

The purpose of this document is to provide a current perspective on science and technology (S&T) based economic development in Delaware with the purpose of catalyzing collaborative partnerships among the academic, private and public sectors to improve the State's competitive position and provide social and economic benefit. State leadership acknowledges the importance of collaborative R&D partnerships to strengthen the innovation economy in Delaware and to advance the state's reputation as an "innovation hub" in the technologies and industries discussed herein. The State recognizes that to sustain an innovation economy, there must be a strategy that fosters the birth, growth, and sustained presence of science and technology companies and the talent they employ. Delaware has among the highest concentrations nationally of science, engineering, and health PhD's in the country, and is surrounded regionally by over 100 higher education institutions. It consistently ranks in the top 10 in national innovation indices.

Leadership in S&T has become both a State and national priority, catalyzed by a global knowledge-based economy and a shift to other countries of high labor content manufacturing and services. The pace of change in technology intensive businesses has dramatically increased, caused by new scientific discoveries and entrepreneurial innovation.

As the mature industries of Delaware decline or shift strategies, new market opportunities emerge. They must be identified early and appropriately supported for Delaware to be competitive, maintain a healthy environment and prosper. Economic growth will be driven by businesses and institutions that are on the cutting edge of science and technology. This requires a business environment that stimulates innovation, entrepreneurship, and knowledge-based partnership. Accelerated change is taking place in technology and in industries, which are repositioning themselves to become more competitive in the face of climate change and global competition. Such changes require a high quality educational system that trains and fosters workforce development at every level.

Along with the emergent nature of new scientific discoveries and technologies there are often steep challenges for social acceptability and their adoption and sustained use by the intended stakeholders To make an emerging technology sustainable, inclusive, trusted, and user-oriented, various stakeholders need to be engaged—starting from the scientific discovery and pre-development stages. Involvement of the end-users and feedback from society and consumers during the development of new technologies is imperative and emphasis should be given to methods that scientifically measure human behavior (instead of just stated behavioral intentions) related to initial adoption and decisions on whether to sustain use.

A productive and vibrant R&D capability that addresses social acceptability is critical to establishing a successful economy and relevant educational programs. Based on extensive review of Delaware's R&D strengths, the State has identified 7 critically important sectors with talent upscaling/workforce training and innovation & entrepreneurship as recurrent themes that apply to all:

- Agriculture**
- Business & Financial Services
- Data Science, Data Analytics & Big Data**
- Energy**
- Environment**
- Human Health

- Manufacturing & Materials**
- Talent Retention, Upskilling & Attraction**

** Areas funded by NSF

The identified sectors should not be considered silos but, rather areas that will encourage multidisciplinary collaboration and innovation. Within these sectors, new and emerging research, education and innovation opportunities will arise that will enhance the ability to compete for sustained funding support and expansion of Delaware's research and workforce capacity. Through the S&T plan, the State has outlined critical R&D sectors and research/focal areas and has identified 6 strategies below to enhance Delaware's competitiveness and prosperity:

- Selecting and nurturing emerging S&T intensive business segments where the focus will be on developing a research and innovation base to create new partnerships, products, jobs and companies.
- Attracting top scientific and entrepreneurial talent to the State, capitalizing on the State's geographic compactness and convenience to mid-Atlantic markets to build internationally recognized, multiinstitutional centers of excellence in targeted fields.
- Supporting and expanding the infrastructure for research at its two research universities, a community college and a private university
- Supporting technology transfer and, where appropriate, commercialization of inventions and innovations developed by universities
- Fostering a culture of innovation, entrepreneurialism and knowledge-based partnerships among private, public and academic institutions state-wide, regionally, nationally and globally.
- Creating ways to increase awareness of the S&T capacity of the state, and to use it to develop regulatory policy based on sound science.

Agriculture

Relevance and Background: Agriculture is a major component of Delaware's economy, producing \$1.5 billion in agricultural sales in the most recent census of agriculture. As a part of the Mid-Atlantic Coastal plain, agricultural research and education in Delaware is driven by questions in grain, fruit, and vegetable production. Due to the large influence of the poultry industry in Delaware, grain crop production for animal feed is a dominant land use. Grain crops have immediate needs in sustainable crop production, including the practice of precision agriculture, water quality for the wider region, and climate and coastal resilience.

