

Building a 21st Century Bioeconomy

Fostering Economic and Physical Security Through Public-Private Partnerships and a National Network of Community Labs

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What is the Bioeconomy, How Big is it, and How Fast is it growing?

Biological production is a substantial economic and employment opportunity for the United States. While the U.S. economy already depends heavily on biology, primarily via production in the agricultural sector, new technologies will enable the biomanufacturing of large volumes of fuels, materials, and enzymes. I hereafter refer to the totality of biological production in the U.S. economy as the “bioeconomy”.

According to the USDA Economic Research Service, the U.S. agricultural sector added \$331 billion to the economy in 2009¹. This figure is impressive, but revenues from biological technologies are rising rapidly and will soon surpass those from agriculture alone.

A recent estimate published by Biodesic put total U.S. revenues from genetically modified (GM) products at more than \$300 billion annually². While “biotechnology” is typically thought of as either drugs or crops, a more detailed look at the sector reveals instructive complexity. Biologics (biotech drugs) had sales of approximately \$75 billion in the United States in 2010. GM crops brought in at least \$100 billion in farm scale revenues and GM seeds added another \$10 billion. Industrial

biotechnology, including biofuels, industrial enzymes, bioplastics, and other materials, generated sales of \$115 billion³. Revenues from GM crops and biologics are growing at approximately 10% annually, while revenues from industrial biotechnology are growing at 15–20% annually.

The difference in growth rates is partly explained by the high cost of developing new biologics and new GM crops. The high costs, in turn, are partially explained by the regulatory barriers accompanying drugs, food, and the environmental release of novel organisms. In contrast, most industrial applications are un-

2010 U.S. revenues from genetically modified products were greater than \$300 billion, or the equivalent of more than 2% of GDP.

regulated because they are used for materials production and do not involve the environmental release of GM organisms. In other words, the largest and fastest-growing sub-sector of the bioeconomy is generally not subject to regulation.

The United States is on course to dramatically increase its reliance upon biological technologies for the production of food, drugs, materials, and fuels. The relative contribution of the different sectors to the total is worth considering. In the past, drugs dominated “biotech” revenues in the United States, but today this

1 See “Table 29—Value Added to the U.S. Economy by the Agricultural Sector”
<http://www.ers.usda.gov/Publications/AgOutlook/AOTables/CurrentTables/aotab29.xls>

2 Carlson, R., “Biodesic 2011 Bioeconomy Update”, Aug 2011, DocID: 20110811_01
http://www.biodesic.com/library/Biodesic_2011_Bioeconomy_Update.pdf

3 For a discussion of the methodology used to derive these figures, and of the resulting uncertainties, please see Carlson (2011).



Table 1: Important Innovations By Small U.S. Firms, 1900–2000

Air Conditioning	Geodesic Dome	Polaroid Camera
Air Passenger Service	Gyrocompass	Portable Computer
Airplane	Heart Valve	Prestressed Concrete
Articulated Tractor	Heat Sensor	Prefabricated Housing
Chassis	Helicopter	Pressure Sensitive Tape
Assembly Line	High Resolution CAT	Programmable Computer
Audio Tape Recorder	Scanner	Quick-Frozen Food
Bakelite	High Resolution Digital	Reading Machine
Biomagnetic Imaging	X-Ray	Rotary Oil Drilling Bit
Biosynthetic Insulin	Human Growth Hormone	Safety Razor
Catalytic Petroleum	Hydraulic Brake	Six-Axis Robot Arm
Cracking	Integrated Circuit	Soft Contact Lens
Cellophane	Kidney Stone Laser	Solid Fuel Rocket Engine
Artificial Skin	Large Computer	Stereoscopic Map Scanner
Computerized Blood	Link Trainer	Strain Gauge
Pressure Controller	Microprocessor	Strobe Lights
Continuous Casting	Microscope	Supercomputer
Cotton Picker	NMR Scanner	Two-Armed Mobile Robot
Defibrillator	Optical Scanner	Vacuum Tube
DNA Fingerprinting	Oral Contraceptives	Variable Output Transformer
Double-Knit Fabric	Outboard Engine	Vascular Lesion Laser
Electronic Spreadsheet	Overnight National Delivery	Xerography
Freewing Aircraft	Pacemaker	X-Ray
FM Radio	Personal Computer	X-Ray Telescope
Front-End Loader	Photo Typesetting	Zipper

Source: U.S. Small Business Administration

contribution accounts for less than half the total. As biological technologies mature, becoming more useful and prevalent across different sectors of the economy, industrial and agricultural applications will amount to an ever larger share of total revenues. But, in order to foster the necessary amount of innovation to supply new technologies domestically, we must foster the necessary structure for that innovation.

