making, underlining the importance of public support and understanding.

Solutions

Drug Development and Genetic Research

- **Develop better drugs**: Focuses on improving the efficacy, safety, and accessibility of pharmaceuticals through innovative research and development strategies.
- **Focus on the power of genetic engineering and stem cell research**: Highlights the potential of these fields to revolutionize treatments for a wide range of diseases, including genetic disorders and conditions lacking effective treatments.

Collaborative Research and Clinical Translation

- **Establish collaborative public-private translational research centers focused on bridging lab advances to clinical implementation**: Proposes creating centers that foster collaboration between academic researchers and industry to accelerate the translation of laboratory discoveries into clinical applications.

Diagnostic Technologies and Tools

- **Identify biomolecular signatures in blood plasma using high-resolution mass spectrometry and artificial intelligence (AI) algorithms**: Aims at developing advanced diagnostic tools that combine cutting-edge analytical techniques with AI to detect diseases early and accurately.
- **Develop scalable microbioreactors that can be engineered to provide cells a friendly microenvironment**: Focuses on creating innovative tools for cell culture and experimentation, enhancing research capabilities in cellular and molecular biology.
- **Support sensor development**: Emphasizes the importance of advancing sensor technologies for health monitoring, environmental detection, and biomedical research, contributing to improved diagnostics and patient care.

Potential Milestones

Pilot Phase and Community Engagement

- **2 yrs. Launch pilot projects for Health Diagnosis PODs**. Initiating pilot projects to test and refine the technology in real-world settings, focusing on effective diagnostics.
- **2 yrs. Refine technology for effective diagnostics**. Enhancing the accuracy, efficiency, and user-friendliness of diagnostic technologies used in the PODs.
- **2 yrs. Establish community partnerships**. Building relationships with community organizations and stakeholders to support the implementation and accessibility of the PODs.

Expansion and System Integration

- **3 yrs. Expand Health Diagnosis POD deployment based on feedback**. Using insights from the pilot phase to improve and scale up the deployment of PODs.
- **3 yrs. Integrate with healthcare systems for better disease detection and diagnosis**. Ensuring that the PODs are seamlessly integrated with existing healthcare infrastructure to enhance disease detection and diagnosis capabilities.
- **3 yrs. Harness data for public health insights**. Leveraging data collected by the PODs to gain insights into public health trends, disease outbreaks, and other health-related metrics.

Widespread Adoption and Policy Influence

- **5 yrs. Aim for widespread adoption of Health Diagnosis PODs**. Expanding the reach of the PODs to ensure they are accessible to a broad segment of the population.
- **5 yrs. Pioneer scalable healthcare models for preventive care**. Developing new healthcare models that emphasize preventive care, leveraging the capabilities of the PODs to detect health issues early.
- **5 yrs. Influence policy for health equity**. Working with policymakers to ensure that the deployment of Health Diagnosis PODs contributes to health equity, making advanced diagnostics accessible to all segments of the population.

Resources Required

Collaboration and Stakeholder Engagement

- **Collaboration with various labs and institutions**: Emphasizes the need for multi-institutional collaborations to pool resources and expertise.
- **Strategically, buy-in and participation across stakeholders**: Including academics, industry, healthcare providers, and government agencies, underlining the importance of a multi-stakeholder approach.
- **Close coordination with universities, startups, hospitals**: To leverage diverse expertise and facilities for clinical implementation and innovation.
- **Collaborations with different sectors, especially in public health and food security**: Points to the need for sector-specific partnerships to address broad challenges.
- **Partnerships with healthcare providers, governments, and community organizations**: For integrating bio-technological advancements with community-specific needs and healthcare systems.

Public Trust and Advocacy

- **Willingness to accept that public trust in research is something bio-researchers play a role in influencing**: Acknowledges the role of researchers in building public trust.
- **Public advocacy and support**: Highlighting the role of advocacy in securing continued funding and favorable legislation for biotechnology initiatives.

