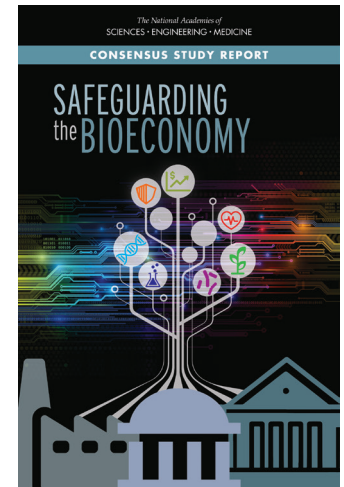




January 2020

## SAFEGUARDING THE BIOECONOMY

*With its value nearing \$1 trillion, the U.S. bioeconomy holds promise for an improved quality of life, with benefits ranging from health care solutions to environmental stewardship. Novel products and innovative solutions include microorganisms that act as environmental biosensors and fabrics made from biosynthetic spider silk. This Consensus Study Report assesses the scope of the U.S. bioeconomy, determines how to assess its economic value, and identifies potential economic and national security risks.*



Over the past 50 years, the integration of engineering principles and advances in computing and information sciences have transformed the life sciences and biotechnology. The ability to read genetic code, edit an organism's genome, and create organisms with entirely synthetic genomes are just a few of the breakthroughs that have changed the way research is done and the types of products that can be created. The economic activity related to the life sciences research enterprise is referred to conceptually as the bioeconomy.

The U.S. bioeconomy provides a means of developing new and innovative products and also has opened up new avenues for job creation and economic growth. Along with its promise, however, the bioeconomy brings vulnerabilities and concerns. A concerted effort is needed to safeguard its potential and minimize associated risks.

Currently, there is no consensus on a definition of a bioeconomy, resulting in differing interpretations of the scope of a bioeconomy. A fundamental challenge is that bioeconomy activities span many sectors and scientific disciplines. A new, more comprehensive definition would enable the U.S. government to better assess the bioeconomy's current state and develop strategies for supporting and safeguarding its continued growth. Such a definition could also guide efforts needed to track the bioeconomy's growth, conduct economic assessments, and enable policy makers to keep abreast of advances with the potential to pose new national or economic security challenges.

**Recommendation 1: For purposes of demarcating the scope and reach of the U.S. bioeconomy and establishing a uniform framework for valuing the bioeconomy and its assets, the U.S. government should adopt the following definition of the U.S. bioeconomy:**

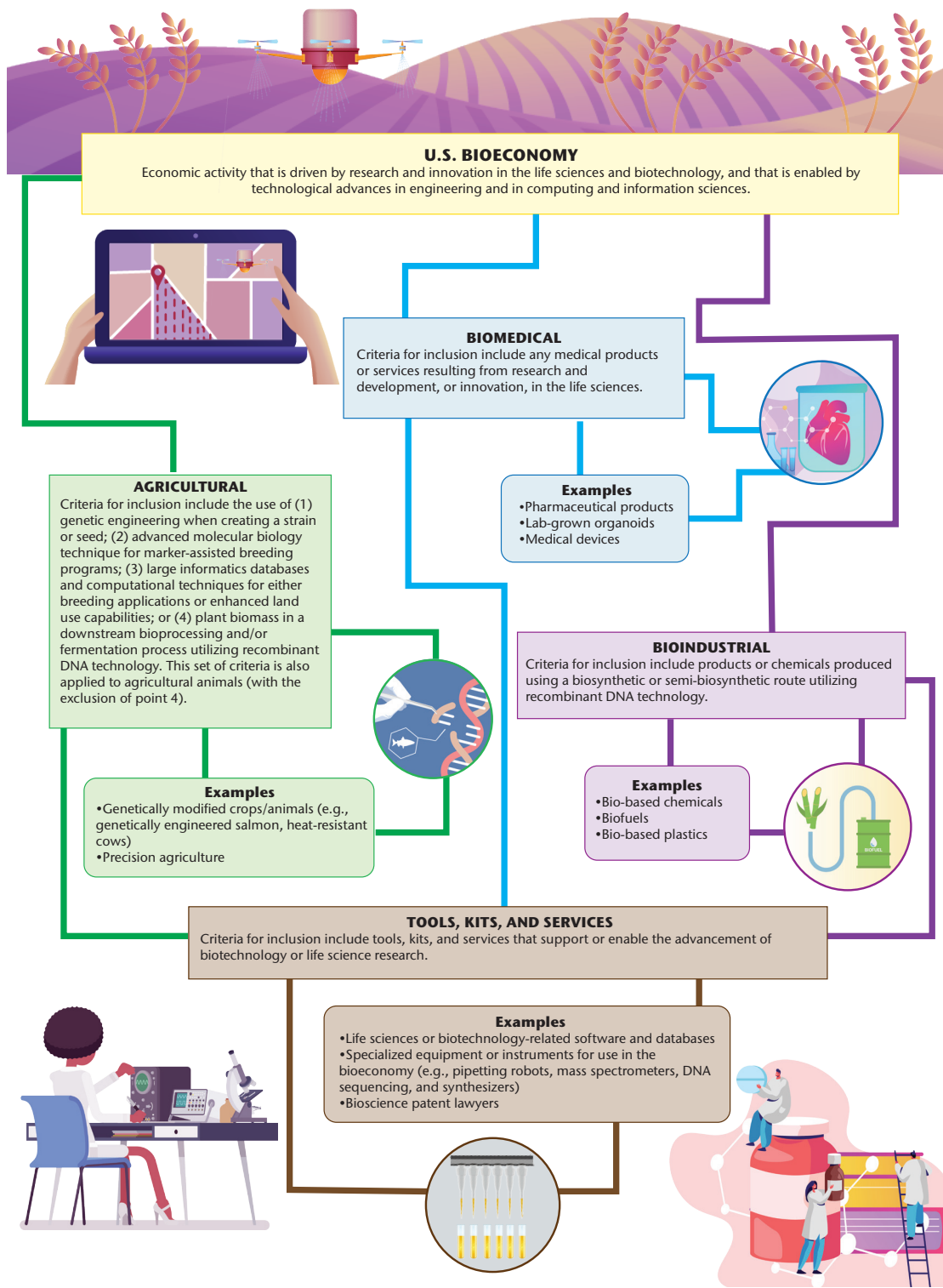
*The U.S. bioeconomy is economic activity that is driven by research and innovation in the life sciences and biotechnology, and that is enabled by technological advances in engineering and in computing and information sciences.*