The U.S. Economy Begins in Garages

Start-ups and small organizations are at the heart of both innovation and job creation in the United States. A recent re-analysis of Census Bureau data published by the Kauffman Foundation determined that 100% of net job creation in the United States is due to start-up companies⁴. Companies in their first year of

business create an average of 5.7 jobs, for a total of 3 million new jobs per year nationwide, while “all other ages of firms are net job destroyers.”⁵

Small firms are also responsible for an impressive array of innovations now driving the U.S. economy. Table 1 includes a list—literally A to Z—of important innovations provided by small firms during the 20th century⁶. Mature products based on these technologies are unlikely to be mass-produced in garages, but garage innovation played a critical role during their development.

⁵ *ibid.*

⁶ This particular list is from Baumol, W., “Small Firms: Why Market-Driven Innovation Can’t Get Along without Them”, U.S. Small Business Administration, 2005, p 183, from the original in U.S. Small Business Administration, Office of Advocacy, “The State of Small Business: A Report to the President”, Government Printing Office, 1994.

⁴ Kane, T., “The Importance of Startups in Job Creation and Job Destruction”, July 2010, The Ewing Marion Kauffman Foundation.

Recommendation 1: An innovation and job creation blueprint for the bioeconomy must include fostering large numbers of start-up companies.

Many of the technologies listed in Table 1 passed through garages as part of, or as a result of, dramatic reductions in cost. Those cost reductions further increased access, which consequently led to innovation that further reduced cost. Biotechnology has been experiencing exponential decreases in cost for several decades⁷. Prices fell precipitously during this period, though they remained sufficiently high to limit access to well-funded academics and relatively large or well-funded companies. Within just the last few years, costs in biotechnology have fallen to the point where a credit card with a modest spending limit is sufficient to outfit a capable laboratory with used equipment. As a result, garages are now beginning to shelter hobbyists, artists, and entrepreneurs interesting in building a new world using biology⁸. Given the history of U.S. innovation, we should expect that burgeoning garage innovation in biology (not just biotechnology) will provide seeds for a more pervasive and more valuable bioeconomy.

Fostering Safe and Secure Garage Innovation in the Bioeconomy

Any honest appraisal of the broad proliferation of a powerful technology must acknowledge both opportunity and risk. As described above, there is a large economic opportunity in embracing innovation in biological technologies and historically this innovation has often been found in garages. Given that biological technologies might be used in ways that cause accidental or intentional harm, how might we encourage garage innovators in biotechnology to conform to practices that reduce risk?

7 Carlson, R., "The Pace and Proliferation of Biological Technologies", *Bio Secur Bioterror*, 2003;1(3):203-14; Carlson, R., *Biology is Technology*, Harvard University Press, Cambridge, MA 2010.

8 Ledford, H., "Garage biotech: Life hackers", *Nature* 467, 650-652 (2010).

Community labs now emerging across the country are an excellent opportunity for the U.S. government to engage budding biological innovators on multiple fronts. The National Bioeconomy Blueprint should include support for a greatly expanded network of community labs through public-private partnerships. The purpose of the network is multifold: 1) the network will provide infrastructure to support "garage style" start-up activity; 2) community labs will enable participants to share information and resources to accelerate their own progress; and 3) community labs will facilitate the ability of the U.S. government to engage the community in discussions that range from Grand Challenges to biosecurity.

Recommendation 2: The National Bioeconomy Blueprint should include support for a network of community laboratories that would provide access to infrastructure, increase communication between innovators, and facilitate engagement with the U.S. government in regards to national security and national technology development goals.

It is already feasible to build a functional garage lab for as little as \$500, assuming one has access to a garage or similar space⁹. However, R&D efforts aimed at commercialization are likely to require greater resources and will usually benefit from dedicated space. It is also generally far easier to work in a biology lab populated by people who may know tricks of the trade or be able to spot potential mistakes. Therefore, access to a larger community laboratory space could enable more innovation and communication among entrepreneurs building the bioeconomy.