Focus Areas and Technology Translation

- **Focus efforts on 1-2 high-potential technology areas**: Like mRNA therapeutics and synthetic biology, to leverage existing momentum for quick wins and demonstration of value.
- **Regulatory expertise and alignment**: Essential for navigating clinical evaluation and approval pathways efficiently.
- **Advancements in biosensors, analytics, and AI to improve diagnostics**: Illustrates

the technological backbone necessary for transforming biotech research into practical applications.
- **A prioritized list of diseases to be targeted**: Suggesting a strategic approach to disease research based on societal needs and potential impact.

Research and Development Infrastructure

- **Access to research infrastructure, bio-entrepreneurial talent**: Underlines the infrastructure and talent necessary for innovation and commercialization.
- **Laboratory, high-resolution mass spectrometry instruments, AI experts**: Points to specific resources required for cutting-edge research, especially in diagnostics.

Privacy, Compliance, and Understanding Complexity

- **Obtaining approvals and ensuring data privacy compliance**: Acknowledges the importance of navigating regulatory landscapes and protecting patient data.
- **Understanding the extreme complexity of plant genome/metabolome**: Emphasizes the need for deep scientific understanding to translate biological insights into human health benefits.

Overall Strategy and Coordination

- **A diverse yet targeted and coordinated effort across public and private stakeholders**: Advocates for a unified strategy that aligns different sectors around impactful biotechnology translation, aiming to bring bio-advancements to practical, real-world applications.

Cross-Cutting Advances

Challenges

Infrastructure and Capacity

- **Bioreactor capacity**: Lack of sufficient capacity for non-pharma grade bioreactors for other applications in the bioeconomy.
- **Scalability**: Challenges in scaling up research findings from lab to production scale.
- **Systems level data**: Lack of scale-up and systems level data in the bioeconomy.

Communication, Awareness, and Advocacy

- **Communication and advocacy**: Need for effective communication to the public about the importance of the bioeconomy.
- **Lack of awareness**: Need for increased awareness of opportunities in the bioeconomy for students and underrepresented communities.

Security and Biosecurity

- **Cyber biosecurity**: Concern about digital security for biomanufacturing devices and data.
- **Digital biosecurity**: Lack of consideration in most bioeconomy discussions.
- **Security by design**: Need for integrating security by design thinking into bioeconomy research and development.

Data Management and Technology Integration

- **Data integration and sharing**: Challenges in integrating and sharing data across partnerships and research fields.
- **Predictive models**: Limited availability of predictive models to shorten timelines for biological experiments.
- **Translation of AI and data science**: Challenges in translating AI and data science research into practical applications for the bioeconomy.

Education, Workforce, and Skills Development

- **Multidisciplinary skills**: Workforce requires multidisciplinary skills to address digital biosecurity needs.
- **Workforce development**: Gaps in workforce development and training programs.

Policy, Funding, and Intellectual Property

- **Equity and access**: Ensuring fair and equitable distribution of benefits and minimizing negative impacts.
- **Funding and investment**: Insufficient research funding and lack of incentives for innovation.
- **New product intellectual property**: Uncovering and pursuing promising intellectual property locked up in academic tech transfer offices.

Research, Collaboration, and Standards

- **Interdisciplinary approaches**: Promoting collaboration between different disciplines.
- **Knowledge gaps**: Lack of fundamental knowledge about biodiversity, which provides raw materials for the bioeconomy.
- **Standards and vocabulary**: Need for standardization and common vocabulary to enable better communication across research fields and partnerships.

Solutions

Material Innovation and Sustainability

- **Develop new renewable materials that are recyclable and/or biodegradable**: Focuses on creating sustainable materials to reduce waste and environmental impact, aligning with circular economy principles.

Education and Skills Development

- **Integrate bioinformatics and biomanufacturing skills into healthcare training**: Aims to equip the healthcare workforce with the necessary skills to leverage advancements in bioinformatics and biomanufacturing, reflecting the interdisciplinary nature of modern healthcare solutions.

