MASSACHUSETTS
TECHNOLOGY
COLLABORATIVE

The ANNUAL INDEX of the Massachusetts Innovation Economy

2017 Edition

MASSACHUSETTS
TECHNOLOGY
COLLABORATIVE

MASSTECH

The Massachusetts Technology Collaborative, or MassTech, is a unique state agency working to strengthen the Commonwealth's position as the leading hub for innovation and entrepreneurship. MassTech serves as a catalyst, convener, project manager, researcher, and partner within the technology community on behalf of state government, driving job growth and statewide economic impact.

We focus on:

- Cluster Development & Ecosystem Support;
- Talent Support & Workforce Development; and
- Business Assistance for Technology Firms.

Through our three major divisions - the Innovation Institute, the Massachusetts eHealth Institute (MeHI), and the Massachusetts Broadband Institute (MBI) - MassTech is fostering innovation and helping shape a vibrant economy.

We develop meaningful collaborations across industry, academia and government which serve as powerful catalysts, helping turn good ideas into economic opportunity.

We accomplish this in three key ways, by:

- FOSTERING the growth of dynamic, innovative businesses and industry clusters in the Commonwealth, by accelerating the creation and expansion of firms in technology-growth sectors;
- ACCELERATING the use and adoption of technology, by ensuring connectivity statewide and by promoting competitiveness; and
- HARNESSING the value of effective insight by supporting and funding impactful research initiatives.

ABOUT THE INDEX

The *Index of the Massachusetts Innovation Economy*, has been published by the Massachusetts Technology Collaborative annually since 1997. The *Index* is the premier fact-based benchmark for measuring the performance of the Massachusetts knowledge economy. To view the *Index* online and for more information on the Massachusetts Innovation Economy, visit us at: masstech.org/index.

For more information visit: masstech.org/index

Dear Reader,

It's a pleasure to welcome you to the 2017 edition of the *Index of the Massachusetts Innovation Economy*, which has been annually published by the Massachusetts Technology Collaborative for the past 21 years. The *Index* is an important barometer for our Innovation Economy, looking at key indicators such as employment in key tech-focused sectors, venture capital funding, and R&D investment--critical drivers for our economy.

The *Index* provides some context for why Massachusetts is often cited as one of the most innovative economies in the U.S., a fact backed up by Bloomberg, which listed the Commonwealth as the #1 innovation state for the past two years. As Governor Baker highlighted in the State of the Commonwealth address this past January, Massachusetts had more people working in 2017 than at any time in state history and our economy added 180,000 new jobs since the start of the Baker-Polito Administration.

We've prioritized investments in economic development and innovation that will hopefully impact future editions of the *Index*. These programs target key innovation sectors where we believe Massachusetts can play a national and global leadership role, while also spurring investments in communities across the Commonwealth, which has been a focus of our Administration. For example:

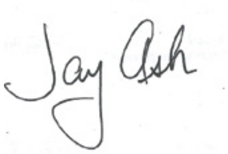
- Nation-leading pledge to boost Advanced Manufacturing, committing over $100 million dollars to match federal investments via the Massachusetts Manufacturing Innovation Initiative (M2I2), funding projects from Boston to the Merrimack Valley, Central, and Western Massachusetts;
- Over $2.5 million in Site Readiness Program grants that has already helped nearly two dozen communities develop properties and "increase the inventory of large, development-ready sites across the Commonwealth";
- Commitment of an additional $45 million in new capital funds for expansion of broadband infrastructure in communities that currently lack connectivity, helping deliver 21st Century technologies to small businesses and residences; and
- Support for community-based innovation in cities and towns of every size, including: $12.5 million in state grants to fund the construction of the Berkshire Innovation Center, a hub for life sciences R&D in Western Massachusetts; $2.5 million in grants to support collaborative workspaces statewide; and a $2.5 million MassWorks grant for the MassRobotics facility in Boston's Seaport.

Being data-driven and results-focused allows us to gauge the impact these investments have on our communities and reports like the *Index* provide a statewide, macro-level view into the key indicators where Massachusetts is ahead, but also those areas where attention or focus is needed.

The *Index* also acts as a conversation starter, allowing us to use the data we've collected to engage our world-class tech companies and innovative universities, to ask them 'how can we do better?' and 'what can the Commonwealth do to help drive your continued success?' This kind of dialogue reflects the spirit of collaboration and partnership that has enabled Massachusetts to achieve national recognition as a leading state for innovation.

My sincere thanks to MassTech for publishing this important report and to all of you who contribute to the success of the country's leading Innovation Economy.

Sincerely,



Secretary Jay Ash
Massachusetts Secretary of Housing and Economic Development
& Board Chair, Massachusetts Technology Collaborative

MASSACHUSETTS TECHNOLOGY COLLABORATIVE

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EXECUTIVE SUMMARY

The 2017 *Index of the Massachusetts Innovation Economy* shows that the Commonwealth is still a top state for innovation, bolstered by our well-trained and talented workers, network of top-tier colleges and universities, and a research & development (R&D) enterprise that, compared to the size of our economy, is second to none. Despite the continued improvement of other states and a handful of challenges faced by the Commonwealth, based on the Massachusetts Technology Collaborative's analysis of 22 indicators that cover the categories of Economic Impact, Research, Technology & Business Development, Capital, and Talent (pages 23-61), we found several areas where Massachusetts' performance continues to stand out:

- **Superior Workforce and Talent Pipeline:** 47.3% of working age adults in Massachusetts had at least a bachelor's degree as of 2015 (1st nationally) while also producing more than 118,000 college graduates (10th nationally);
- **STEM Leadership:** Massachusetts produced 19,500 STEM graduates in 2015 (10th nationally) and more STEM graduates per capita than any state in the country; and
- **Powered by R&D:** Massachusetts had the second highest overall level of R&D funding in the country in 2015 ($28.7 billion), ahead of third-place Texas ($23.7 billion). Given its much smaller size relative to its nearest competitors California (#1) and Texas (#3), the gross R&D numbers show how Massachusetts 'punches above its weight' when it comes to these investments. The vast majority of these investments come from private industry (75%).

While a top performer on many metrics, Massachusetts does face some headwinds. The *Index* also shows several areas where Massachusetts needs to improve relative to other Leading Technology States (LTS) and national trends facing Massachusetts and most LTS, including:

- **Venture Capital Investment Correction:** Venture capital (VC) investment in Massachusetts fell by 7% in 2016 to a total of $6.2B, but saw a much smaller decrease than California (down 18%). Twelve (12) of the 15 LTS saw declines in VC investment in 2016.
- **Middling Innovation Economy (IE) Job Growth:** From Q1 2016-Q1 2017, Massachusetts Innovation Economy jobs increased by 1.4%, similar to the Commonwealth's overall rate of job creation of 1.5%. Massachusetts placed 7th in the LTS on this measure.
- **Positive, but Declining, Net Migration:** Massachusetts attracted a net of +15,000 new residents from elsewhere in 2016, down from +32,000 in 2013. Massachusetts is 6th among the LTS in net migration as a % of the population.

This year's *Index* contains a Special Analysis section focused on "Massachusetts and Convergence," (page 6), which takes a look at the increasing trend toward "interaction and overlap between different technology areas and industry sectors" both among and within firms, and how this change is and will shape the Massachusetts Innovation Economy over the years to come. We've also included a collection of commentaries from thought leaders within the Commonwealth on how they think the state should prepare for the coming convergence.

For this edition, continued from 2016, the *Index* has kept the expanded field of LTS, comparing Massachusetts with 14 other states. All but one of the 2016 LTS made the list in 2017, with newcomer Florida replacing Missouri (page 16). We have included profiles for each state that list key data points, economic sectors, major universities & research institutions, and a selection of representative Innovation Economy companies. We have also provided three examples of unique economic development initiatives that impact and support the development of the Innovation Economy for each LTS member (pages 17-22).

MASSACHUSETTS

2016 POP: 6,811,779
2016 GDP: $505.8 billion
# of IE Jobs: 1,296,952
% of IE Jobs: 37.1%

KEY SECTORS

- Biopharma & Medical Devices
- Computer & Communications Hardware
- Defense Manufacturing & Instrumentation
- Financial Services
- Healthcare Delivery
- Postsecondary Education
- Scientific, Technical, & Management Services
- Software & Communications Services

2017 Leading Technology States
State
Massachusetts
California
Pennsylvania
New York
Illinois
Ohio
Connecticut
Minnesota
North Carolina
Texas
New Jersey
New Hampshire
Rhode Island
Florida
Wisconsin

Convergence & the Commonwealth: *How Massachusetts Can Address & Embrace the Challenges of Fast-Paced Innovation*

Massachusetts, more than perhaps anywhere else in the world, is reliant upon innovation for powering its economic growth. This means that the shape of the Commonwealth's economy is constantly in flux, as it changes and morphs along with the rapid pace of innovation. In the 1980's, the mini-computer industry along Route 128 was king, yet today, it and the companies that boomed during that period are largely defunct. Despite the collapse of mini-computers, Massachusetts has retained its thriving economy because of its ability to adapt to the decline of old industries by evolving, innovating, and generating new industries from its strong base of research and educational institutions, its deep talent pool, and diverse economy.

> **"In a converging world, all industry spaces will be hotly contested. As boundaries break down, incumbent companies will face competitive threats from start-ups with disruptive business models and from formidable companies in previously unrelated sectors."**
>
> **- EY, The Upside of Disruption, 2016**

Often, the decline and rise of new industries is catalyzed by a disruptive innovation which results in the development of new and superior products (for instance, the PC's that replaced mini-computers) or, through a process where formerly distinct products are incorporated into a single, new package through a process known as 'technological convergence.' Prime examples of this Convergence are the evolution of smartphones into substitutes for cell phones, point & shoot/video cameras, music players, PCs, and gaming devices. In a similar manner, entire industries can blur together in a phenomenon sometimes referred to as 'industrial or industry convergence'.[1]

These economic and technological phenomena, shorthanded as 'convergence,' have shaped and will continue to shape our economy over the coming decades. To better understand these processes, we will delve into the topic of convergence to identify what it is, to highlight some current/ongoing examples, and to identify ways that institutions in the Commonwealth of Massachusetts can proactively prepare for future convergence.

As the economic fortunes of Massachusetts are closely tied to innovation and the cutting-edge discoveries being created here each day, by better understanding convergence, identifying ways to invest in it, and finding ways to build on the Commonwealth's core competencies to evolve new industries, we can create a recipe for continued economic growth and resiliency over the coming decades, particularly as the issues of digitization, automation, and artificial intelligence continue to impact the global economy.

What is Convergence?

Convergence is the increasing level of interaction and overlap between different technology areas and industry sectors, both among and within firms. These interconnections can arise in several ways.

1. **Technology Overlap**

As an initial example, firms specializing in a sector such as cybersecurity may undertake business with a wide variety of end users, including companies in sectors such as Finance, Retail, and Healthcare. Diverse sets of companies are adopting common technology platforms that are useful to a wide variety of end-use industries, for example, Internet of Things (IoT) and Data Analytics platforms, which are aimed at a broad audience. Firms in previously distinct industries will find themselves faced with new competitors as convergence creates companies with overlapping skillsets that can be applied to the same customer needs. IBM's 2016 C-Suite Survey found that 54% of C-level executives think more competition will come from companies outside their industry than within it.[2]

> ***Convergence is the increasing level of interaction and overlap between different technology areas and industry sectors, both among and within firms.***

2. **Talent Overlap**

> ***Adoption of common technology platforms is causing firms to have similar demands for talent.***

Another manifestation of convergence is the increasing competition among firms in different industries for the same human capital. While specialization is still important, adoption of common technology platforms is causing firms to have similar demands for talent, regardless of what end-use industry they serve. Those same Finance, Retail, and Healthcare companies that are adopting cybersecurity solutions will also need to hire their own cybersecurity staff to utilize those platforms and tools, and will thus compete within the same talent pool.