This definition is flexible enough to allow for the inclusion of new developments—not limiting the scope of the bioeconomy to particular sectors, technologies, or processes.

## MEASURING THE U.S. BIOECONOMY

Based on calculations and available data, in 2016, the bioeconomy accounted for about 5.1 percent of the U.S. gross domestic product (GDP). In dollar terms, this represents \$959.2 billion. Figure 1 shows the primary domains, or segments, of the bioeconomy—agricultural, bioindustrial, and biomedical—considered the major categories of activity encompassed by the bioeconomy.

A full assessment of the inputs and outputs of the bioeconomy could enable better tracking of the results of public investments. Better metrics for bioeconomy growth could serve as an indicator of the health and growth of the sector, allow for an assessment of the



impact of policy changes on the economic potential of the bioeconomy (or its subsectors), and help identify areas worth protecting from a security standpoint.

Many factors make it difficult to measure the contribution of the bioeconomy to the overall economy. The bioeconomy is tied to both science and commercialization, which leads to divergent approaches for assessing its value. Concepts used to value the bioeconomy present additional challenges. Social welfare analysis, which attempts to quantify benefits to producers and consumers, is a particularly demanding approach for valuing a sector as diffuse as the bioeconomy.

**Recommendation 2: The U.S. Department of Commerce and the U.S. National Science Board should expand and enhance data collection efforts relevant to the economic contribution of the U.S. bioeconomy as defined by this committee.\***

The report lays out specifics for several organizations to improve collection, analysis, and characterization of bioeconomic data and assets.

FIGURE 1

## STRATEGIES FOR SAFEGUARDING THE U.S. BIOECONOMY

A history of strong and sustained U.S. government investment in the life sciences, computing and information sciences, and engineering has powered the development of today's bioeconomy. As other countries invest in their bioeconomies at increasing rates, current U.S. leadership will be challenged. To retain a world leadership position, strategies will be needed both to address risks to and from the U.S. bioeconomy and to ensure that it is supported and optimized for growth.

**Recommendation 3: The Executive Office of the President should establish a government-wide strategic coordinating body tasked with safeguarding and realizing the potential of the U.S. bioeconomy.\***

#### FUNDING, BUILDING, AND SUSTAINING THE BIOECONOMY RESEARCH ENTERPRISE AND A SKILLED WORKFORCE

Insufficient support for fundamental research will erode the United States' ability to produce breakthrough scientific results or achieve incremental learning—both of which can have a direct economic application. Inadequate support will also erode the nation's ability to develop and recruit the best research talent, particularly as competition with other countries that are investing heavily in their own bioeconomies increases. Analysis of past and current U.S. investments suggests that the rate of federal investment in the biological sciences has become stagnant.

In addition to the importance of training a domestic bioeconomy workforce, the United States has historically benefited from the ability to attract students and scientists from around the world. International students and foreign-born employees in the U.S. STEM research workforce have contributed immensely to the vibrant research enterprise on which the nation currently depends. Recent changes in visa policy and new policies regarding researchers with potential ties to foreign governments have the potential to discourage talented researchers from around the world from coming to the United States or even collaborating with U.S.-based scientists.

