



A Vision for the Future of Biopharmaceutical Manufacturing, Education, Training, Process Development, and Research in North Carolina: BTEC 2.0

EXECUTIVE SUMMARY

The Golden LEAF Biomanufacturing Training and Education Center (BTEC) at NC State was established in 2007 to address the growing demands of the biomanufacturing industry in NC through novel education and training programs. Since its inception, BTEC has been tremendously successful providing a wide variety of high-quality educational and training opportunities to develop skilled professionals for the industry. BTEC has also been providing process services to industry, government, and academia, as well as executing research programs aimed at advancing bioprocessing technologies. BTEC's role has been an integral part of the extraordinary growth of the biotech and biopharmaceutical industry in North Carolina, not only in attracting new companies to the state but, critically, in helping provide the skilled workforce needed to sustain this growth. BTEC is recognized both nationally and internationally as a premier provider of biopharmaceutical manufacturing training, education, and process research and development programs.

Since the BTEC facility opened its doors almost two decades ago significant changes have occurred in the biopharmaceutical industry. New modalities, such as gene and cell therapies, have entered the marketplace, and disruptive changes in biopharmaceutical processing and analytical technologies have been introduced to enhance process efficiency and lower costs. Further, there are fundamentally new areas being created by the advances in big data, predictive analytics, the internet of things, and artificial intelligence. Additionally, the reality of a global biopharmaceutical supply chain means that it is not sufficient to instruct in domestic regulatory sciences alone, but that education in global compliance standards is required as well.

Another important development within the industry in NC is that biomanufacturing needs are rapidly expanding beyond the biopharmaceutical area, including production of industrial enzymes, and precision fermentation of advanced proteins for human food and animal health.

To remain relevant, BTEC must keep up with these advances and changes. Otherwise, this competitive advantage will in time be lost. Other states are currently investing heavily to build and expand infrastructure that will attract to their geographic regions the industry expansion created by an unprecedented growth in the need for biomanufacturing capacity. In contrast, BTEC's budget has remained flat since its creation and, therefore, lost budgetary capacity over the years due to inflation. Local bioindustry looks to BTEC to provide a dependable source of

trained talent that is current in all these advances, standards, and complexities. This fact is an important factor for selecting North Carolina for location and expansions.

BTEC is in a unique position to evolve and meet the new expectations of the biomanufacturing industry that is undergoing unprecedented growth and investment in NC. There needs to be a dependable workforce educated in the new manufacturing technologies, therapeutic modalities, and novel analytical techniques that are being developed for the bioindustry investments in NC to continue. The corresponding investment in BTEC's infrastructure and faculty growth is needed immediately. The needed capability and capacity expansion will enable significant enhancement of current programs and activities, including amplifying academic programs at all levels, expanding the scope of process and analytical services, allowing for collaboration research projects with industry, and building state-of-the-art manufacturing and analytical technology platforms for teaching and research. BTEC will also need to invest in more sophisticated adult education capabilities, such as multimedia developers and educational technologists, to create high-quality, interactive virtual education opportunities.

BTEC's plan to meet these challenges is the creation of the North Carolina Facility for Advanced Biomanufacturing (NCFAB) described in this proposal. Plans have been designed for the creation of this new facility and the NC State Centennial campus offers a singular environment for the success of this enterprise that will ensure the future viability of one of the most important sources of economic strengths for the state of North Carolina. At its core, the creation of the NCFAB elevates the role of NC State University as a premier center of biomanufacturing training, support, and innovation, principally for North Carolina, but also nationally and internationally.

BTEC background

In 2003, North Carolina State University (NC State), in concert with North Carolina Central University and the North Carolina Community College System, requested and subsequently received funding from North Carolina's Golden LEAF (Long-term Economic Advancement Foundation) to establish the North Carolina Biomanufacturing and Pharmaceutical Training Consortium. This public/private partnership between North Carolina's university and community college systems and industry—now renamed NCBioImpact—was formed to meet the growing demands of the biotechnology and pharmaceutical industries through novel education and training programs. The Golden LEAF Biomanufacturing Training and Education Center (BTEC) at NC State was established as part of the funding request.

BTEC is part of NC State's College of Engineering and has a mission to contribute to the social and economic well-being of the state of North Carolina by providing high-quality educational and training opportunities to develop skilled professionals for the biomanufacturing industry. In addition, BTEC provides process services to industry, government, and academia, and executes research programs aimed at advancing bioprocessing. BTEC has established four core programs to meet this mission.