An early example of this trend is the proliferation of both personal computing and the internet across a wide variety of industries. Today, most companies have an in-house Information Technology (IT) department or purchase services from an IT Services firm that serves a variety of industries. In some cases they have both. This same trend is beginning to happen with Data Analytics, Cybersecurity, and the IoT as well. PwC and IBM already find that there is widespread demand across the economy for workers with Data Science and Analytics skills.[3][4]

[1] EY. (2016). The Upside of Disruption: Megatrends Shaping 2016 and Beyond. EY.
[2] IBM. (2016). IBM Global C-Suite Study. Armonk, NY: IBM.
[3] IBM, Burning Glass, Business Higher Education Forum. (2017). The Quant Crunch. IBM.
[4] PwC. (2017). What's Next for the 2017 Data Science and Analytics Job Market? Retrieved from www.pwc.com: https://www.pwc.com/us/en/library/data-science-and-analytics.html

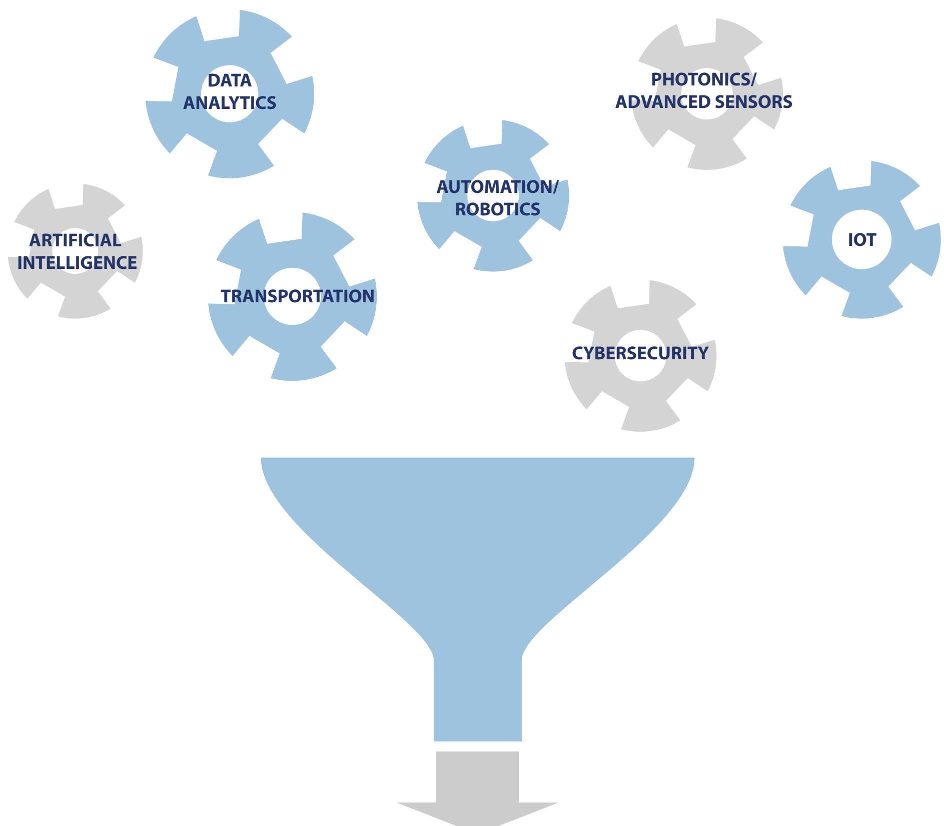
SPECIAL ANALYSIS

Industry Convergence

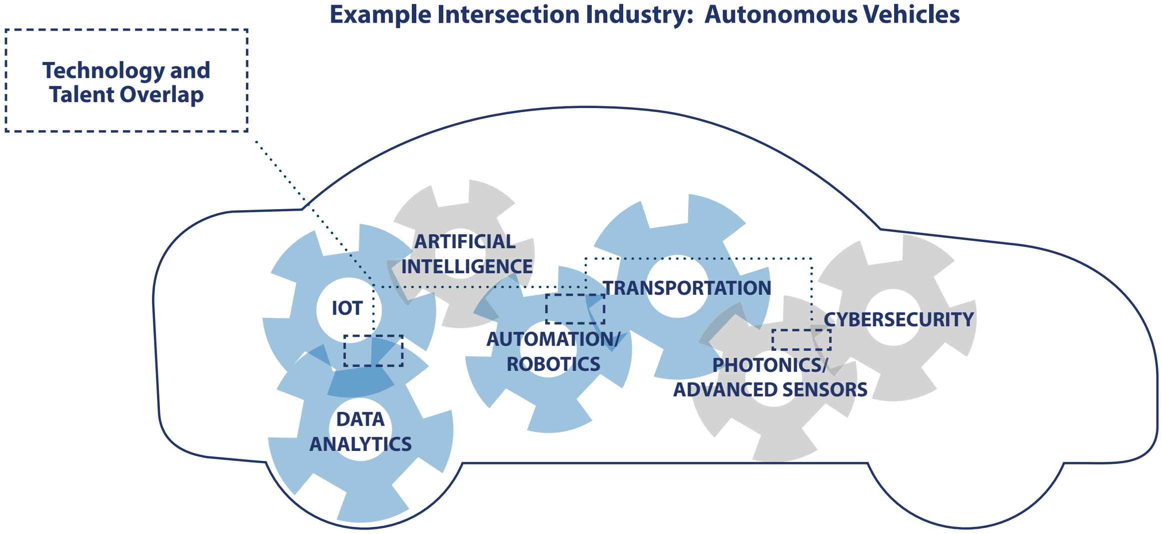
Three Types of Convergence

- **Technology Overlap -** Companies in many industries have similar technology needs such as cybersecurity and data analytics
- **Talent Overlap -** Companies in many industries have similar talent needs such as computer science and data science
- **Intersection Industries -** Companies in a variety of existing end-use industries and technology areas come together to form a new one

Example Existing Industries



Example Intersection Industry: Autonomous Vehicles



3. Intersection Industries

Convergence is also creating new “Intersection Industries” that combine multiple end users and/or technology areas. These are the areas that we think hold the most promise for transforming our economy through disruptive innovations that will re-make entire industries. Intersection industries can form in many possible combinations, but at their core they are offering new or greatly improved products and services compared with existing industries, enabling greatly enhanced productivity, and often a combination of both. Massachusetts needs to cultivate an environment conducive to forming as many of these intersections as possible.

Examples of Intersection Industries

Below we've identified three example industries which are being impacted by convergence or are the creation of convergence. We've selected three industries which highlight strong convergence zones here in the Commonwealth, but numerous other examples exist.

Convergence is also creating new “Intersection Industries” that combine multiple end users and/or technology areas.

i. Digital Health

Convergence is re-shaping the healthcare industry, one of the Commonwealth's largest employers, by incorporating a variety of new digital technologies into healthcare-focused products and services. This new intersection industry, commonly referred to as electronic health or 'digital health', is having a substantial impact on major sectors of our economy, including:

- The healthcare sector, through the increased use of the electronic health records, digital monitoring, and patient engagement technologies;
- Government, as a major provider, payer, and regulator of healthcare through driving improvements in patient outcomes, lowering costs, and dealing with privacy and safety concerns stemming from rapid adoption of new technologies; and
- Consumer-focused healthcare products, such as the expansion of widely adopted technologies including the FitBit and other 'wearables'.

Digital Health products and services can also incorporate a wide variety of technologies, including but not limited to:

- *Cybersecurity* - New tools are needed to protect patient data and privacy, particularly in increasingly digitized, connected, and mobile work environments;
- *Data Analytics* - Utilizing increases in computing power, artificial intelligence, and machine learning to gain actionable insight from large volumes of patient and workflow data; and
- *The Internet of Things (IoT)* - The increase in connected hospitals and medical devices, including connected healthcare products for in-home patient use, will allow for better optimization of workflows and deeper analysis of public health data, not to mention increased engagement with patients both inside and outside of healthcare settings.

On behalf of the Commonwealth, MassTech has been an early promoter of the Digital Health sector and adoption of Digital Health technologies. Through the Massachusetts eHealth Institute (MeHI), MassTech has pushed the adoption of electronic health records throughout the state, supporting smaller healthcare providers that have struggled to onboard these systems.

Expanding on these efforts, the Baker-Polito Administration joined leaders from the City of Boston, top hospitals in the Commonwealth, and healthcare companies in early 2016 to launch a comprehensive public-private partnership called the Massachusetts Digital Health Initiative. This is an effort designed to accelerate the competitiveness of the Commonwealth's digital healthcare industry.

Mass Digital Health works as a partner and funder to support budding digital health entrepreneurs with vital programming, learning sessions, and networking events. The Commonwealth has also provided grants for co-working spaces, including PULSE@ MassChallenge in Boston and BayState Health's innovation lab, TechSpring, in Springfield.

Under this initiative, MeHI is promoting business development efforts in the space, focused on fostering the world's largest digital health ecosystem. These efforts include the development of the Digital Health Marketplace, a unique market access program that aims to build strategic connections between entrepreneurs and healthcare leaders statewide.

orbita

Current PULSE @MassChallenge participant, Orbita, uses voice controlled software to connect providers and payers to patients through a variety of devices.

ii. Advanced Manufacturing

Far from its past reputation for rote work and hands-on labor, manufacturing in Massachusetts now lies at the forefront of convergence, as a suite of new technologies are enabling rapid advances in productivity, allowing previously impractical or seemingly impossible products to be manufactured. This newly revitalized field is frequently referred to as Advanced Manufacturing.

The IoT is a key driver of convergence in manufacturing, allowing companies to collect data and gain useful insights from connected sensors embedded throughout the factory. Advanced manufacturers use IoT-derived insights to enable predictive maintenance, better inventory management, and increased workflow efficiency.

In addition to IoT, Advanced Manufacturing incorporates many other technology areas, including but not limited to:

- *Cybersecurity* - As with healthcare, newly connected factories will need cybersecurity to protect equipment, employees, and trade secrets from cyber threats;
- *Data Analytics* - Factories will increasingly use rich and continuous data to fine-tune the production process;
- *Automation/Robotics* - Already in wide use, automation and robotics will continue to transform manufacturing as systems far more capable of complex tasks become available. This includes collaborative robots designed to work 'hand-in-hand' with human workers; and
- *Next Gen Materials* - New advances in materials science and manufacturing techniques will allow for entirely new products with capabilities once thought impossible.

iii. Autonomous Vehicles

Autonomous vehicles represent the intersection of transportation, government, and a wide variety of technology areas. Autonomous vehicles are on pace to transform the transportation sector, which will have major implications for government entities which act as transportation providers, regulators, and infrastructure owners.

nuTonomy

Cambridge-based NuTonomy, recently acquired by Delphi, develops software for autonomous vehicles and is currently conducting real-world testing in Boston and Singapore.

Examples of technology areas that will intersect in the Autonomous Vehicles industry include:

- *Automation/Robotics* - Autonomous vehicles will transfer control of vehicle systems currently operated by humans to the vehicle itself;
- *Artificial Intelligence* - Development of smart, intuitive, and responsive systems that can interact with the built world will be required to enable decision making and obstacle avoidance as well as power advanced analytics;
- *IoT* - Autonomous vehicles are likely to be connected within large fleets, allowing them to be dispatched on-demand and routed to optimize traffic flow;
- *Data Analytics* - Advanced analytics will be needed to process and make rapid decisions based upon the data collected by large fleets of autonomous vehicles;
- *Cybersecurity* - Large fleets of autonomous, connected vehicles will create a need for rigorous, built-in defense against a wide range of cyber threats; and
- *Photonics & Advanced Sensors* - Highly capable sensors, including photonics-enabled LIDAR systems will be necessary to provide autonomous vehicles with a complete and accurate picture of their surroundings and environment.