**Recommendation 4: To maintain U.S. competitiveness and leadership within the global bioeconomy, the U.S. government should prioritize investment in basic biological science, engineering, and computing and information sciences. In addition, talent development, at all levels, to support these research areas should be a high priority for future public investment.\***

#### SECURING VALUE CHAINS AND EXAMINING FOREIGN INVESTMENTS

The U.S. bioeconomy needs to be able to sustain itself by securing the value chains that fuel it. Disruption of or risks to critical parts of bioeconomy value chains, such as supply shortages, interruptions in transport, or reliance on single sources, represent important risks to the nation. Reliance on single sources is particularly important if the source is based overseas and thus subject to changes in political relationships or other factors beyond U.S. control.

The source of venture capital funding for early- to mid-stage developers may require more scrutiny in order to protect intellectual property, particularly given the increased trend of foreign investment in U.S. bioeconomy companies and start-ups.

**Recommendation 5: The U.S. government should convene representatives from its science and economic agencies who can access relevant classified information to provide security agencies with subject-matter expertise so as to (1) identify aspects of bioeconomy global value chains that are vital to U.S. interests and to which access must be ensured, and (2) assist the Committee on Foreign Investment in the United States in assessing the national security implications of foreign transactions involving the U.S. bioeconomy.**

#### PRIORITIZING CYBERSECURITY AND INFORMATION SHARING

Life sciences research is driven by the collection and analysis of large amounts of data that are often generated through the use of automated and network-connected instruments. Inadequate cybersecurity practices and protections expose the bioeconomy to significant new risks. Large companies tend to be aware of traditional cyber concerns and have information technology infrastructures that provide protection; however, smaller companies and academic institutions may not always be aware that they are targets for cyber intrusions.

The bioeconomy relies on the use of open-source software and sharing data to public databases. The availability of software and its source code introduces the potential for misuse. Concerns regarding the availability of software and its source code could potentially be mitigated by establishing a more formal repository of open-source software for the bioeconomy, a formal regime for controlling changes to source code, a testing regimen for any changes to the code, and restrictions on who can make changes.

**Recommendation 6: All bioeconomy stakeholders should adopt best practices for securing information systems (including those storing information, intellectual property, private-proprietary information, and public and private databases) from digital intrusion, exfiltration, or manipulation.**

**Recommendation 7: To protect the value and utility of databases of biological information, U.S. science funding agencies should invest in the modernization, curation, and integrity of such databases.**

**Recommendation 8: Bioeconomy stakeholders should pursue membership in one or more relevant information sharing and analysis centers or information sharing and analysis organizations, or consider creating a new sector-based, information-sharing organization for members of the bioeconomy. The Cybersecurity and Infrastructure Security Agency within the Department of Homeland Security should convene bioeconomy stakeholders to build awareness about relevant models for sharing information on cyber threats.**

## OPPORTUNITIES FOR INTERNATIONAL ENGAGEMENT

There is immense value to be gained from participating in a global scientific enterprise; in particular, one that enables and embraces the free flow of ideas and discussion, the wide dissemination of published results, and collaboration across disciplines and borders. Moreover, future challenges are going to be global in nature and will require a coordinated, global response. This will entail partnering with

others who are actively growing and investing in their own bioeconomies, especially those who are likewise committed to open science, open economic development, and responsible research and innovation.

**Recommendation 9: The U.S. government should work with other countries that are part of the global bioeconomy to foster communication and collaboration. The goals of such international cooperation would be to (1) drive economic growth, (2) reinforce governance mechanisms within a framework that respects international law and national sovereignty and security, and (3) create a level playing field.\***

\*Recommendations have been shortened in this Consensus Study Report Highlights. To see the full text of the recommendation visit [www.nap.edu/catalog/25525](http://www.nap.edu/catalog/25525).

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### COMMITTEE ON SAFEGUARDING THE BIOECONOMY: FINDING STRATEGIES FOR UNDERSTANDING, EVALUATING, AND PROTECTING THE BIOECONOMY WHILE SUSTAINING INNOVATION AND GROWTH:

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**For More Information . . .** This Consensus Study Report Highlights was prepared by the National Academies of Sciences, Engineering, and Medicine based on the Consensus Study Report *Safeguarding the Bioeconomy (2020)*. Any opinions, findings, conclusions, or recommendations expressed in this publication do not necessarily reflect the views of any organization or agency that provided support for the project. Copies of the Consensus Study Report are available from the National Academies Press, (800) 624-6242; <http://www.nap.edu> or via the Board on Life Sciences web page at <http://www.nationalacademies.org/bls>.

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