- **Academic.** Serves NC State students and focuses on education and training in all aspects of biopharmaceutical manufacturing (medicines manufactured by or from living organisms— e.g., microorganisms—or cells from living organisms). Since the facility opened in 2007, BTEC has graduated more than 800 students with a minor, certificate, or master’s degree in biomanufacturing, and hundreds more students have taken one or more courses at BTEC. BTEC’s undergraduate students come from numerous departments across campus, both within and outside of the College of Engineering. Among students with a BTEC minor, certificate or master’s degree, more than 97% find employment within six months of graduation; among that group, more than 85% remain in North Carolina.
- **Professional development.** Serves professionals from throughout the world by providing education and training in all aspects of biopharmaceutical manufacturing. Since 2008, more than 6,000 scientists and engineers working in industry, federal agencies (e.g., FDA), and non-profits, have taken a short course at BTEC.
- **Bioprocess and analytical services.** Provides process development, technology development, and analytical development and testing support to organizations. Since its beginning in 2010, this program has conducted more than 200 projects for various small and large companies and academic groups.
- **Research.** BTEC has led and participated in several bioprocess-focused research projects supported by the National Institute for Innovation in Manufacturing Biopharmaceuticals (NIIMBL) and the Novo Nordisk Foundation. Those programs have included developing processes for gene therapy products and control/automation for bioprocessing.

All these programs are carried out in BTEC’s 77,000-gross-square-foot facility, which opened in 2007 on NC State’s Centennial Campus. The facility features bench- and pilot-scale bioprocessing labs suitable for teaching and research/development activities. Nearby on Centennial Campus, the BTEC Annex provides 5,000-gross-square-foot of rented space dedicated to bioprocess services.

By any measure, BTEC is a great success and, as stated earlier, is widely recognized both nationally and internationally as a premier provider of biopharmaceutical manufacturing training, education, and process research and development programs.

Current biopharmaceutical landscape

Significant changes have occurred in the biopharmaceutical industry in North Carolina and throughout the world since the BTEC facility opened its doors in 2007.

BTEC has made major contributions to the unprecedented growth of the biopharmaceutical industry in North Carolina by helping to attract new companies to the state, and this growth has led to an increased need for a skilled workforce. It is estimated that 8,000 new jobs will be created by the North Carolina biopharmaceutical industry through 2026. Candidates with a bachelor’s or master’s degree are likely to be in highest demand, with Ph.D. degrees in demand for process development, manufacturing sciences, and product development (Window on the Workplace 2023) . More than \$6 billion in investments in new biopharmaceuticals facilities

were announced between July 2019 and August 2021, presaging an increased demand for skilled employees for these operations. Many new small- and medium-sized companies have located in the Triangle area, and many large companies have announced new facilities and significant expansions in North Carolina (Fujifilm Diosynth Biotechnologies, Amgen, Eli Lilly, and Biogen, as examples). Further, President Biden's executive order to launch a National Biotechnology and Biomanufacturing Initiative will likely lead to further growth and activity in the biopharmaceutical sector (<https://www.whitehouse.gov/briefing-room/statements-releases/2022/09/14/fact-sheet-the-united-states-announces-new-investments-and-resources-to-advance-president-bidens-national-biotechnology-and-biomanufacturing-initiative/>). With no changes to BTEC's operations, it will be extremely challenging to keep up with the increased demand for highly skilled professionals. This, in turn, is likely to jeopardize the continued industry growth that BTEC has helped foster.

Since 2007, new biopharmaceutical modalities, such as gene and cell therapies, have entered the marketplace, and significant changes in biopharmaceutical processing and analytical technologies have been introduced to enhance process efficiency and lower costs. Further, there is a rapid increase in the sophistication of data analytics and the integration of artificial intelligence in all aspects of the manufacturing of drugs. The level of integration of automation, predictive analytics, in-line sensors, and other high-data processes is by definition disruptive. To remain relevant in all its programs, BTEC must keep up with these advances.

BTEC's success in the last 15 years and its outstanding national and international reputation have encouraged other organizations, other states and other countries to make similar investments in centers focused on biomanufacturing. The list, among others, includes:

- The Securing American Biomanufacturing Research and Education (SABRE) cGMP Center, University of Delaware
- the Jefferson Institute for Bioprocessing (JIB) at Thomas Jefferson University
- the National Center for Therapeutics Manufacturing (NCTM) at Texas A&M Experiment Station
- the Stack Family Center for Biopharmaceutical Education and Training (CBET) at Albany College of Pharmacy and Health Sciences
- Biomanufacturing Education and Training Center (BETC) at Worcester Polytechnic Institute
- the National Institute for Bioprocessing Research and Training (NIBRT) at University College Dublin
- the University of Delaware's Pinnizzotto Biopharmaceutical Innovation Center, funded in part by the National Institute for Innovation in Manufacturing Biopharmaceuticals
- the New Jersey Institute of Technology's Cell and Gene Therapy Development Center and Biotechnology and Pharmaceutical Innovation Laboratory.