MassTech is involved in several manufacturing-related initiatives that seek to promote Advanced Manufacturing. Working in close collaboration with the Commonwealth's Executive Office of Housing and Economic Development, the Innovation Institute at MassTech administers the Collaborative Research and Development Matching Grant Program to support large-scale, long-term projects that have the potential to spur innovation, promote cluster development, and grow jobs by investing in R&D infrastructure. These investments support R&D partnerships that bring together the Commonwealth's world-class research institutions and class-leading companies. The program's funds are not limited to manufacturing, but through it MassTech has made investments in printed electronics research at UMass Lowell and nanomanufacturing at Northeastern.

Massachusetts has made a substantial commitment to develop the Manufacturing USA infrastructure within the state's academic, research and manufacturing industry. Through the creation of sector-specific Manufacturing USA Centers, the Massachusetts Manufacturing Innovation Initiative(M2I2) will advance innovations and job growth within the state through cross-collaboration among companies, universities, national labs, government, incubators, accelerators and other academic and training institutions. Through M2I2, the state has made a commitment to promote research and training in photonics, advanced fibers, flexible electronics, and robotics.

rethink robotics

Boston-based ReThink Robotics designs and builds collaborative robots, including the well-known Baxter. ReThink's robots are easy for workers to train and can be used for a wide variety of rote tasks in the manufacturing sector, freeing up employees for higher value-added activities.

Preparing for Convergence

Convergence is already re-shaping some of Massachusetts' largest economic sectors, perhaps most notably the Commonwealth's world-class healthcare industry. More convergence is yet to come and Massachusetts must be prepared if we are to take full advantage of the opportunities it presents.

Organizations and individuals around the state will need to consider convergence when making a variety of decisions over the coming years.

- **Convergence will change our education and training systems by expanding formerly specialized technical courses into the mainstream**, beginning at the college level, but eventually filtering down into K-12. Institutions around the state need to begin planning in advance, alongside and in consultation with private-sector employers, on ways to identify and disseminate what will eventually become ubiquitous *skills*. In their book *The Second Machine Age*, authors Erik Brynjolfsson and Andrew McAfee of MIT argue that people will need to develop a broader set of intellectual and interpersonal skills in order to work alongside increasingly capable machines in nearly all industries.[5]
- **People will need to think about careers in new ways and shift from having careers in a given industry to having a widely applicable set of skills that can be applied in new industries as they arise.** The days of spending an entire career with one firm are largely gone and it is likely that the days of spending a whole career within a single industry will be numbered as well. The World Economic Forum expects jobs related to specialist technical skills will increase rapidly as companies across all industries seek such workers to help them apply new technologies to transform their industries.[6]
- **Convergence, especially when it happens rapidly, will increase pressure on regulators to adapt to shifting industrial structures**, such as a potential shift from individual car ownership to shared fleets, and determining which companies or technologies do/do not fall under a given regulator's purview. As these new sectors emerge, privacy and the security of personal information will also be a top focus. Autonomous Vehicles, Advanced Manufacturing, Digital Health, Financial Technology or 'FinTech', and other intersection industries present myriad opportunities for economic growth, but new requirements will also be needed to ensure that citizens' physical and digital security are protected. Convergence means regulatory bodies will need to react more quickly and flexibly than ever before to keep up with this quickly changing tide.
- **Businesses will need to consider convergence when making investment decisions as their firms find themselves faced with previously unimagined business opportunities, but also as they confront new competition.** Not all firms will be agile enough to transition into new industries, but there are plenty of existing examples of companies moving into new industries. For example, internet search and consumer electronics companies are moving into the transportation space, as they utilize their existing capabilities in artificial intelligence and software in new ways to develop autonomous vehicles. To pull this off, companies will need a skilled and agile workforce that can tackle challenges in multiple spaces. **A convergence-ready workforce will position them to take advantage of new opportunities, but open up even fiercer competition for talent as companies in previously distinct industries will find themselves fishing in the same talent pool.**
- **Supporting institutions where convergence occurs is another important step. Public-private initiatives should continue to foster the intermingling of people, research institutions, businesses, and technology disciplines.** Supporting the creation of centers where cutting-edge R&D occurs, as well collaborative workspaces which bring together innovators from across separate industry sector or technology disciplines are a few potential steps. Educational institutions and employers can continue cooperation around the design of academic and workforce training programs, to better prepare works for the needs of the 21st century economy.

[5] Brynjolfsson, E., & McAfee, A. (2014). *The Second Machine Age: Work, Progress, and Prosperity in a Time of Brilliant Technologies*. New York: W.W. Norton & Company.
[6] World Economic Forum. (2016). *The Future of Jobs*. World Economic Forum.

Perspectives on Convergence

In the following section, several thought leaders in business, academia, and the non-profit space express how they are planning for convergence and how they think others can, so that Massachusetts maintains and builds upon its position as a global leader in innovation.

Colin Angle, CEO of iRobot, comments upon how firms can adjust to and gain from convergence as well as why Massachusetts is well positioned to benefit from it.

Dr. Joseph E. Aoun, President of Northeastern University, submits an excerpt from his new book, *Robot-Proof: Higher Education in the Age of Artificial Intelligence*, which makes the case that universities need to reform their offerings to better prepare students for a world with increasingly capable machines permeating ever more areas of the economy, including white-collar occupations formerly thought safe from automation. This trend is itself a manifestation of convergence, both among technologies and industries. Dr. Aoun's book lays out a path forward for institutions of higher education in this new era, one that focuses on building skills and competencies that are hard to automate, which will better prepare people to work alongside intelligent machines.

Steve Vinter, Co-Founder of the Massachusetts Computing Attainment Network (MassCAN), comments upon three technologies that are driving convergence - cloud computing, data analytics, and cybersecurity - and writes about the need for K-12 education to build general skillsets in these areas among all students, not just those planning for careers as engineers or scientists.

Since its founding in the early 1980's, MassTech's mission as a public agency has been "to support the vibrant, growing innovation economy across Massachusetts." This includes supporting business formation and growth in the state's technology sector, but also helping the Commonwealth lead in the global digital economy.

While the phrase 'convergence' has not always been used, the Commonwealth's continued leadership in the increasingly digital global economy will be dependent on harnessing and driving convergence, by fostering these new intersection industries and promoting the adoption of new next-gen convergent technologies.

In the past, MassTech has used a variety of approaches to accomplish this goal. One of the simplest has been convening groups of industry leaders to discuss issues and come to a consensus plan of action regarding the development of an industry.

While convening in and of itself is a cost effective way of uniting different technology areas and end-use sectors, MassTech also uses a variety of small and large investments to help drive success. These range from sponsoring small prize challenges focused on a specific issue, and providing stipends for internships at start-ups, all the way up to multi-million dollar, multi-year investments in university-industry R&D centers, collaborations which include private-sector partners and in many cases drive research in these new convergence-driven sectors.

SPECIAL ANALYSIS: Commentary

Industry Perspective

Colin Angle, Chairman, CEO and Founder, iRobot

Mass Convergence

Massachusetts has long been a leading area for technology-focused companies to establish themselves and grow. Over the past decade, the state has seen growth across multiple sectors, including biopharmaceuticals, software services, robotics, healthcare delivery and computer hardware. Companies that began and are headquartered in Massachusetts, including the likes of Boston Scientific, iRobot, Bose, Wayfair and Akamai have long thrived here. The state has also seen the arrival of some of the largest out-of-state technology-minded firms like Google, GE, Amazon and Microsoft, all who have set up operations in Massachusetts. It's clear that companies of all shapes, sizes and areas of expertise recognize the benefits that the region provides. It's also no coincidence that these companies are finding a home in Massachusetts because many, if not all, need specialization across multiple disciplines to operate. It is the convergence of disciplines including hardware, software and information systems that enable these companies to succeed and create value. It is also the convergence of multiple sectors that is creating an ecosystem of diverse, yet like-minded companies, enabling continued growth and long-term success within the Massachusetts economy.

The emphasis on education within Massachusetts positions the state well for supporting the growth of convergence in the future. Massachusetts is home to a leading university system that graduates many of the most talented students and professionals in the world. In 2015, Massachusetts ranked number one in the U.S. in terms of STEM graduates on a per capita basis. As of 2016, 47.3% of the Massachusetts workforce possessed at least a Bachelor's Degree, which ranks first in the U.S. With so many graduates from top-tier universities possessing technology-related expertise, the region's talent infrastructure is well equipped to adjust and thrive as convergence plays a driving role within the Massachusetts economy.

Looking ahead to where convergence will play a major role in the future, the Internet of Things (IoT) holds tremendous opportunities for companies within Massachusetts, however they will need to work together to ensure the growth of all within the IoT. No one company can go it alone. This is an area where Massachusetts has thrived. The state has been very successful bringing companies and organizations together, allowing them to share knowledge, address large challenges, build successful business models and compete on a global level. Massachusetts is an emerging leader in the IoT, and the continued support of our state government and cooperation within the business community will be especially important here moving forward. By leveraging our community, we can powerfully scale.

The state also has a venture capital system which is very high functioning, and investment funding continues to increase, providing greater opportunities to start, sustain and scale companies. There are more startups per capita than anywhere else in the world here, one reason why Massachusetts ranked first in 2015 and 2016 in Bloomberg's *Most Innovative States* list. The knowledge, diverse areas of expertise and creative thinking that startups provide to the larger ecosystem is extremely valuable in addressing convergence. Also important is that companies within Massachusetts have traditionally not only been focused on inventing and showcasing new technologies, but also on bringing them to market. This domain expertise is important, ensuring that companies develop products that provide value to customers, enabling future economic growth.

As a Massachusetts Institute of Technology graduate and entrepreneur who founded and grew iRobot here, I have experienced firsthand the many benefits that Massachusetts provides for businesses as they seek to grow. As the CEO of a robotics company that depends upon a talented and varied employee base, and a company that works with others to address today's and tomorrow's challenges, I also recognize the importance that convergence plays. With Massachusetts serving as a global center of innovation, convergence will enable new markets, visions, business strategies and a grand future for the state's economy, however cooperation within and amongst businesses is a must. Like robotics, convergence breeds success when the sum of the parts is greater than the individual.

SPECIAL ANALYSIS: Commentary

Academic Perspective

Dr. Joseph E. Aoun, President of Northeastern University and author of the book *Robot-Proof: Higher Education in the Age of Artificial Intelligence*

Excerpt adapted from *Robot Proof*

As advanced machines and computers become more and more proficient at picking investments, diagnosing disease symptoms, and conversing in natural English, it is difficult not to wonder what the limits to their capabilities are. This is why many observers believe that technology's potential to disrupt our economy—and our civilization—is unprecedented. Over the past few years, my conversations with students entering the workforce and the business leaders who hire them have revealed something important: to stay relevant in this new economic reality, higher education needs a dramatic realignment. Instead of educating college students for jobs that are about to disappear under the rising tide of technology, twenty-first-century universities should liberate them from outdated career models and give them ownership of their own futures. They should equip them with the literacies and skills they need to thrive in this new economy defined by technology, as well as continue providing them with access to the learning they need to face the challenges of life in a diverse, global environment. Higher education needs a new model and a new orientation away from its dual focus on undergraduate and graduate students. Universities must broaden their reach to become engines for lifelong learning.

There is a great deal of evidence that we need such an educational shift. An oft-quoted 2013 study from Oxford University found that nearly half of U.S. jobs are at risk of automation within the next twenty years. In many cases, that prediction seems too leisurely. For example, new robotic algorithmic trading platforms are now tearing through the financial industry, with some estimates holding that software will replace between one-third and one-half of all finance jobs in the next decade. A 2015 McKinsey report found that solely by using existing technologies, 45 percent of the work that human beings are paid to do could be automated, obviating the need to pay human employees more than $2 trillion in annual wages in the United States.