The coastal soils of Delaware are variable and can benefit from precision application of seeds, fertilizers, and lime. The Delaware grain production community is largely underserved in precision agriculture applications, which includes needs in both science and engineering for established and newer technologies. Research in yield response for grid or zone soil sampling, variable rate application, and precision placement (seeds and fertilizer) is necessary for our region. Remote sensing, while an established field in agricultural production, is becoming more accessible to the ag industry through both drone and high-resolution satellite imagery. The interpretation of these images will require research in machine learning and model training, where algorithms may be specific to our soils and regional climate.

Precision agriculture can also play a role in improving water quality in the region, where variable rate applications may improve nitrogen use efficiency and reduce runoff and leaching to regional water resources. This can include both sensor technology as well as nitrogen models which best fit our soil types. Managing soil quality and health through innovative methods such as cover crops or intercropping also deserves investigation and will overlap with maintaining Delaware water quality. The concentrated poultry industry benefits grain farmers, but the excess production of poultry litter must also be sustainably managed on the Delmarva peninsula. This can include both sustainable land application as well, engineering research in composting, energy production and byproducts, or other value-added products for poultry litter.

Precision Agriculture: The application of modern information technologies to provide, process and analyze multisource data of high spatial and temporal resolution for decision making and operations in the management of crop production. At its core, it's about providing more accurate farming techniques for planting and growing crops. In turn, this results in less wasted seed, fertilizer, fuel, and time.

Research/Focal Areas Including: Application of seed, fertilizer etc.; yield response from grid/zone sampling; variable rate application/precision placement; remote sensing-drone/high resolution satellite imaging; application machine learning and model training; and sensor technology; crop production; farm management; improved water quality

Poultry Enterprise

Relevance and Background: Delaware is one of the country's leading producers of broiler chickens, generating more than \$1 billion in sales annually. Leading poultry processors such as Perdue, Allen Harim, and Mountaire have significant operations in the state, and the poultry industry represents approximately 70% of Delaware's cash farm income. (DPP, 2021). Southern Delaware has the highest output of broiler chickens in the US. Much of the State's agriculture sector serves the poultry industry, either through growing inputs such as grains or through the processing and the delivery of this low-cost protein to a growing population. However, this intense agriculture in Delaware takes place in a fragile coastal landscape with the State's long tidal shoreline, low elevation, and polluted waterways. These coastal areas are also of importance for conservation and face pressures of a growing human population. Protecting poultry health by developing and implementing strategies for disease surveillance, diagnosis, and control, applying fundamental knowledge gained from avian genomics to diagnose and control poultry diseases and improve the efficiency of poultry production, and integrating the latest advances in food science into innovative technologies that ensure the safety of poultry products consumed in human diets is critical. Key research questions exist on how best to encourage the adoption and persistence of nutrient and sediment management practices by agricultural producers and landowners in Delaware, while continuing to provide a robust and high-quality protein source.

Research/Focus Areas: Poultry Science including management of poultry mortality and litter quality, disease prevention, ventilation and energy, poultry house construction, animal standards of care and overall best practices in poultry management

Behavioral Science and the Adoption and Sustained Use of New Technology

Relevance and Background: The emergent nature of new scientific discoveries creates steep challenges for social acceptability and their adoption and sustained use by the intended stakeholders. One historical challenge with wide adoption of new technology has been mistrust and lack of understanding among the stakeholders. Examples include the reluctance to accept vaccines, concerns about the use of

bioengineering and hormones to increase agricultural production, and the hesitancy to invest in recycled wastewater projects that could improve environmental sustainability. Likewise, promising policy efforts to address emerging challenges with climate change, sea level rise, and the COVID-19 pandemic have been hamstrung by distrust, behavioral deviations from the policy prescriptions, and the fractured nature of public opinion. To make an emerging technology sustainable, inclusive, trusted, and user-oriented, various stakeholders need to be engaged—starting from the scientific discovery and pre-development stages. Involvement of the end-users and feedback from society and consumers during the development of new technologies is imperative and emphasis should be given to methods that scientifically measure human behavior (instead of just stated behavioral intentions) related to initial adoption and decisions on whether to sustain use.