As a result, in future years BTEC will need to succeed in a much more competitive environment.

Despite the growth in North Carolina's biopharmaceutical industry and the changes in biopharmaceutical products and manufacturing technologies that have taken place over the past 15–20 years, the state budget for BTEC has stayed essentially constant since 2007, and there has been no increase in its laboratory and other critical spaces needed to meet its mission. Meeting the needs of an evolving biopharmaceutical industry requires a reevaluation of BTEC's operations and resources.

Vision for BTEC 2.0

BTEC aims to address the future needs of the biopharmaceutical industry in North Carolina for the next 10–20 years. This will require significant enhancement and expansion of its current programs and activities involving: (1) undergraduate, graduate, and professional development; (2) process and analytical services for small and large companies; (3) process and analytical research and development funded by external sources; (4) providing access to state-of-the-art analytical and process equipment to manufacture and characterize next-generation biologics. Each of these areas will bring significant benefit to the state of North Carolina.

Objective #1: Increase the capacity for teaching undergraduate, graduate, and professional development courses to a multi-disciplinary audience with a wide range of interests and expertise.

Benefits: This will help meet the growing need for skilled professionals in North Carolina biomanufacturing companies that are addressing the challenges posed by pandemics and innovative drug modalities for the prevention, treatment, and cure of chronic and deadly diseases. Increasing capacity will also enable BTEC to accommodate the increased demand likely to result from the College of Engineering's planned enrollment increase of 4000 students over the next five years, many of whom are likely to seek educational opportunities at BTEC.

Objective #2: Become a Center of Excellence for Biomanufacturing, not only for biotherapeutics, but also production of proteins by precision fermentation, including enzymes and advanced proteins for human food and animal health.

Benefits: This can further promote high-value job creation, since precision fermentation is a cutting-edge field requiring highly skilled professionals. An expanded focus to animal health and alternative proteins can create new markets for agricultural products, such as feedstocks for fermentation processes. Improving fermentation processes can significantly reduce the environmental impact of traditional animal agriculture by lowering greenhouse gas emissions and reducing use of water. Efforts will accelerate research and development of new protein production methods and optimizing processes. The new facility will serve as a collaborative space where academia and industry work together to innovate, leading to breakthroughs in precision fermentation of health-related proteins, food technology and animal health. By developing expertise in precision fermentation, NCFAB can help bridge the skills gap in biotechnology and food science. This can establish clear career pathways, linking educational institutions with industry needs and ensuring a steady pipeline of talent. Finally, increased capacity and capabilities will support small and medium companies or academic researchers in

need of bioprocess and analytical development assistance to enhance the biomanufacturing readiness levels of their technologies.

Objective #3: Enhance BTEC academic participation in research efforts, covering areas from drug development to drug manufacturing, by establishing a multi-disciplinary biopharmaceutical research cluster at NC State to address global health challenges and by reaching out to other research groups in the state that could be potential collaborators in grants from outside sources including NIIMBL, FDA, NIST, industry, and non-profits.

Benefits: Ph.D. graduates with biopharmaceutical research experience are more likely to start new companies, which will potentially lead to an increase in “home grown” companies in North Carolina. Stronger integration of BTEC activities with NC State’s research mission will supplement its already strong outreach component. Enhanced multi-disciplinary research efforts in topics related to biopharmaceutical products and processing will leverage NC State’s growing critical mass of researchers in the field and forge closer linkages to other academic groups at Duke, UNC–Chapel Hill, NC Central University, and other universities that are heavily invested in biopharmaceutical manufacturing efforts.

Objective #4: Update the bioprocess and analytical capabilities in the existing facility to enable educational, professional development, process services, and research efforts focused on next-generation technologies and modalities.

Benefit: These updates will keep NC State and BTEC relevant to industry, enhance their capacity to work with new technologies and drug modalities, and increase their readiness to deal with pandemics and other global health challenges. Updates will bring BTEC and their partners up to date with current practices and future trends in industry, including single-use and disposable devices, gray areas for manufacturing, hybrid and continuous process, process automation and control, high-throughput screening, information technologies such as ML and AI, scale-down models for personalized medicine, and process equipment and analytical equipment necessary for the production and qualification of gene therapies, cell therapies, oligonucleotides, and mRNA-based vaccines/therapeutics.

Realizing this vision will not only allow BTEC to meet future needs of the biopharmaceutical industry but also will enable BTEC to continue its leadership in the growing ecosystem of biomanufacturing education, training, and process research programs in this country and worldwide.