This is not the first time we have faced a scenario like this. In past industrial revolutions, the ploughmen and weavers who fell prey to tractors and spinning jennies had to withstand a difficult economic and professional transition. However, with retraining, they could reasonably have expected to find jobs on the new factory floors. Likewise, as the Information Age wiped out large swaths of manufacturing, many people were able to acquire education and training to obtain work in higher-skilled manufacturing, the service sector, or the office park. Looking ahead, education will remain the ladder by which people ascend to higher economic rungs, even as the jobs landscape grows more complex. And it undoubtedly is getting knottier. One of the reasons for this is that the worldwide supply of labor continues to rise while the net number of high-paying, high-productivity jobs appears to be on the decline. To employ more and more people, we will need to create more and more jobs. It is not clear where we will find them.

I believe that college should shape students into professionals but also creators. Creation will be at the base of economic activity and also much of what human beings do in the future. Intelligent machines may liberate millions from routine labor, but there will remain a great deal of work for us to accomplish. Great undertakings like curing disease, healing the environment, and ending poverty will demand all the human talent that the world can muster. Machines will help us explore the universe, but human beings will face the consequences of discovery. Human beings will still read books penned by human authors and be moved by songs and artworks born of human imagination. Human beings will still undertake ethical acts of selflessness or courage and choose to act for the betterment of our world and our species. Human beings will also care for our infants, give comfort to the infirm, cook our favorite dishes, craft our wines, and play our games. There is much for all of us to do.

To that end, my book, *Robot-Proof* offers an updated model of higher education—one that will develop and empower a new generation of creators, women and men who can employ all the technological wonders of our age to thrive in an economy and society transformed by intelligent machines. It also envisions a higher education that continues to deliver the fruits of learning to students long after they have begun their working careers, assisting them throughout their lives. In some ways, it may seem like a roadmap for taking higher education in a new direction. However, it does not offer a departure as much as a continuity with the centuries-old purpose of colleges and universities—to equip students for the rigors of an active life within the world as it exists today and will exist in the future. Education has always served the needs of society. It must do so now, more than ever. That is because higher education is the usher of progress and change. And change is the defining force of our time.

SPECIAL ANALYSIS: Commentary

Industry/Non-Profit Perspective

Steve Vinter, Engineering Director, Google, Inc. and Co-founder of MassCAN, an initiative to offer computer science to every K-12 student in Massachusetts

The 2017 Index of the Massachusetts Innovation Economy provides a comprehensive assessment of Massachusetts' economic leadership and health, and documents the Commonwealth's ability to sustain high performance over the past decade. Looking forward, two questions come to mind: what are the key elements of the Commonwealth's economic health that will sustain our leadership position in coming years, and how are we positioned to respond to emerging technology innovations that will create new opportunities for economic competition and growth in the future?

The heart of our economic health is the diversity and growth of a broad array of industry sectors. We have ten sectors larger than $5 billion, five of which have experienced double digit growth since 2011. This variety immunizes our overall economy against sector-specific downturns that periodically arise, and creates the opportunity for cross-sector innovation that derives from interdisciplinary collaboration and advances in our research community. The *Index* identifies the nutrients that enable sector vitality as being distinctive leadership areas for Massachusetts: world class research, a deep reservoir of talent produced by stellar education institutions, and a continuous flow of financial investment to convert potential into economic outcomes. The Massachusetts innovation economy is an ecosystem of mutually complementary systems that reinforce and enrich one another.

As the Internet has matured over the past several decades, the most transformative technology in recent years affecting all of our lives is mobile computing. In combination with the Internet, today's mobile phones are powerful computers that offer us thousands of applications to access unlimited amounts of information from anywhere in the world, placing the power of the internet in our pockets. What new technologies are maturing that can transformative, cross sector effects driving our innovation economy forward in the coming years?

One highly impactful maturing technology for businesses is cloud computing services. Over the past two decades, technology advances, such as Search, Ads, laptops and mobile computing have been driven by consumers' willingness to instantly and continuously adopt the latest advances, pay for them, and integrate them into their lives. In contrast, businesses have moved more slowly, being limited by the cost and challenges of managing changes to their own technology infrastructure.

Cloud computing changes this equation, as businesses shift their infrastructure dependency from internal facilities and services to the cloud. This shift has four benefits. First, businesses can scale and shrink their service usage instantaneously in response to their business needs, making them efficient, responsive to market forces, and cost effective. Second, new services and technologies can be introduced much more rapidly, since service changes are managed by the cloud companies rather than the IT departments within each business. This reduces the barriers for adoption, increasing business flexibility and adaptability. Third, the explosion in the use of these cloud services by ever-increasing numbers of businesses creates a virtuous cycle: greater business adoption of cloud services yields greater investment in those services, greater investment yields greater innovation in cloud services, greater innovation yields greater value to businesses, and in turn greater adoption.

The last benefit of cloud services is the ability to scale data storage at commodity rates. This is essential because of the emergence of "big data", the practice of creating extremely large data sets collected from both human and systems behavior, and analyzing them computationally to reveal patterns, trends, and associations that drive increased business insight and value to the business. The explosion of data collection drives deeper understanding and value in every sector: routing traffic more efficiently, developing personalized drugs, more intelligent financial decisions, and so on. Cloud services, and their use to collect and analyze massive amounts of data, will have a transformative effect on every large business sector within Massachusetts in the next decade.

The second technology innovation to transform industry is machine intelligence being applied to large data sets. Machine intelligence, and specifically machine learning, requires three ingredients that have historically not been available to businesses: enormous quantities of data to train learning algorithms, the algorithms themselves, and the enormous computing power to process that data against the learning models. Cloud computing delivers all three, and the machine learning algorithms will evolve and mature as demand for their use and their value expands. Machine intelligence provides the insights to reveal those patterns, trends and associations in data that are more complex than most, and increasingly all, humans are been capable of understanding. In the past computing was predominantly used in businesses for back office, IT functions. Machine intelligence changes the role of computation in all businesses across all sectors -- it becomes core to the value proposition of businesses, and thereby becomes a competitive advantage to use machine intelligence most effectively.

The third technology advance that will affect every sector is in the area of cybersecurity. As can be seen by our daily headlines, the dependence on computing and the generation and use of massive amounts of data throughout our society has caused our lives, businesses, countries, and political institutions to be vulnerable to ever increasing security attacks. And the quality and sophistication of security threats will increase as our dependence increases. Consequently, security systems will need to be developed that respond to these threats, creating a cycle of investment and escalation in security. Massachusetts is responding to this escalation by investing in education, research and workforce development in this area, which will, in turn, benefit our Commonwealth's economy.

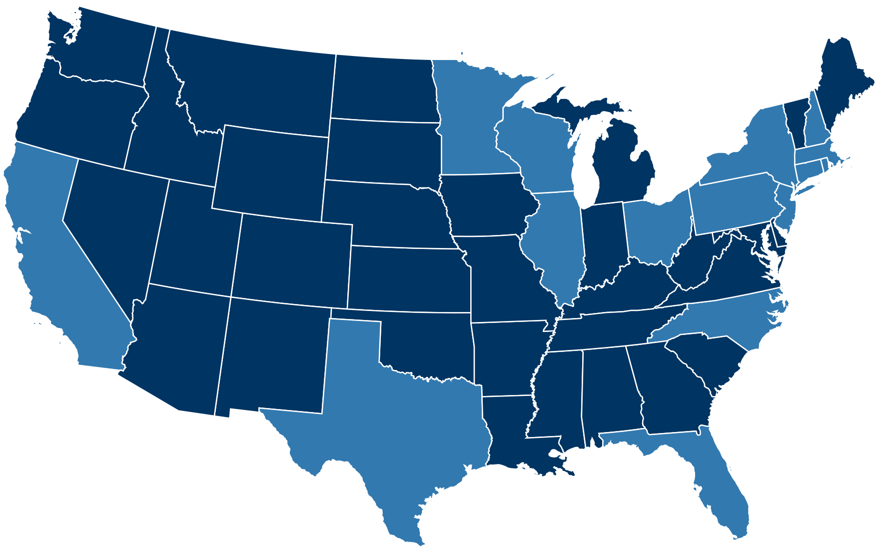
SPECIAL ANALYSIS: Commentary

As technology becomes increasingly important to achieving a competitive advantage in the core business areas in all sectors, the demand for technology talent, already in short supply, will increase. Massachusetts is not self-sufficient for growing its talent pool, as we rely on students from other states and countries to stay after they graduate, and a higher percentage of graduates leave Massachusetts after graduating than in other states. Our most effective response to mitigate this dependency is to teach computational thinking concepts, as defined by our Digital Literacy and Computer Science standards, to all Massachusetts students at the K-12 level, and to offer pathways through high school to prepare students to contribute to the wide range of problem-solving skills needed across all sectors. Preparing the next generation of professionals for the Massachusetts innovation economy is our best investment to ensure it will thrive in the years ahead.

A local student works on a hands-on project at Mass Robotics, an innovative shared workspace in Boston's Seaport District that aims to grow robotics startups and expand learning opportunities. As noted by MassCAN's Steve Vinter, the best way for the Commonwealth to address the tech talent pool is "to teach computational thinking concepts…to all Massachusetts students at the K-12 level, and to offer pathways through high school to prepare students to contribute to the wide range of problem-solving skills needed across all sectors."

SELECTION OF THE LEADING TECHNOLOGY STATES (LTS)

Every year, the *Index* compares Massachusetts' performance on a number of metrics to a group of **"Leading Technology States" (LTS)**. The LTS have economies with a significant level of economic concentration and size in the 11 key sectors that compose the **Innovation Economy (IE)** in Massachusetts. The *Index* accounts for three metrics deemed representative of not only the intensity of the Innovation Economy but also the size and breadth of a state's innovation economy and evaluates them simultaneously.



2017 Leading Technology States (LTS)	
State	**LTS Selection Score**
Massachusetts	2.27
California	2.15
Pennsylvania	2.00
New York	1.71
Illinois	1.66
Ohio	1.63
Connecticut	1.56
Minnesota	1.54
North Carolina	1.40
Texas	1.40
New Jersey	1.39
New Hampshire	1.39
Rhode Island	1.35
Florida	1.33
Wisconsin	1.32

THE METRICS USED TO SELECT THE 2017 LTS:

Number of key sectors with significantly above average employment concentration

Defined as the number of innovation economy sectors in each state where employment concentration is more than 10% above the national average and is a measure of the breadth of a state's Innovation Economy.

Overall Innovation Economy employment concentration relative to the nation

Defined as the percent of a state's workers who are employed in the Innovation Economy relative to the national percentage and is a measure of the overall intensity of a state's Innovation Economy.

Total Innovation Economy employment

Measures the number of employees who work within one of the Innovation Economy sectors in each state and is a measure of the absolute size of a state's Innovation Economy. A score is then applied to all of the states in order to determine the top 15.

To learn more about the selection methodology for the LTS, see page 63.

PROFILES OF THE LEADING TECHNOLOGY STATES (LTS)

The following pages include short profiles of the LTS intended to provide data supporting their inclusion, as well as some contextual information such as examples of leading universities and research institutions, notable Innovation Economy employers, and a few examples of public, private, and non-profit initiatives underway in each state that are intended to support some aspect of the Innovation Economy.