Research/Focal Areas Including: Behavioral Science; Experimental Economics; Health Sciences; Randomized Controlled Trials; Development of new courses and interdisciplinary undergraduate minors and graduate programs, including new online certificates and micro credentials for workforce development.

Business & Financial Services

Relevance and Background: Delaware became a credit card and wholesale-banking center after the 1981 passage of the Financial Center Development Act, which lifted interest-rate limits (usury laws) and taxed bank profits at regressive rates (the more a company makes, the lower its tax rate.) The rise of fintech—the use of technology and innovation to provide financial products and services—is transforming the financial services landscape and will be a key growth opportunity for the Delaware economy in the years to come. The nearly 48,000 jobs in Delaware’s broad financial activities sector today are distributed across firms of all shapes and sizes—with established financial services such as JPMorgan Chase, Bank of America, Capital One, WSFS, and M&T Bank operating alongside payments pioneers like PayPal and fast-growth, early-stage companies like Acorns, College Ave Student Loans, Fair Square Financial, Marlette Funding, and SoFi. (DPP FinTech Report, 2019)

Delaware ranks highly on measures of fintech innovation. Between 2009 and 2018, 199 fintech patents were assigned to Delaware-based individuals and companies, ranking first in the U.S. on a per capita basis, and fifth in absolute terms. While large states like California, New York, and Texas are home to the largest financial services workforces in absolute terms, Delaware has the highest relative concentration of financial services jobs of any U.S. state. The financial services sector accounts for 9% of all jobs in Delaware, a figure nearly twice the U.S. average. A focus of the Delaware banking industry is to use technology software and hardware tools, techniques and risk management processes that assure the confidentiality, integrity and availability of data and systems, thus providing the means to store and share information without undue risk of unauthorized disclosure, loss, or modification.

Research/Focal Areas Including: Cybersecurity; FinTech (merging of finance and “technology” to enhance or automate financial services and processes that allow consumers to have more influence on their financial outcomes)

Tourism

Relevance and Background: Delaware’s tourism contribution to the state's GDP (the total market value of goods and services produced) was \$3.5 billion. Delaware is a “drive-to” state and in 2018, there were 9.2 million visitors. The Delaware tourism industry is the 4th largest private employer in the state, accounting for 44,030 jobs. The tourism industry generated \$545.1 million in tax revenue. Without

tourism, each Delaware household would pay an additional \$1,562 in taxes. (De Tourism, 2018). Delaware seeks increased tourism that can lead to new or improved roads and highways, development of parks, improved public spaces, and in some instances better schools and hospitals. Tourism provides a stimulus for the development of ancillary businesses that encourages entrepreneurs to establish new services that would not be sustainable with local communities of residents alone. A productive and thriving tourism industry helps to support Delaware's infrastructure.

Research/Focal Areas Including: Infrastructure improvement; Beach replenishment; Small business development; Hotel industry; land/real estate development; insurance industry; restaurant industry

Data Science, Data Analytics, & Big Data**

Relevance and Background: As the vast resource of new and diverse datasets are rapidly becoming available in nearly every aspect of life, data science has the potential to advance human understanding in all branches of science and humanities, and address grand challenges facing society. Data Science is an interdisciplinary field that integrates statistics, computer science, engineering, communications, design, and ethics and to create the societal capability for conversion of data into actionable knowledge. It offers a real potential for Delaware that has a global reach and can strengthen every type of organization in the state, from healthcare, education, banking, energy, tourism, agriculture and the environment. We seek to catalyze interdisciplinary science and engineering research to understand and build the human-technology relationship; design new technologies to augment human performance and predictive abilities; illuminate the emerging socio-technological landscape; and foster lifelong and pervasive learning with technology; pursuit of fundamental research in data science and engineering, the development of a cohesive, approach to research data infrastructure, and the development of a 21st century data-capable workforce. Delaware seeks to be recognized as a:

- a data-driven state, where decision support is based on data available to all citizens and stakeholders;
- a data-empowered state, where a diverse data science savvy workforce has well-paid jobs supporting every sector of the economy

Research/Focal Areas Including: Data Analytics; Data Science; Artificial Intelligence; Machine Learning; High Performance Computing; Augmented Reality; Development of sensors and sensor networks for enhanced inputs to data analysis through high performance computing; Development of new courses and interdisciplinary undergraduate minors and graduate programs, including new online certificates for workforce development

Energy**

Relevance and Background: Energy challenges define our world. Two primary themes of the global, national, and local energy markets are the conservation of energy and replacement of carbon based sources for fuel and power with renewable forms of energy. From global competition and lightning-quick advances in technology to climate change and fossil fuel depletion, crises in production and consumption threaten our environment, our prosperity, and our future. Now more than ever, it is imperative that Delaware face these energy challenges and opportunities head on.