Objective #5: Broaden BTEC’s impact by developing training opportunities that can be deployed throughout the state of North Carolina.

Benefit: BTEC’s ability to offer focused training on all aspects of biopharmaceutical manufacturing is unique throughout the state. Expanding BTEC’s reach offers these unique opportunities to a wider audience thus enabling growth of the industry beyond the Triangle region.

An additional program for the new facility is to make space available for summer internships and directed learning experiences during the school year for STEM High School education. It is known that the interest in careers in engineering and science, in general, is mostly influenced during early formative years and high school education is a critical period in this regard. Making opportunities available for students at this age that exposes them to a scientific career and the potential for science to solve real-world problems is an important area of focus and an opportunity where NCFAB can make a considerable contribution.

NCFAB Program Requirements

1. Additional technical instructional staff to support development and implementation of new education and training programs.
2. Subject matter experts in next-generation biopharmaceutical modalities to push forward research and education efforts in these cutting-edge technologies.
3. Additional multimedia developers and/or educational technologists to create high-quality, interactive virtual education opportunities.
4. Subject matter experts in machine learning, automatic control, data security, etc., to drive BTEC into the future of automation and control of biopharmaceutical processing.
5. Faculty and/or dedicated investigators studying and developing the latest advancements in drug product and drug production.
6. Additional dedicated space for collaborative projects where contractors, vendors, researchers, students, and support staff can all meet and innovate.
7. Increased laboratory space for hands-on training and education as well as research, development, and contract services. Both animal cell culture and microbial fermentation capabilities will be available.
8. State-of-the-art analytical and process equipment.
9. cGMP manufacturing classified space, equipment, and personnel.
10. Increased classroom and meeting room space and technology to enable learning and discussion both in person and virtually.

Implementing the vision for BTEC 2.0

Meeting the objectives and addressing the needs described previously will require the following investments.

1. **Expanded space on Centennial Campus** in proximity to the BTEC facility to accommodate the BTEC 2.0 vision. Approximately 125,000 gross square feet of offices, meeting spaces, GMP space, and process development and research space are needed, separate from locations dedicated to educational and training programs.

2. **Hire BTEC 2.0 staff** at various levels to meet the academic, training, process development and research objectives of the program. Staff include lab technicians, engineers, scientists, with instructional and research duties and educational technologists (or whatever label you opted to use for objective #3) for course development.

3. **Acquire equipment and analytical instrumentation** that allows the existing facility to keep up with trends in process and analytical technologies and are needed to develop programs around new biopharmaceutical modalities.

4. **Increase the number of faculty members** across the campus to pursue research on the discovery, development, and manufacturing of biopharmaceuticals. This includes initiating a multi-disciplinary Biopharmaceutical Discovery, Development and Manufacturing Institute (**BDDMI**). This effort should be accelerated by hiring a cluster of new faculty members at various academic ranks to work collaboratively in a wide range of fields at the forefront of biopharmaceutical research, which cuts across many disciplines from science, engineering, veterinary medicine, information technology, and others. The faculty hired into the cluster would have joint appointments in the departments associated with their respective areas of expertise and at BTEC. The biopharmaceutical industry is one of the leading pillars of the North Carolina economy, and it is important that there be faculty and research programs capable of serving the future of this industry. The faculty members in the BDDMI would have access to BTEC 2.0 space, equipment, and facilities that can serve as a cost sharing for potential research and process development grants from a wide variety of federal and private sources.

5. **Engage** in this effort appropriate groups and state agencies (North Carolina Biotechnology Center, Department of Commerce, North Carolina Board of Science and Technology), NC State University, the UNC GA, industry trade organizations (NCBIO), and foundations associated with biopharmaceutical companies with facilities in the state.

An estimate of the funds required to implement the vision for BTEC 2.0 is given below.

Category	Cost	Period
Building	\$128,000,000	Up front
Equipment	\$32,000,000	Over 5 years
Faculty and staff	\$7,500,000	Recurring
Graduate students	\$500,000	Recurring

BTEC was founded to respond to the critical workforce needs of the biopharmaceutical industry in North Carolina early in this century (2003). We are now faced with an even larger need for the next decade and beyond resulting from increased industry investments in the state as well as the tremendous changes in technology that are driving the industry. The establishment of BTEC was the result of a concerted effort by NCBiotech, NC BIO (now NCLifeSci), the UNC System Office, NC State and many individual companies that recognized the need and the opportunity at that time. It is time to reconvene this group to drive a similar effort to take advantage of the even larger opportunities enabled by the BTEC 2.0 vision and to maintain BTEC's recognized leadership in biopharmaceutical manufacturing education, training, and process and research development.

Task Force for the Future of BTEC

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