MASSACHUSETTS

2016 POP: 6,811,779
2016 GDP: $505.8 billion
# of IE Jobs: 1,296,952
% of IE Jobs: 37.1%

KEY SECTORS

- Biopharma & Medical Devices
- Computer & Communications Hardware
- Defense Manufacturing & Instrumentation
- Financial Services
- Healthcare Delivery
- Postsecondary Education
- Scientific, Technical, & Management Services
- Software & Communications Services

EXAMPLE UNIVERSITIES & RESEARCH INSTITUTIONS

- Boston University
- Broad Institute
- Harvard University
- Mass General
- MIT
- Northeastern University
- Tufts University
- UMass System
- Worcester Polytechnic Institute

EXAMPLE COMPANIES

- athenahealth
- Biogen
- Dell EMC
- Fidelity Investments
- General Electric (GE)
- Genzyme
- Raytheon
- State Street Bank

EXAMPLE INITIATIVES

Collaborative R&D Matching Grant Program: A program to make seed investments in non-profit research centers matched by funds from non-state sources with the end goal of strengthening existing clusters and increasing research activity in Massachusetts, leading to more economic growth in the future. Investments have been made so far in cloud computing, printed electronics, marine robotics, data science & cybersecurity, and health technologies.[1]

Massachusetts Life Sciences Center (MLSC): A quasi-public state agency tasked with implementing a $1B life sciences initiative through a set of incentives and collaborative programs to support innovation, education, R&D, and commercialization. As of June 2017, MLSC had invested $650M around the state, attracting $2.8B in matching funds from non-state sources and creating thousands of new jobs.[2]

MassChallenge: A non-profit startup accelerator that runs a highly competitive program that attracts applicants from all over the world. MassChallenge participants do not give up equity in their companies as winners, and share over $1.5M of grants at the end of each annual program, made possible by public and private sector donors. Since being founded in 2010, MassChallenge has been the world's largest accelerator program and has expanded to Israel, the UK, Switzerland, Mexico, and Texas. In 2016, PULSE@MassChallenge, a digital health focused program, was set up in Boston's Longwood Medical Area, with state and private sector support.[3]

CALIFORNIA

2016 POP: 39,250,017
2016 GDP: $2.6 trillion
# of IE Jobs: 4,647,045
% of IE Jobs: 27.8%

KEY SECTORS

- Biopharma & Medical Devices
- Computer & Communications Hardware
- Defense Manufacturing & Instrumentation
- Scientific, Technical, & Management Services
- Software & Communications Services

EXAMPLE UNIVERSITIES & RESEARCH INSTITUTIONS

- Cal Tech
- Lawrence Livermore National Lab
- Scripps Oceanographic Institute
- Stanford University
- UC Berkeley
- UCLA

EXAMPLE COMPANIES

- Amgen
- Apple
- Cisco
- Facebook
- Google
- Intel
- Lockheed Martin
- Oracle
- Qualcomm

EXAMPLE INITIATIVES

Biotech Connection Los Angeles (BCLA): This organization seeks to build connections between academics across multiple disciplines and with the broader biotech industry in Los Angeles. BCLA hosts seminars, workshops, panel discussions, and networking events to foster interaction on college campuses between industry professionals and rising young academics.[4]

SFMade: A non-profit organization dedicated to building and sustaining a manufacturing industry in San Francisco. It accomplishes this by connecting manufacturers and workers to local job training and hiring resources, offering education and networking opportunities, and engaging with the broader community about opportunities in manufacturing.[5]

CONNECT: A non-profit organization spun out of UC San Diego tasked with fostering the growth of San Diego's innovation ecosystem by acting as an incubator of sorts for cluster organizations, eventually spinning them off when they are able to stand on their own. Past successes include BIOCOM, San Diego Telecom Council, and CleanTECH San Diego. CONNECT's Springboard mentorship program in the 20 years since inception has grown to a network of 500 mentors. Participating companies have raised $1.5B and created 4,000 jobs. 65% of Springboard companies still exist. CONNECT also creates programming aimed at helping executives grow their businesses.[6]

PROFILES OF THE LEADING TECHNOLOGY STATES

PENNSYLVANIA

2016 POP: 12,784,227
2016 GDP: $719.8 billion
# of IE Jobs: 1,832,102
% of IE Jobs: 31.9%

KEY SECTORS
- Advanced Materials
- Biopharma & Medical Devices
- Business Services
- Diversified Industrial Manufacturing
- Financial Services
- Healthcare Delivery
- Postsecondary Education

EXAMPLE UNIVERSITIES & RESEARCH INSTITUTIONS
- Carnegie Mellon
- Penn State
- Temple University
- University of Pennsylvania
- University of Pittsburgh

EXAMPLE COMPANIES
- Allegheny Technology
- Comcast
- GE Transportation
- PNC Financial
- Uber
- Wyeth Pharmaceuticals

EXAMPLE INITIATIVES

Catalyst Connection: A non-profit organization headquartered in Pittsburgh that provides consulting and training services to small manufacturers in southwestern Pennsylvania, with the goal of accelerating revenue growth and improving productivity. In 2015, 178 recent Catalyst Connection partners reported $131M in increased revenue and 982 jobs created or retained.[7]

Ben Franklin Technology Partners (BFTP): BFTP has been an important seed stage capital provider for the Southeastern PA's technology sectors, investing over $175M in more than 1,750 regional technology companies over the last 30 years, many of which have gone on to become industry leaders. BFTP has also launched university/industry partnerships that accelerate scientific discoveries to commercialization, and has seeded regional initiatives that strengthen the entrepreneurial community in Southeastern PA.[8]

The Science Center: Five educational and medical institutions in Philadelphia joined together in 1963 to create the Science Center, an organization that promotes place and innovation-based economic development in the Philadelphia region by convening entrepreneurs, investors, and academia as well as through the creation of a large, urban science park.[9]

NEW YORK

2016 POP: 19,745,289
2016 GDP: $1.5 trillion
# of IE Jobs: 2,884,403
% of IE Jobs: 31.5%

KEY SECTORS
- Business Services
- Financial Services
- Postsecondary Education

EXAMPLE UNIVERSITIES & RESEARCH INSTITUTIONS
- Columbia University
- Cornell University
- New York University
- State University of New York System
- University of Rochester

EXAMPLE COMPANIES
- Bristol Myers Squibb
- IBM
- Global Foundries
- Most major banks
- Xerox

EXAMPLE INITIATIVES

Cornell Tech: In 2011, New York City created a $100M prize paired with free land to attract a graduate engineering school. The winning proposal was submitted by Cornell University of Ithaca, NY and Technion-Israel Institute of Technology for Cornell Tech, located on Roosevelt Island. The new campus is a multi-decade endeavor, purpose built to encourage collaboration, innovation, and entrepreneurship. As of this writing 14% of Cornell Tech graduates have gone on to found start-ups.[10]

Albany Nanotech: SUNY Poly's Albany Nanotech Complex is a 1.65M square foot integrated research, development, prototyping, and educational facility dedicated to providing strategic and technology support to on-site corporate partners in the nanotech industry. Albany Nanotech has over 300 corporate partners and has created thousands of R&D jobs on-site.[11]

NYSTAR Centers for Advanced Technology (CAT): Created in 1983, CAT funds and facilitates a program of basic and applied R&D as well as technology transfer in collaboration with private industry. NYSTAR identifies strategically important technology fields for New York State and uses a competitive process to award 10-year CAT designations to universities, university-affiliated research institutes, or consortia of several institutions. There are currently 15 active CATs.[12]

PROFILES OF THE LEADING TECHNOLOGY STATES

ILLINOIS

2016 POP: **12,801,539**
2016 GDP: **$796.0 billion**
# of IE Jobs: **1,782,571**
% of IE Jobs: **30.2%**

KEY SECTORS
- Advanced Materials
- Diversified Industrial Manufacturing
- Financial Services
- Postsecondary Education
- Scientific, Technical, & Management Services

EXAMPLE UNIVERSITIES & RESEARCH INSTITUTIONS
- Northwestern University
- University of Chicago
- University of Illinois
- University of Illinois Urbana-Champaign

EXAMPLE COMPANIES
- AbbVie
- Boeing
- Caterpillar
- Chase Bank
- Chicago Mercantile Exchange
- John Deere
- Motorola

EXAMPLE INITIATIVES

University of Illinois Research Park: On-campus research park home to more than 100 companies, 1,700 employees, and 600 interns that also includes a 43,000 sq. ft. incubator for early stage tech companies.[13]

Illinois Innovation Network: Common platform through which startups, innovation-driven enterprises, service providers, research and academic institutions, and community leaders connect, share ideas, and offer tools and resources to accelerate the growth of businesses and industries in the state and beyond.[14]

Illinois Technology Development Account: In 2003, the State Treasurer was authorized to invest up to 1% of the state's investment portfolio into venture capital and private equity in Illinois. Illinois has invested nearly $45 million since then, which was matched by $742M in private investment, creating 3,500 jobs in 60 local companies.[15]

OHIO

2016 POP: **11,614,373**
2016 GDP: **$626.6 billion**
# of IE Jobs: **1,621,182**
% of IE Jobs: **30.5%**

KEY SECTORS
- Advanced Materials
- Business Services
- Defense Manufacturing & Instrumentation
- Diversified Industrial Manufacturing
- Healthcare Delivery

EXAMPLE UNIVERSITIES & RESEARCH INSTITUTIONS
- Case Western Reserve
- Cleveland Clinic
- Kent State University
- Ohio State
- University of Cincinnati
- Wright-Patterson Air Force Base

EXAMPLE COMPANIES
- GE Aviation
- General Dynamics
- Jones Day
- Nationwide Insurance
- Timken Steel

EXAMPLE INITIATIVES

Bioenterprise: A public-private partnership started by the state government, several foundations, research universities, and hospitals to grow the biotech industry in the Cleveland Metropolitan Area.[16]

Edison Welding Institute: A non-profit organization that links manufacturers to cutting-edge research in advanced materials joining and manufacturing technology.[17]

Partners for a Competitive Workforce: A public-private partnership in the Greater Cincinnati Area that seeks to meet current and future demands for skilled workers through creating job matching programs, designing new training programs, and working with educational institutions to develop career pathways.[18]

CONNECTICUT

2016 POP: **3,576,452**
2016 GDP: **$259.9 billion**
# of IE Jobs: **561,223**
% of IE Jobs: **33.7%**

KEY SECTORS
- Biopharma & Medical Devices
- Computer & Communications Hardware
- Defense Manufacturing & Instrumentation
- Diversified Industrial Manufacturing
- Financial Services
- Postsecondary Education

EXAMPLE UNIVERSITIES & RESEARCH INSTITUTIONS
- Hartford Hospital
- UConn
- Yale

EXAMPLE COMPANIES
- Accenture
- Aetna
- Apex
- Cigna
- United Technologies
- General Dynamics
- General Electric (GE)
- Kayak
- Priceline
- Sikorsky
- The Hartford
- Travelers

EXAMPLE INITIATIVES

UConn Tech Park: Phase one of a new university technology park, the Innovation Partnerships Building, was completed in 2017. The goal is to facilitate partnerships between industry and the university by providing flexible lab space and access to UConn's research resources and "Industry Centers."[19]

CT Next: Statewide network that connects start-ups to mentors, collaborative workspaces, universities, suppliers, and other entrepreneurs. CT Next offers easy to navigate resource guides tailored to entrepreneurs and start-ups in different phases of development. It also offers a variety of grant programs to first-time entrepreneurs, start-ups, and municipalities aimed at making it easier to start a business, find talent, and attract more of each to Connecticut.[20]

Connecticut Skills Challenge: Coding and engineering contests for college students to test their skills and get noticed by employers. Challenge participants are entered into an online directory where employers can search for talent and are invited to participate in Connecticut Technology Council job fairs.[21]

PROFILES OF THE LEADING TECHNOLOGY STATES

MINNESOTA

2016 POP: 5,519,952
2016 GDP: $339.1 billion
# of IE Jobs: 894,950
% of IE Jobs: 31.8%

KEY SECTORS
- Biopharma & Medical Devices
- Business Services
- Computer & Communications Hardware
- Diversified Industrial Manufacturing
- Financial Services

EXAMPLE UNIVERSITIES & RESEARCH INSTITUTIONS
- Mayo Clinic
- University of Minnesota

EXAMPLE COMPANIES
- 3M
- IBM
- Medtronic
- St. Jude Medical
- U.S. Bancorp
- United Health

EXAMPLE INITIATIVES

Minnesota's Discovery, Research, and Innovation Economy (MnDRIVE): An $18M annually recurring investment in four research areas at the University of Minnesota: Robotics, Global Food, Environment, and Brain Conditions. To date this has leveraged $167M in external funding and launched 13 start-up companies.[22]