Electric Power: Electrification and developing highly efficient, secure, and sustainable sources of electricity are a critical societal need. Present day challenges include intelligent interfaces for efficient

power transfer to devices, vehicle electrification, efficient storage and transmission of electricity from renewable energy sources, and security of the electrical grid.

Research/Focal Areas Including: Systems engineering on strategies for electric power with sustainable energy sources; distributed energy storage; power electronics (circuits and devices for power electronics); efficiency of power devices - SiC and GaN based devices and devices based on gallium oxide and diamond materials. EV automotive system engineering to use EV batteries for grid storage.

Research/Focal Areas: System design for controls, interconnection rules, and standards to allow EVs to provide grid storage and participate in grid power markets. Management of distributed power for grid support (i.e. via charging stations with enhanced controls). Development of state and Federal laws and regulations governing this new, low cost, clean energy resource. Development of professional and international standards (IEEE, SAE, IEC, UL) regarding communications and safety requirements and establishment of V2G Hubs.

Offshore Wind Power

Relevance and Background: The US mid-Atlantic and NorthEast coastal states have now committed to 29 GW of offshore wind purchases, 9 GW of which is already under signed contracts between utilities and wind developers. This implies a \$100 Billion investment into our region over the next 10 years. Additionally, the Biden Administration has committed to 30GW on a faster schedule than the states so far, along with at least \$3.2B to support industrial, vessel, and port development. The technology that new offshore wind turbines are using is changing very rapidly, with many opportunities for R&D in mechanical engineering, superconducting generators, aerodynamics, blade materials and structures, grid integration, electricity policy, meteorology, oceanography and floor geology, and many other fields. There will also be tens of billions of dollars in construction of factories, ports, vessels, and testing facilities with many economic opportunities for the region. The University of Delaware is arguably held in the highest regard of US universities in Offshore Wind research, reports, and training, used for example by US DOE, Dept of Interior, the US Congress, the States of New York, Massachusetts, and New Jersey, but little utilized by the state of Delaware. Delaware has the best location on the East Coast for an offshore wind marshalling port (UD OEIP, 2020), land on the DE Bay is available. Such a facility would lead to over 1,000 high-paying jobs. UD's Special Initiative on Offshore Wind (SLOW) carries out policy analysis, including a report for procurement options for the State of Delaware.

Research/Focal areas: Wind energy; offshore wind management; offshore wind testing sites; ocean regulation and governance; spatial planning; public preferences and economics of offshore wind; continental shelf and estuarine geophysics; mapping and prediction of offshore wind; offshore wind ecosystem Impact; robotics, smart sensors

Solar Power: Agrivoltaics: symbiosis between solar photovoltaic energy and shade crop production

Relevance and Background: Agrivoltaics is an emerging nexus of food and energy that is gaining attention for its ability to increase income for farmers and keep cropland in production while increasing the generation of clean solar electricity. Agrivoltaics or agrophotovoltaics is co-developing the same area of land for both solar photovoltaic power as well as for agriculture. The coexistence of solar panels and crops implies a sharing of light between these two types of production. As the climate becomes hotter and wetter, loss of vegetable and fruit crops is expected to increase due to heat stress and damage from heavy rains. A sun-tracking solar array system can generate electricity for sale to the grid while providing controllable shading for the crops underneath, opening up existing agricultural land for large scale PV installations by giving individual farmers and rural communities a way to remain financially solvent while

retaining their agricultural heritage. This provides an opportunity to meet the Governor's goal of 40% renewable energy by 2035 without sacrificing tomorrow's farm production. The co-location of PV and agriculture could offer win-win outcomes across many sectors, increasing crop production, reducing water loss, and improving the efficiency of PV arrays. Adopting such synergistic paths forward can help build resilient food-production and energy-generation systems (NREL, 2019).