A network of community labs would also provide an opportunity to improve security and reduce risk. Because biotechnology is already so widespread, it is likely that reducing risk will be more readily accomplished through building open networks that increase informa-

9 Brunstein, J., "The quest for the \$500 home molecular biology laboratory", <http://www.mlo-online.com/features/201112/tips-from-the-clinical-experts/the-quest-for-the-500-dollar-home-molecular-biology-laboratory.aspx>

tion transfer than by attempting to prohibit or control access to the technology¹⁰. Indeed, The National Strategy for Countering Biological Threats has identified broad access to biological technologies as a key component of physical and economic security; “The beneficial nature of life science research is reflected in the widespread manner in which it occurs. From cutting-edge academic institutes, to industrial research centers, to private laboratories in basements and garages, progress is increasingly driven by innovation and open access to the insights and materials needed to advance individual initiatives.”¹¹ The National Strategy explicitly recognizes that as costs continue to fall, and as skill and access proliferate, we should expect important innovations to be generated in “basements and garages”. Going beyond this recognition, the National Bioeconomy Blueprint should include strategies that actively engage innovators in a conversation around 1) the risks and benefits of biological technologies and 2) priorities for technology development in the service of national needs ranging from environmental monitoring of pathogens, to new human and animal diagnostics, to biofuel production technologies.

The FBI already has a program in place to facilitate communication between its agents, local law enforcement, and biotechnology innovators working in unconventional settings¹². As a result of this process, innovators and artists are reassured that the FBI's primary interest is public safety and security, and the law enforcement community is introduced to the mindset and working environment common in garages and community labs. This ongoing conversation should serve as a foundation for extending the model of engagement beyond national security and law enforcement policy to become a pillar of national economic policy.

10 See Carlson (2003) and Carlson (2010).

11 “National Strategy for Countering Biological Threats”, National Security Council, November 2009, http://www.whitehouse.gov/sites/default/files/National_Strategy_for_Countering_BioThreats.pdf

12 See Ledford (2008).

Supporting the Formation and Funding of Community Labs as a National Resource

Existing community labs have been set up in empty office spaces and mixed-use buildings around the country. These facilities are supported by a combination of donations, membership fees, and revenues from courses that cover everything from ecology, to genetic engineering, to growing functional architectural elements out of mushrooms.

The funding requirements for these facilities are generally modest. They are typically set up as non-profit organizations, and are therefore eligible to receive grant support and donations of equipment. The National Bioeconomy Blueprint should forward guidelines that clearly identify the roles and responsibilities of community labs—and of members of those labs—that would enable qualifying labs to receive government grants of financial support, surplus equipment, and expired but still useful laboratory supplies.

Recommendation 3: The National Bioeconomy Blueprint should contain guidelines that clearly identify the roles and responsibilities of community labs—and of members of those labs—that would enable qualifying labs to receive government grants of financial support, surplus equipment, and laboratory supplies.

An alternative approach to the direct funding of non-profit community labs might be grants to local governments to fulfill the same role. Local libraries are already examining ways to expand their offerings beyond books and internet access to hosting “Maker spaces” with 3D printers and computer controlled machine tools¹³. These efforts could be expanded to add or convert space in public libraries into community labs that promote the safe and secure learning and practice of skills related to biological technologies. This strategy would

13 Reeder, J., “Are Maker Spaces the Future of Public Libraries?”, <http://www.shareable.net/blog/the-future-of-public-libraries-maker-spaces>, and Torronne, P., “Is It Time to Retool Public Libraries as TechShops?” *Make*, 28, 28, and <http://blog.makezine.com/archive/2011/03/is-it-time-to-rebuild-retool-public-libraries-and-make-techshops.html>

build upon the long relationship the public has with libraries as a resource at a time when many of those facilities are seeing less use due to electronic books.

In general, the National Bioeconomy Blueprint should make it easier for innovators to try ideas. Facilities within the community lab network would not need to be elaborate, perhaps only providing access to basic laboratory needs such as a sink, deionized water, freezers, and waste disposal, while leaving other expenditures to “members”. Publicly funded community labs could still charge for classes or sublet space to start-ups. One component of a successful application for government support of funds or material might be a financial plan that leads to self-sufficiency. These facilities should not be viewed as “incubators” per se, or at least not as envisioned by venture capital firms and many state agencies. Community labs, as described here, should probably not aim to generate revenue. Policy makers should recognize that some subsidy may be acceptable in exchange for the public good of a safer network and greater overall innovation.

Conclusion

If the past is any guide, producing future biotech innovation will require the involvement of small businesses and entrepreneurs. Government policies intended to foster economic growth and job creation are therefore best focused on facilitating the founding of start-ups and their participation in domestic and global markets. One mechanism of connecting small business with consumers would be the continued expansion of the USDA Bio-preferred Program to include a greater array of products, and to include certification of products that are the subject of large daily demand on “Main Street”.

The National Bioeconomy Blueprint must include the contributions of small organizations. Defining standards and a national role for community labs, and then supporting those

labs, will improve both economic and physical security.

***More information is available at
www.biodesic.com***