Enterprise Minnesota: A non-profit manufacturing consulting organization that works with small-and medium-sized companies to increase efficiency and profitability. Also administers the Growth Acceleration Program through which the Minnesota state government provides matching funds to small business looking to invest in improving their operations.[23]

University Ave Innovation District: An effort led by the University of Minnesota to develop an Innovation District between its campus and downtown St. Paul, made possible by large infrastructure investments by the state and local governments , including development of light rail in the area.[24]

NORTH CAROLINA

2016 POP: 10,146,788
2016 GDP: $521.6 billion
# of IE Jobs: 1,274,933
% of IE Jobs: 29.9%

KEY SECTORS
- Advanced Materials
- Biopharma & Medical Devices
- Computer & Communications Hardware
- Postsecondary Education

EXAMPLE UNIVERSITIES & RESEARCH INSTITUTIONS
- Duke University
- North Carolina State
- UNC Chapel Hill

EXAMPLE COMPANIES
- Bank of America
- Cisco Systems
- GlaxoSmithKline
- IBM
- Red Hat
- SAS Institute

EXAMPLE INITIATIVES

Research Triangle Park (RTP): An industry, university, and government partnership leveraging proximity to Duke, UNC Chapel Hill, and NC State to create the world's largest research park run by a non-profit that re-invests profits in improving the community. RTP is home to 200 companies, and 50,000 skilled workers, and it invests $296M annually in R&D at local universities.[25]

NCBioImpact: A partnership between the North Carolina Biotechnology Center, NCBIO (an industry group), the North Carolina Department of Commerce, and the state's university and community college systems that created a training program to support the needs of the nascent biotech industry in the state. More than $100M has been invested in training facilities and programs around the state.[26]

NC IDEA: NC IDEA serves as a "catalyst for young, high-growth, technology companies in North Carolina". Its main focus is providing grant financing for companies in IT, Medical Diagnostics and Devices, Material Sciences, and Green Technology. Grantees may also utilize the extensive expertise of NC IDEA management in growing early stage companies.[27]

TEXAS

2016 POP: 27,862,596
2016 GDP: $1,599.3 billion
# of IE Jobs: 3,346,643
% of IE Jobs: 28.3%

KEY SECTORS
- Computer & Communications Hardware

EXAMPLE UNIVERSITIES & RESEARCH INSTITUTIONS
- NASA Johnson Space Center
- Rice University
- Texas Medical Center
- Texas A&M
- University of Houston
- University of Texas

EXAMPLE COMPANIES
- Apple
- Celanese
- Dell
- Freescale Semiconductor
- Rackspace
- Texas Instruments

EXAMPLE INITIATIVES

Governor's University Research Initiative (GURI): A matching grant program to assist eligible institutions of higher education in recruiting distinguished researchers, with the goal of bringing Nobel Laureates, winners of other prestigious awards, and members of national honorific societies to Texas universities.[28]

Texas Enterprise Fund (TEF): A financial incentive program awarding cash grants to economic development projects where significant job creation and capital investment are projected, with the stipulation that a single Texas site be in competition with a viable out-state-option. The fund is intended as "deal closer" to push companies to choose Texas over the next closest competitor. Award amounts are determined by projected job creation and investment: TEF has awarded 140 grants totaling nearly $600M to projects that have committed to create 80,000 jobs and generate more than $27B in investment.[29]

BioHouston: A non-profit organization leading a broad-based effort to establish the Houston region as a top-tier global competitor in life science and biotechnology commercialization. Its mission is to create an environment that will stimulate technology transfer and research commercialization, thereby generating economic growth for the Houston region and making it a global competitor in the life sciences industry.[30]

PROFILES OF THE LEADING TECHNOLOGY STATES

NEW JERSEY

2016 POP: 8,944,469
2016 GDP: $575.3 billion
# of IE Jobs: 1,190,832
% of IE Jobs: 30.0%

KEY SECTORS
- Biopharma & Medical Devices
- Financial Services
- Scientific, Technical, & Management Services
- Software & Communications Services

EXAMPLE UNIVERSITIES & RESEARCH INSTITUTIONS
- New Jersey Institute of Technology
- Princeton University
- Rutgers University
- Stevens Institute of Technology

EXAMPLE COMPANIES
- Brystol Myers Squibb
- Johnson & Johnson
- Merck
- Pfizer
- Prudential

EXAMPLE INITIATIVES

New Jersey Innovation Institute: New Jersey Innovation Institute is a non-profit organization intended to match local firms with university researchers in order to accelerate research and development in health care, bio-pharmaceutical production, civil infrastructure, defense and homeland security and financial services. This program proved successful for New Jersey in 2014, with 20 start-ups initiated from universities, hospitals, research institutions, and technology investment firms, more than doubling the total amount from 2013.[31]

Technology Center of New Jersey: A technology park developed by the New Jersey Economic Development Authority to leverage its prime location between Princeton and Rutgers University. The park has 325,000 square ft. of lab space and ready-to-build sites for over 500,000 square ft. more, as well as the Commercialization Center for Innovative Technologies, a 46,000 square ft. biotech incubator. Tenants may also utilize additional lab space and researchers through a collaboration agreement with Rutgers University.[32]

Newark Innovation Acceleration Challenge: Entrepreneurs submit ideas to be evaluated by a panel of judges for the opportunity to win $3,000 to fund a summer fellowship to work on their idea. Open to Newark college students and residents.[33]

NEW HAMPSHIRE

2016 POP: 1,334,795
2016 GDP: $77.2 billion
# of IE Jobs: 205,244
% of IE Jobs: 31.7%

KEY SECTORS
- Computer & Communications Hardware
- Defense Manufacturing & Instrumentation
- Diversified Industrial Manufacturing
- Financial Services
- Postsecondary Education

KEY SECTORS (cont)
- Software & Communications Services

EXAMPLE UNIVERSITIES & RESEARCH INSTITUTIONS
- Dartmouth College
- Dartmouth Hitchcock Medical Center
- University of New Hampshire

EXAMPLE COMPANIES
- BAE Systems
- Dyn
- Fidelity Investments
- Hypertherm
- Lonza Biologics
- Portsmouth Naval Shipyard

EXAMPLE INITIATIVES

New Hampshire Innovation Research Center (NHIRC): A program at the University of New Hampshire, created in 1991 by the state legislature with the goal of increasing university-industry collaboration and resulting commercialization of innovations to increase the number of high wage jobs in New Hampshire. To date, $8M of state funds have been awarded to support research projects, resulting in at least 685 new jobs. Awardees have received $32M in Small Business Innovation Research (SBIR) funding and $900M in investment/acquisition capital.[34]

Game Assembly: A group of video game developers committed to advancing the video game industry in New Hampshire. They aim to achieve this by growing the number of game studios in NH, retaining talent in-state and creating awareness and education opportunities for local students.[35]

Future Tech Women: An initiative to increase the number of women in technology through empowerment, and various programs such as mentorship to increase awareness and success of women in technology related fields.[36]

RHODE ISLAND

2016 POP: 1,056,426
2016 GDP: $57.5 billion
#of IE Jobs: 148,663
% of IE Jobs: 31.3%

KEY SECTORS
- Biopharma & Medical Devices
- Business Services
- Diversified Industrial Manufacturing
- Financial Services
- Healthcare Delivery
- Postsecondary Education

EXAMPLE UNIVERSITIES & RESEARCH INSTITUTIONS
- Brown University
- Rhode Island School of Design
- University of Rhode Island
- U.S. Naval War College

EXAMPLE COMPANIES
- Amica Insurance
- Citizens Financial
- CVS Caremark
- Fidelity Investments
- General Dynamics
- Metlife
- Textron

EXAMPLE INITIATIVES

UnderSea Technology Innovation Consortium (UTIC): A consortium of private defense and marine companies, the University of Rhode Island, and the U.S. Navy intended to accelerate the development of advanced undersea and maritime technologies for academic, commercial, and defense purposes.[37]

Innovation Vouchers: This Rhode Island Commerce Corporation program lets businesses utilize R&D capacity in the state. Rhode Island businesses with fewer than 500 employees can receive grants of up to $50,000 to fund R&D assistance from a Rhode Island university, research center, or medical center.[38]

Innovate RI Fund: The Fund supports a variety of programs through which eligible Rhode Island small businesses may apply for grants to reduce the cost of applying for SBIR/STTR awards, match SBIR/STTR Phase I and Phase II awards, and hire interns.[39]

PROFILES OF THE LEADING TECHNOLOGY STATES

FLORIDA

2016 POP: 20,612,439
2016 GDP: $926.0 billion
# of IE Jobs: 2,224,706
% of IE Jobs: 26.8%

KEY SECTORS
- Biopharma & Medical Devices
- Business Services
- Scientific, Technical, & Management Services

EXAMPLE UNIVERSITIES & RESEARCH INSTITUTIONS
- Florida State
- NASA Cape Canavrel
- University of Florida
- University of South Florida

EXAMPLE COMPANIES
- Boeing
- Electronic Arts-Tiburon
- First Data
- FIS
- Lockheed Martin
- Raymond James
- Sanofi Pasteur/Vax Design
- SRI International

EXAMPLE INITIATIVES

High School Technology Initiative: A program within the Florida Advanced Technological Education Center, aimed at attracting and retaining more high school students in science and technology career paths.[40]

Innovation Florida: A non-profit organization working to create an innovation economy in Florida through five different strategies: Academic Outreach, Connecting Business to Government, Venture Capital Outreach, Cross Border Collaboration, and Supporting Innovation.[41]

Scripps Research Institute Florida: A private non-profit research organization which "stands at the forefront of basic biomedical science, a vital segment of medical research that seeks to comprehend the most fundamental processes of life". One of its two campuses was launched in Jupiter, Florida in 2003, and is internationally recognized for its research work in several areas of bioscience.[42]

WISCONSIN

2016 POP: 5,778,708
2016 GDP: $313.1 billion
# of IE Jobs: 849,037
% of IE Jobs: 30.0%

KEY SECTORS
- Advanced Materials
- Business Services
- Defense Manufacturing & Instrumentation
- Diversified Industrial Manufacturing
- Financial Services

EXAMPLE UNIVERSITIES & RESEARCH INSTITUTIONS
- Marquette
- Milwaukee School of Engineering
- University of Wisconsin System

EXAMPLE COMPANIES
- Caterpillar
- Epic Systems
- Fiserv
- Harley Davidson
- John Deere
- Johnson Controls
- Kohler
- Oshkosh
- Rockwell Automation

EXAMPLE INITIATIVES

Qualified New Business Venture Program (QNBV): A program intended to incentivize investment in early stage businesses developing innovative products, processes or services by angel investors, angel investment networks, and qualified venture capital funds. Recipients are provided a tax credit, equal to 25 percent of the amount of the equity investment.[43]

The Water Council: A non-profit organization led by a group of Milwaukee-area businesses, universities, and government agencies with the aim of turning the region into the global hub for the Water Industry. The Water Council pursues this goal through economic, technology, and talent development as well as convening industry leaders in Milwaukee, which is now home to over 200 water technology businesses. The Water Council also operates the Global Water Center, a 98,000 square-foot hub for industry-university collaboration and developing new companies in Milwaukee.[44]

UW Milwaukee Innovation Campus: A "third generation" research park that offers technology transfer and business incubation services, as well as incorporates the academic and research enterprise of the university directly into the development of a private sector park that will leverage the research and intellectual property generated by the university.[45]

Why are these Indicators Significant?

Indicator 1: Industry Sector Employment and Wages - pp. 24-25

Technology and knowledge-intensive industry sectors provide some of the highest paying jobs in Massachusetts. Increased employment concentration in these sectors also indicates a competitive advantage for Massachusetts and the potential for future economic growth as strength in these areas usually indicates innovation and business growth.