Research/Focal Areas: Sustainable Agriculture; solar arrays; development of new courses and interdisciplinary undergraduate minors and graduate programs; workforce development in electrical and construction trades; new approach to agricultural economics with additional solar electricity revenue stream

Solar Power: Microgrids for Low-carbon Electricity and Resilience

Relevance and Background: Microgrids are emerging as the most cost-effective way to achieve simultaneously a greener and a more resilient grid by providing clean, mission-critical power on-demand to corporate and academic campuses, disaster-prone communities, military bases and data centers when the grid goes down. They are self-contained electric networks that integrate diverse clean energy sources (solar arrays, fuel cells, microturbines), batteries, advanced sensing and control strategies, and local energy management to provide reliable low-carbon electricity independent of the electrical grid. A microgrid not only provides backup for the grid in case of emergencies, but can also be used to cut costs, or connect to a local resource that is too small or unreliable for traditional grid use. A microgrid allows communities to be more energy independent and, in some cases, more environmentally friendly.

Research/Focal Areas: Microgrid development; smart cities; cybersecurity; global studies; First step grand challenges and sustainability.

Solar Power: Next Generation Solar Energy Towards a Carbon-Free Energy Future

Relevance and Background: Delaware is among the states most vulnerable to the impacts of climate change and, therefore, has a tremendous stake in a transition to carbon-free energy. While solar energy implementation has grown rapidly as costs have plummeted in recent years, accelerated development and deployment of solar energy is needed to meet a national goal of 100% clean electricity by 2035 and a statewide goal that 40% of all energy be renewable by 2035. Delaware has a long history and international reputation for excellence at the forefront of research and development in the science and technology of photovoltaic solar energy. The existing multi-disciplinary expertise in materials, engineering, electronic systems and manufacturing can be harnessed to continue to play a big part in the development of next generation solar technologies that will be required to reach these goals. Increased investment in solar energy approaches and their increased deployment can bring many jobs in areas ranging from R&D, manufacturing, and deployment including installing solar from rooftops to utility-scale solar power stations.

Research/Focal Areas: New materials and processes for low-cost, high-performance solar cells and modules; design and validation of new solar cell and module architectures; approaches for integration of photovoltaics to buildings or agricultural applications; power electronics and control systems for integrating high levels of solar into the grid; education in the science and technology of solar energy and workforce development.

Environment**

Relevance and Background: Global climate change, land use change due to population growth, and air and water pollution are major environmental challenges facing Delaware. Environmental conditions have a significant impact on quality of life and human health, and also affect major Delaware industries, including tourism and agriculture. Ecosystem services, such as the state's water supplies provide a powerful engine for the economy, contributing up to \$6.7B, including more than 70,000 jobs, providing over \$2 billion in wages (Narvaez and Kauffman, 2012). Tourism, including beach resorts is the third largest employer in the State. Tourism in Delaware has grown to a \$2.1B industry, employing 39,000 people and attracting more than 7M visitors to Delaware each year. Agriculture, propelled by the large poultry industry, provides a total economic contribution of nearly \$8B to the State.

Delaware is the lowest lying state in the U.S. an average 60 feet above sea level. The state is vulnerable to Atlantic storms, and impacts of sea level rise (SLR) due to climate change. Sea level is rising faster in our region than other parts of the world (Sallenger, 2012), with significant projected impacts on the natural and built environment, including degraded wetland habitats that buffer floodwater, and saltwater intrusion effects on water. A large part of the state's infrastructure including factories, wastewater treatment plants, bridges, and roads are located in flood-prone and low-lying areas. The state is also faced with subsidence of coastal areas and failing century-old dikes. The latter issue impacts cities, such as historic New Castle and Delaware City, where the dikes also protect two industrial sites contaminated with hazardous waste from tidal flooding.

Coastal Resiliency

Relevance and Background: Building a community's ability to "bounce back" after hazardous events such as hurricanes, coastal storms, and flooding – rather than simply reacting to impacts is a critical need as climate change is exacerbated. A community that is more informed and prepared will have a greater opportunity to rebound quickly from weather and climate-related events. Understanding where and how communities are vulnerable to coastal hazards, and adapting planning and development practices to compensate for these vulnerabilities will ultimately result in lives and dollars saved.