Research Advancements

- **Invest in microbial physiology research**: Emphasizes the importance of understanding microbial processes, which could lead to breakthroughs in various

applications, from healthcare to environmental management.

- **Enable microbial processing of minerals and metals**: Targets the exploration of using microorganisms for bio-mining or bioremediation, offering environmentally friendly alternatives to traditional methods.
- **Establish a national biodiversity genome sequencing initiative**: Proposes a comprehensive effort to catalog the genetic diversity of species, which could support conservation efforts and biotechnological applications.

Infrastructure and Community Resilience

- **Create and implement an innovation hub to accelerate the ability for communities to implement resilient and sustainable infrastructure systems**: Suggests developing a centralized platform or network to foster innovative solutions for community resilience and sustainable development.

Strategic Collaborations and Tools

- **Develop a tool to identify critical technological hurdles to realizing engineering biology and synthetic biology capabilities**: Aims to streamline the development and application of synthetic and engineering biology by identifying and addressing technological challenges.
- **Establish a public-private partnership to advance the safety and security of the bioeconomy**: Proposes collaboration between government and industry to ensure the bioeconomy's development is both safe and secure, emphasizing the need for shared responsibility and coordinated efforts.

Potential Milestones

Synthetic Biology and Biomanufacturing

- 2-5 yrs. Develop prototype RNA system for peptide synthesis and advanced bio-based manufacturing techniques.
- 2-3 yrs. Develop a set of common protocols for synthetic cells, allowing researchers to use components from other labs.
- 2-3 yrs. Develop functional synthetic cells with hundreds of engineered elements.
- 2-3 yrs. Expand the types of molecules made using methanoarchaea.
- 2-3 yrs. Design microbial consortia for renewable fuel conversion.
- 2-3 yrs. Enable microbial processing of minerals and metals.
- 2-3 yrs. Develop tools for identifying technological hurdles in engineering biology and synthetic biology.

Education and Community Engagement

- 2-3 yrs. Introduce interdisciplinary curricula integrating medical and bioeconomy education.
- 2-5 yrs. Develop biodegradable bio-based materials, focusing on education and community awareness about sustainable materials.

Data Management and Research Infrastructure

- 3-5 yrs. Develop a standardized data framework for biotechnology research.
- 3-5 yrs. Establish a national biodiversity genome sequencing initiative.
- 3-5 yrs. Create an innovation hub for implementing resilient and sustainable infrastructure systems.

Safety, Security, and Supply Chain

- 2-3 yrs. Establish an effective network for advancing bioeconomy safety and security.
- 2 yrs. Conduct data collection and coordination for supply chain resilience.
- 2-3 yrs. Modernize and scale up biorefineries in rural cities, addressing both supply chain issues and local economic development.

Resources Resources

Collaboration and Community Engagement

- **Formalizing and funding an integrated and focused effort for collaboration among federal government agencies, research communities, industry, and non-profit organizations**. Emphasizes the need for structured and dedicated resources to facilitate collaboration across different sectors, enhancing the bioeconomy ecosystem through synergistic efforts.
- **A community/research match program; resources for developing community/**

research match programs. Highlights the importance of connecting research initiatives with community needs and opportunities, ensuring that scientific advancements translate into tangible benefits for communities.

Workforce Development

- **Resources and alignment with industry and local, state, and federal governments for workforce development in biorefineries**. Points to the need for coordinated efforts and resources to train and develop a skilled workforce tailored to the needs of the biorefinery sector, ensuring that workers are prepared for the jobs created by this growing industry.

Educational Investment

- **Investment in education at 2-year colleges and universities**. Recognizes the critical role of higher education institutions, especially 2-year colleges, in preparing students for careers in the bioeconomy. Investments would support the development of relevant curricula, training programs, and research opportunities aligned with industry needs.