Indicator 2: Occupations and Wages - pp. 26-27

The Innovation Economy supports jobs with above average wages, thereby contributing to a higher standard of living in the Commonwealth. Changes in occupational employment and wages suggest shifts in job content and skill utilization. Generally, professional and technical employment has tripled as a percentage of the workforce in the last century, so anything but continued employment growth would indicate a shift away from the norm. An important difference between this indicator and the previous one is that Industry Sector Employment and Wages tracks total employment in an industry for all job types found within in it, while Occupations and Wages tracks employment by job type across all industries.

Indicator 3: Household Income - p. 28

Median household income tracks changes in the general economic condition of middle-income households and is a good indicator of prosperity. Rising household incomes enable increased purchasing power and higher living standards. The distribution of income also provides an indication of which Massachusetts economic groups are benefiting.

Indicator 4: Output - p. 29

Industry Output is an important measure of the value of the goods and services produced by each sector of the innovation economy. Output per employed worker is a measure of labor productivity, which is a key driver of wage growth within an economy. It can also be viewed as an indicator of business cycles and used as a tool for GDP and economic performance forecasts.

Indicator 5: Exports - pp. 30-31

Nearly all of Massachusetts' top 25 exports are produced within the Innovation Economy. Manufacturing exports are an indicator of global competitiveness and selling into global markets can bolster growth in sales and employment. In addition, diversity in export markets and products can offset domestic economic downturns. Manufacturing represents approximately ten percent of all private sector jobs in the state and approximately 20% of manufacturing jobs in Massachusetts are tied to exports. In Massachusetts, 111,000 jobs are supported by manufacturing exports, compared to 6.2 million nationwide.

INDICATOR 1: Industry Sector Employment and Wages

How Does Massachusetts Perform?

Among the LTS, California, Florida, Minnesota, New Hampshire, Texas and Wisconsin were the only states where Innovation Economy growth exceeded that in the economy as a whole. **In Massachusetts, Innovation Economy employment grew at a similar rate as the state employment figures as a whole (1.4% vs 1.5%).** Scientific, Technical & Management Services and Business Services were the leading innovation sectors, in terms of employment growth, expanding at 4.6% and 3.7% respectively. Overall, there has been a growing trend of jobs shifting from manufacturing sectors to service-oriented ones, particularly software and scientific/technical services. Multiple factors contribute to this, including outsourcing manufacturing to places with cheaper labor, as well as automation and the rising tech industry.

The Defense Manufacturing and Instrumentation Sector experienced employment declines from Q1 2015-Q1 2016 in 10 out of the 15 LTS, including Massachusetts. This sector has struggled with reduced federal funding, resulting from Department of Defense cost-cutting measures, and the winding down of major overseas deployments. Defense Manufacturing and Instrumentation, along with two other sectors (Computer & Communications Hardware and Diversified Industrial Manufacturing), have experienced declining employment in at least half the LTS since Q1 2012.

Wage growth has been particularly strong in several Massachusetts Innovation Economy sectors since 2011. These include Financial Services, Biopharmaceuticals & Medical Devices, and Scientific, Technical & Management Services. The Commonwealth's fastest growing sector in terms of wage growth, Financial Services (7.7%), experienced mild employment growth relative to 2011 (2%). Biopharmaceuticals & Medical Devices, saw an average wage increase of 6.8% and employment growth of 9% since 2011.

MASSACHUSETTS & ...
INDUSTRY SECTOR EMPLOYMENT & WAGES

- **1.4% Innovation Economy employment growth from Q1 2016-Q1 2017, tied for 7th in LTS**
- **Software & Communications Services was the fastest growing sector over the last 5 years (2011-16), with 15% growth and topping 159,000 total employees**
- **Employment declines in Advanced Materials, Defense Mfg, Computer and Communications Hardware, and Diversified Industrial Mfg from Q1 2016-Q1 2017**

Employment and Annual Average Wage in Key Sectors
Massachusetts, 2011-2016

Sectors	2011 Employment Total	2016 Employment Total	% Change in Employment 2011-2016	2011 Average Wage	2016 Average Wage	2011-2016 % Wage Change
Advanced Materials	30,703	28,620	-7.3%	$67,468	$69,581	3.1%
Biopharma & Medical Devices	57,650	63,159	8.7%	$122,426	$130,699	6.8%
Business Services	141,402	152,070	7.0%	$108,227	$107,458	-0.7%
Computer & Communications Hardware	38,303	31,699	-20.8%	$116,250	$121,733	4.7%
Defense Manufacturing & Instrumentation	36,791	36,319	-1.3%	$110,518	$113,475	2.7%
Diversified Industrial Manufacturing	40,076	37,956	-5.6%	$80,762	$76,709	-5.0%
Financial Services	157,664	160,167	1.6%	$130,170	$140,230	7.7%
Healthcare Delivery	345,530	385,062	10.3%	$67,884	$67,440	-0.7%
Postsecondary Education	141,537	156,878	9.8%	$63,507	$63,362	-0.2%
Scientific, Technical & Management Services	74,618	86,171	13.4%	$114,679	$122,455	6.8%
Software & Communications Services	135,485	158,851	14.7%	$120,510	$122,253	1.4%

Data Source for Indicator 1: Bureau of Labor Statistics (BLS) Quarterly Census of Employment and Wages (QCEW)

INDICATOR 1: Industry Sector Employment and Wages

Employment Growth in Key Sectors
Massachusetts & LTS, Q1 2016-Q1 2017

Sectors	CA	CT	FL	IL	MA	MN	NH	NJ	NY	NC	OH	PA	RI	TX	WI
Advanced Materials	-1.1%	1.3%	1.2%	0.2%	-0.9%	4.6%	-0.2%	-0.2%	-3.8%	0.0%	1.3%	1.1%	1.0%	0.3%	0.5%
Biopharma & Medical Devices	3.6%	-3.2%	2.1%	0.2%	0.3%	4.4%	0.7%	2.3%	0.4%	-0.1%	3.9%	0.0%	1.4%	2.7%	1.4%
Business Services	1.7%	0.4%	2.2%	0.0%	3.7%	1.7%	1.2%	5.1%	1.3%	1.3%	1.9%	0.5%	3.3%	2.8%	1.5%
Computer & Communications Hardware	-1.3%	-4.8%	-1.2%	-0.8%	-3.6%	-4.1%	1.1%	5.2%	-3.3%	-2.7%	-3.5%	-2.0%	4.5%	0.2%	-4.5%
Defense Manufacturing & Instrumentation	-1.4%	0.4%	3.7%	-2.2%	-1.7%	1.0%	4.5%	-1.6%	-0.2%	2.0%	-0.7%	-0.8%	-0.9%	-4.8%	-1.6%
Diversified Industrial Manufacturing	1.0%	0.1%	2.6%	-1.2%	-0.3%	-0.7%	-0.7%	0.2%	-4.3%	0.4%	-1.6%	0.9%	-3.9%	-5.1%	-0.8%
Finance	1.5%	-0.8%	3.4%	0.3%	0.0%	3.5%	-9.6%	2.5%	-0.5%	2.3%	1.7%	0.7%	7.1%	2.7%	0.9%
Healthcare Delivery	3.7%	2.2%	3.7%	1.5%	1.9%	3.0%	3.0%	1.7%	4.4%	0.4%	1.1%	1.9%	-1.4%	3.6%	4.8%
Postsecondary Education	2.1%	0.5%	2.9%	0.1%	1.2%	1.7%	-1.0%	1.5%	-0.7%	2.6%	0.9%	1.8%	1.7%	1.5%	-1.3%
Scientific, Technical & Management Services	-4.9%	-2.4%	3.3%	0.3%	5.0%	7.4%	3.0%	-3.4%	0.1%	3.0%	-1.4%	0.2%	9.6%	2.6%	-1.5%
Software & Communications Services	4.7%	-1.1%	4.2%	1.4%	2.2%	0.0%	14.2%	-0.9%	1.6%	4.1%	1.7%	0.0%	-14.9%	3.4%	1.5%
Innovation Economy	2.0%	0.2%	3.2%	0.5%	1.4%	2.4%	1.6%	1.4%	1.4%	1.4%	0.9%	1.1%	0.2%	2.4%	1.5%
Total Jobs	1.6%	0.3%	2.9%	0.5%	1.5%	1.9%	1.4%	1.4%	1.4%	1.4%	0.8%	1.2%	1.3%	2.2%	1.0%

For additional charts on this indicator visit: masstech.org/index

Data Source for Indicator 1: Bureau of Labor Statistics (BLS) Quarterly Census of Employment and Wages (QCEW)

INDICATOR 2: Occupations and Wages

How Does Massachusetts Perform?

Massachusetts had higher average wages than the LTS in 10 of 11 occupational categories tracked by the *Index* and higher average wages than the U.S. overall in all 11 categories. The gap between Massachusetts and both the LTS and U.S. is even larger in terms of overall wages than within any occupational category, at 20.1% higher than the LTS and 22.6% higher than the U.S., indicating that Massachusetts has a larger percentage of its employment in high paying occupational categories. Below we highlight certain key occupational categories.

- The Computers & Math and Business, Financial & Legal occupational categories had significantly higher wages than the LTS and the U.S. for these occupations. Computers & Math occupations in Massachusetts paid 12.7% more in average wages to workers in those occupations compared to competing LTS states.
- Healthcare occupations continued their positive wage growth in Massachusetts and remain higher than the LTS and U.S. Employment in the healthcare industry also increased by 9,020 jobs from 2015 to 2016.
- Science & Engineering experienced increased positive employment growth in Massachusetts in 2016, but employment and wages for Science & Engineering occupations have still not returned to 2009 levels.

MASSACHUSETTS & …
OCCUPATIONS & WAGES

- **Higher average wages in 10 of 11 occupational categories than the LTS average**
- **Higher average wages in all 11 occupational categories than the U.S. average**
- **Largest difference between MA and both U.S./LTS averages: Business, Financial & Legal Occupations (+$11,500 vs LTS, +$13,300 vs U.S.)**

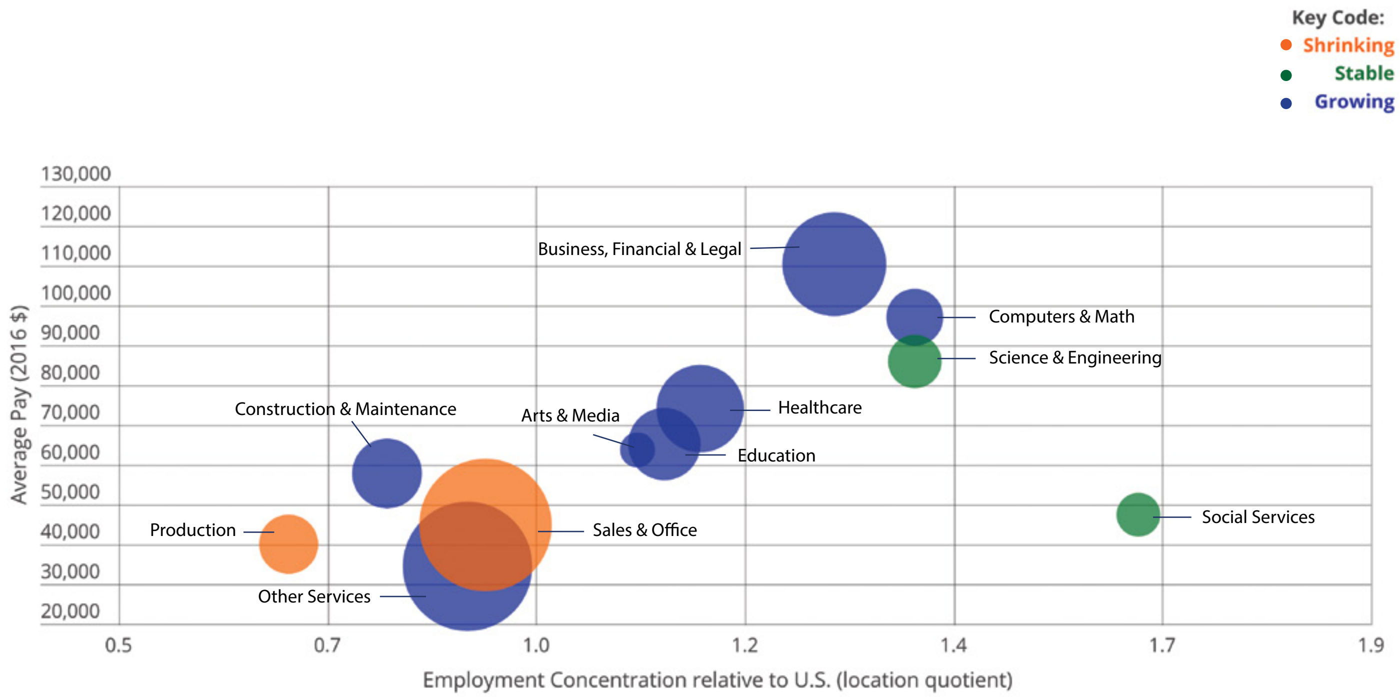
Average Wages by Occupation
Massachusetts, LTS, & U.S., 2016