Research/Focal Areas Including: Salinization; Soil biogeochemistry; Crop rotation; Wetland transition; Coastal Flooding and Modeling; Coastal Resiliency; Coastal Hazards; Water Quality; Water Security; Engineering with Nature and Green Infrastructure Approaches

Water Security

Relevance and Background: In Delaware, threats to water security relate primarily to water quality and arise largely due to human behavior-whether from excess nutrients from agriculture and households, increased salinity due to groundwater pumping and sea-level rise, or degradation of ecological systems from an expanding human footprint. Thus, improving water security is fundamentally about making better decisions, based on clear scientific understanding, reliable methods and models for predicting future outcomes, improved technologies, and evidence-based policies and programs that cost-effectively invoke positive behavioral change.

Water Quality

Relevance and Background: As a coastal state, Delaware is already experiencing the effects of a changing climate. Saltwater intrusion is inundating fields more frequently through both stormwater surges and saline groundwater. Most soil salinity research has been performed in drier climates with less leaching and different soil types. Research in soil biogeochemistry, alternative crop rotations, and wetland transitions are necessary to serve Delaware landowners and farmers and can provide a model for the Mid-Atlantic.

Research/Focal Areas Including: Salinization; Soil biogeochemistry; Crop rotation; Wetland transition; Coastal Flooding and Modeling; Coastal Resiliency; Coastal Hazards; Water Quality; Water Security; Engineering with Nature and Green Infrastructure Approaches

Human Health

Relevance and Background: Over the past decade, Delaware has successfully enhanced its biomedical research and biopharmaceutical manufacturing capabilities by taking full advantage of the institutional networking, research collaboration, and infrastructure-building initiatives supported by the National Institutes of Health (NIH) Institutional Development Award (IDeA) program. The IDeA program provides catalytic funds to states like Delaware with the goal of creating a sustainable and impactful biomedical research capability across the nation.

Delaware has benefited greatly from its growing collection of IDeA programs. The IDeA network consists of Six Centers of Biomedical Research Excellence (COBREs), one IDeA Clinical and Translational Research (CTR) program and one IDeA Network of Biomedical Research Excellence (INBRE). The COBRE programs, as well as the INBRE and CTR programs, generate, complement, and enrich DELAWARE's research strengths by leveraging NIH investment in personnel, equipment, core facilities and student programs to solve health problems, build research capacity, and build a better student pipeline for the next generation of physicians, healthcare workers, and scientists. Clinical and translational research supported by the CTR program seeks to reduce health disparities in underserved and understudied populations. Together, these programs have received greater than \$300M in NIH funding which has led to greater than 1000 additional awards totaling more than \$500M in additional biomedical research funding.

The overall mission of the Delaware INBRE (DE-INBRE) program is to further grow a multidisciplinary biomedical research network in Delaware that creates and supports sustainable collaborative research programs that address strategic health issues for the State, embraces diversity, and produces a positive impact on Delaware's workforce and economy. The DE-INBRE Biomedical Research Network consists of six Partner Institutions led by the University of Delaware (UD), three affiliated institutions, and an extensive set of affiliated research programs. The six Partner Institutions consist of UD; three minority-serving primarily undergraduate institutions (PUIs), Delaware State University (DSU), Delaware Technical Community College (DTCC), and Wesley College (Wesley); and the region's two largest medical institutions, ChristianaCare (CC) and Nemours/Alfred I. duPont Hospital for Children (Nemours). Joining the network in 2017, affiliated institutions include the Wilmington Veterans Affairs Medical Center (WVAMC), Wilmington University (WilmU), and the Delaware BioScience Association (Delaware Bio). The DE-INBRE program has established research strengths in three thematic areas: cancer, cardiovascular health, and neuroscience. DE-INBRE's administrative and scientific cores provide support for research in these areas as well as capacity building across the network. The Administrative and Evaluation Core manages network services and programmatic activities with an in-depth evaluation program. A broadly engaged and highly impactful Bioinformatics Core supports investigators, educates students, and supports inter-institutional research initiatives. The Centralized Shared Resources (CSR) Core provides investigators and students access to state-of-the-art research instrumentation and scientific expertise via a network of partner and affiliated core facilities. The Education and Professional Development (EPD) Core seeks to train and engage Delaware's faculty, clinicians, and a diverse population of students and fellows (K-12, undergraduate, graduate, and post-doctoral) with exceptional

mentors. Finally, the Developmental Research Project Program (DRPP) aims to increase the number of independent investigators and faculty at minority-serving PUIs who are engaged in research.

The impact of DE-INBRE I-III has been broad and substantial. DE-INBRE has provided mentored research experiences to over 70 graduate students and 600 undergraduate students. 57% of the student scholars are from underrepresented minority groups, and women constitute 64% of the undergraduates and 70% of the graduate students. DE-INBRE has also provided support for 98 Pilot Project investigators. Since 2014, more than 1,000 researchers and clinicians, and over 100 junior investigators statewide, have received research support. Annually, Delaware's biomedical workforce engages in six scientific symposia and 12 student- and community-focused workshops. During one recent five-year period, these activities led to 375 peer-reviewed publications, 1,115 published meeting abstracts, and 160 downstream grant awards valued at \$111M. These funds created an estimated 765 one-year jobs during the first three years of the current award cycle. Since 2001, the program's 600 plus downstream grants totaling over \$300M have created an estimated 4000 additional jobs in Delaware.

The National Institute for Innovation in Manufacturing Biopharmaceuticals (NIIMBL) project grew within Delaware's thriving biomedical research community. It is a public-private partnership whose mission is to accelerate biopharmaceutical innovation, support the development of standards that enable more efficient and rapid manufacturing capabilities, and educate and train a world-leading biopharmaceutical manufacturing workforce, fundamentally advancing U.S. competitiveness in this industry.

Research/Focal Areas: Nursing, Human Health; Neuroscience; Cardiovascular; Cancer; Gene Editing; Bioinformatics; Musculoskeletal; Advanced Biomaterials; Membrane Protein Production; Pediatric Research; Osteoarthritis; Sickle-Cell disease

Manufacturing & Materials**

Relevance and Background: Advanced Manufacturing integrates innovative technology in the production process or within an end product itself. Advanced Materials drive higher levels of end-use performance while also making more efficient use of inputs such as energy and raw materials. Coupling materials and manufacturing advances enables increased productivity and sustainability, enhances global competitiveness, and provides enhanced value to the customer through products.

The chemical revolution and population growth have increased the demand for energy, water, food, and goods, with little attention paid to how we manufacture and supply these goods and the fate of materials at the end of their lifespan. Single-use plastics, such as face masks, and food, exemplify the challenge; most of them end up in landfills. This has created a tremendous waste stream from plastics, food waste, paper industry, biorefineries, biologics, and municipalities that threaten the globe due to global warming and numerous other health aspects. Developing breakthrough technologies and processes that will decrease environmental impacts and boost energy productivity especially related to chemical manufacturing is critical.

Advanced manufacturers assess, investigate, and invest technology areas across a wide spectrum of scientific, engineering, and information technology fields. Delaware is the center of the largest consumer market in the U.S. with more than 50 million people within 250 miles, close proximity to major airports with international and domestic cargo capacity, a major international port four hours from the Atlantic Ocean and an intermodal transfer points and rail freight facilities throughout the region. The National Institute for Innovation in Manufacturing Biopharmaceuticals (NIIMBL), part of the

Manufacturing USA network of institutes, is headquartered at University of Delaware's STAR Campus and lives at the nexus of advanced manufacturing and biopharmaceutical development. It is a public-private partnership whose mission is to accelerate biopharmaceutical manufacturing innovation, support the development of standards that enable more efficient and rapid manufacturing capabilities, and educate and train a world-leading biopharmaceutical manufacturing workforce. By leading a coalition of 190 biopharmaceutical companies, universities, community colleges, and nonprofits, NIIMBL creates advanced manufacturing technologies and supports high wage job creation with an estimated 480 jobs created in Delaware since 2017. The University of Delaware is also leading a major research project in the Rapid Advancement in Process Intensification Deployment (RAPID) Manufacturing Institute, led by the American Institute of Chemical Engineers (AIChE). The U.S. Department of Energy announced RAPID as the newest and tenth member of the national network of Manufacturing USA Institutes and the project will focus on catalysis and reactors. Delaware seeks to be a leader in advanced manufacturing by supporting manufacturing systems that reuse, refurbish, remanufacture and recycle in order to create a closed-loop system, minimizing the creation of waste, pollution and carbon emissions, and to drive the commercialization of inherently sustainable advanced materials through novel manufacturing processes.

Composite materials are advanced materials formed by combination of two or more dissimilar materials to impart a new set of characteristics that neither of the constituent materials could achieve on their own. Advanced composites replace traditional materials such as metals in numerous applications such as aerospace and construction. Delaware's seeks to continue to be a leader in designing new composites to accomplish multiple performance objectives in a single system; developing models and simulations in a "virtual manufacturing" environment for process optimization and improved quality, affordability, and innovative new composite manufacturing processes; connecting industry with researchers through creating new materials, concepts, and technologies and inserting those elements in new products and applications; and providing access to potential employees with the capability to make immediate contributions to new products and applications.

Research/Focal Areas Including: Plastics: Chemically transforming plastic waste into fuels, lubricants, and other valuable products; Municipal and food waste (Food Science, Biology, Civil, Chemical and Environmental Engineering): Additive or Distributive Manufacturing: Catalysis and reactors; Materials synthesis; Multifunctional materials; Materials mechanics and design; Processing and manufacturing sciences; Advanced materials and characterization; Sensing and control; Scale-up of next generation advanced composites, which can be handled like metals in manufacturing processes; Therapeutic protein manufacturing; Coronavirus; gene therapy and cell therapy manufacturing; vaccine development and manufacturing Education and workforce development platforms

Talent Retention, Upskilling & Attraction

Relevance and Background: Continuous learning and education are required to stay competitive in today's job market. Transforming education and career pathways to help broaden participation in science and engineering is critical. In Delaware, ensuring that our citizens are provided with occupational training and employment service opportunities to help them obtain sustainable employment is a high priority. A study conducted by McKinsey & Company found that 40 percent of American business leaders are experiencing difficulty finding employees with in-demand skills, even for entry-level positions. An additional 20 percent of employers claim that most of their new talent is underprepared for the job that they're entering. The discrepancy between the demand for skilled talent and the supply of talent available represents a "skills gap." This gap has widespread negative effects on

economic growth (McKinsey & Company, 2017). Talent upscaling programs can close the gap and lead to improved employee performance, improved satisfaction and morale, address employee workplace weaknesses, ensure consistency and increased productivity as well as potentially lead to increased innovation in products and strategies. We seek to design programs to provide students with necessary skills to make them successful in the workplace, for those who want to upgrade their skills, change their career path, secure a higher paying job or one that they enjoy more. The objective is to create economic prosperity for individuals, businesses, and communities. Workforce training and development should be an ongoing process of educating and empowering the workforce so that they can tackle the industry problems of the future. Delaware has a robust network of technical education, including college, vocational high schools, trade schools and certificate programs. In the area of IT/data/fintech, Delaware is home to a wide range of targeted education and training initiatives, from K-12 programs like Delaware Pathways to a range of postsecondary offerings. These include innovative short-term programs like Zip Code Wilmington, associate degree programs at Delaware Technical Community College, and bachelor's and advanced degree programs at the University of Delaware, Delaware State University, Goldey-Beacom College, and Wilmington University. The number of graduates across tech-related programs at the University of Delaware has increased by approximately 30% since 2015, with Zip Code Wilmington nearly doubling its cohort size between December 2015 and July 2018.

Research/Focal Areas Including: Internships; Experiential learning; On the job training; Course embedded research; Professional career development activities; Delaware Technical Community College: Workforce Development and Community Education Division; Delaware Department of Labor: Registered Apprenticeships State Summer Youth Employment Program. Work Opportunity Tax Credits; Veterans Services, Foreign Labor (Alien) Certification Program, Bonding Program, Migrant & Seasonal Farm Worker Program, Dislocated Worker Program; UD Continuing and Professional Studies programs; Biopharmaceutical Processing Workforce Development Continuum;

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