	Average Wage		
Occupation	Massachusetts	LTS	U.S.
Arts & Media	$63,880	$55,234	$58,390
Business, Financial, Legal	$110,281	$98,743	$96,937
Computers & Math	$96,860	$85,958	$87,880
Construction & Maintenance	$57,719	$49,664	$47,808
Education	$65,060	$55,588	$54,520
Healthcare	$74,231	$64,454	$63,234
Other Services	$34,526	$30,581	$30,203
Production	$40,130	$37,703	$37,190
Sales & Office	$44,738	$39,816	$38,572
Science & Engineering	$85,821	$78,651	$80,711
Social Services	$47,240	$48,000	$47,200
All Occupations	$60,840	$50,658	$49,630

Data Source for Indicator 2: BLS Occupational Employment Statistics, Consumer Price Index (CPI)

INDICATOR 2: Occupations and Wages

Occupations by Employment Concentration and Annual Pay
Massachusetts, 2016



Data Source for Indicator 2: BLS Occupational Employment Statistics, Consumer Price Index (CPI)

INDICATOR 3: Household Income

How Does Massachusetts Perform?

Massachusetts had a higher median household income than both the average LTS and the U.S. as a whole in 2016. After experiencing a sharp decline in 2011, Massachusetts has seen a faster recovery in household income than the LTS or U.S. Massachusetts recorded 12% median household income growth since 2011, while the LTS grew by only 6%, and the U.S. by 6.9%. Median household income growth in Massachusetts surged 5.3% from 2015 to 2016. The difference between the median household income in Massachusetts and that of the LTS and the U.S. is increasing **as Massachusetts' median income is rising faster than the LTS or the U.S.**

Massachusetts has proportionally many more households with incomes above $100,000 than both the LTS and U.S. This could partly explain why incomes have recovered at a faster rate in Massachusetts than elsewhere, since over the last several decades higher income households have seen larger gains in household income than the population as a whole. This is largely due to increasing returns on college education, and Massachusetts, having a high relative proportion of degree holders. As such, the state should see larger income gains than would be experienced elsewhere. New Jersey, another highly educated state, is the only state among the LTS to have a higher median household income than Massachusetts.

MASSACHUSETTS & … HOUSEHOLD INCOME

- **Higher median household income in 2016 ($75,000) than either the LTS or U.S.**
- **Median household income rising faster than either the LTS or U.S. averages in 2016**

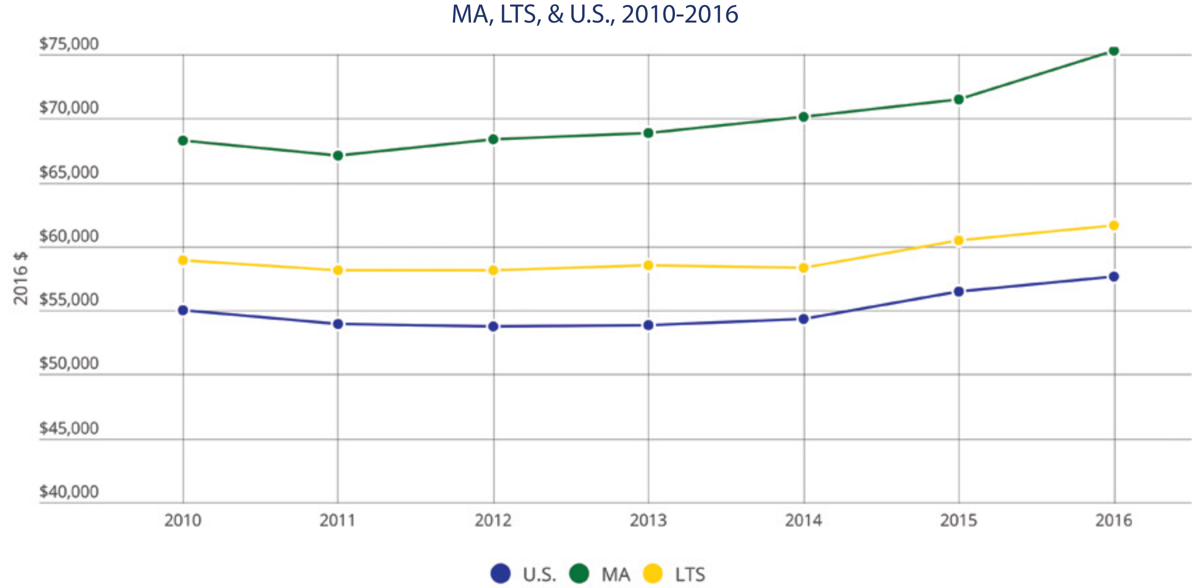
Percentage of Households by Income Level

Massachusetts, LTS, & U.S., 2016

Household Income	MA	LTS Average	US
Under $35,000	24.80%	29.07%	30.70%
$35,000- $99,999	37.50%	42.67%	43.00%
Above $100,000	37.60%	28.23%	26.20%

Median Household Income

MA, LTS, & U.S., 2010-2016



	2011	2012	% Change 2011-2012	2013	% Change 2012-2013	2014	% Change 2013-2014	2015	% Change 2014-2015	2016	% Change 2015-2016	% Change 2011-2016
U.S.	$53,911	$53,768	-0.3%	$53,861	0.2%	$54,372	0.9%	$56,472	3.9%	$57,617	2.0%	6.9%
MA	$67,102	$68,388	1.9%	$68,827	0.6%	$70,082	1.8%	$71,511	2.0%	$75,297	5.3%	12.2%
LTS	$58,112	$58,126	0.0%	$58,489	0.6%	$58,292	-0.3%	$60,439	3.7%	$61,597	1.9%	6.0%

For additional charts on this indicator visit: masstech.org/index

Data Source for Indicator 3: U.S. Census Bureau, Bureau of Economic Analysis (BEA)

INDICATOR 4: Output

How Does Massachusetts Perform?

Between 2011 and 2016 output increased in all of the Commonwealth's Key Sectors with the exception of Diversified Industrial Manufacturing. Four Key Sectors experienced output growth above 15% from 2011-2016: Biopharmaceuticals & Medical Devices (21.7%), Software and Communications Services (19.3%), Scientific, Technical, and Management Services (16.8%), and Financial Services (15.3%). In absolute terms, Software & Communications Services, the largest of the Key Sectors in terms of output, is a clear driver of growth in the economy as its output increased by $6.8 billion from 2011-2016.

Massachusetts' position as a leader in Biopharmaceuticals & Medical Devices has been further strengthened by the relocation of the headquarters or major R&D facilities of several pharmaceutical companies to the Boston area. There are now almost 1,900 establishments in the Biopharmaceuticals and Medical Devices industry in Massachusetts.

In per capita output, Massachusetts outperforms the LTS average in all Key Sectors except for Advanced Materials. Advanced Materials is the Commonwealth's smallest sector in terms of output and made up only 2.2% of Innovation Economy employment in 2016. Massachusetts fares well in comparison to the LTS in most sectors in per capita terms. The largest difference in absolute terms is in the Software & Communications Services sector where the state is $2,628 per capita or 73.7% ahead of the LTS average. The Financial Services and Healthcare Delivery Sector are also roughly $2,000 per capita ahead of the LTS average. Postsecondary Education is 207% higher than the LTS average, the largest difference in percentage terms. Massachusetts ranks highest in per capita output, among the LTS States, in Software & Communications Services; Scientific, Technical & Management Services; Biopharmaceuticals, Medical Devices & Hardware; Postsecondary Education, and Healthcare Delivery.

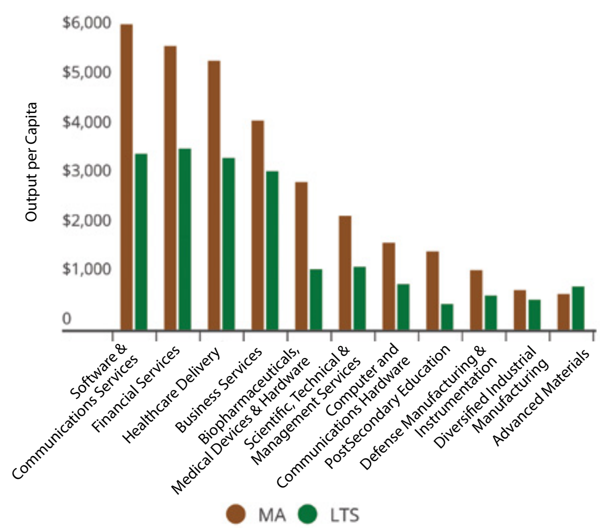
MASSACHUSETTS & ... OUTPUT

- **Output increased in all sectors from 2011 to 2016 except Advanced Materials**
- **Higher per capita output than LTS average in all but Advanced Materials**
- **Largest Sector: Software & Communications Services ($42.2B in 2016)**

Output in Key Sectors
Massachusetts, 2011 & 2016
$M

Key Sectors	2011	2016	2011-2016 Output Growth	2011-2016 % Change
Software & Communications Services	$35,375	$42,200	$6,825	19.3%
Financial Services	$34,011	$39,200	$5,189	15.3%
Healthcare Delivery	$32,876	$37,138	$4,262	13.0%
Business Services	$27,082	$28,873	$1,791	6.6%
Biopharmaceuticals, Medical Devices & Hardware	$16,757	$20,398	$3,641	21.7%
Scientific, Technical & Management Services	$13,458	$15,714	$2,256	16.8%
Computer and Communications Hardware	$11,475	$11,994	$519	4.5%
PostSecondary Education	$10,529	$10,784	$255	2.4%
Defense Manafacturing & Instrumentation	$7,853	$8,219	$366	4.7%
Diversified Industrial Manafacturing	$6,746	$5,469	($1,277)	-18.9%
Advanced Materials	$4,791	$4,901	$110	2.3%

Output per Capita in Key Industry Sectors
Massachusetts & LTS, 2016



Key Sectors	MA	LTS
Software & Communications Services	$6,195	$3,567
Financial Services	$5,755	$3,675
Healthcare Delivery	$5,452	$3,484
Business Services	$4,239	$3,215
Biopharmaceuticals, Medical Devices & Hardware	$2,994	$1,225
Scientific, Technical & Management Services	$2,307	$1,276
Computer and Communications Hardware	$1,761	$925
PostSecondary Education	$1,583	$516
Defense Manufacturing & Instrumentation	$1,207	$691
Diversified Industrial Manufacturing	$803	$608
Advanced Materials	$719	$877

Data Source for Indicator 4: U.S. Census Bureau, Moody's, QCEW

INDICATOR 5: Exports

How Does Massachusetts Perform?

Massachusetts has seen some variability in the destination of its exports between 2011-2016, with destinations that have historically been important trade partners, such as the United Kingdom and Canada, purchasing fewer goods from Massachusetts businesses. Canada was the largest export destination for Massachusetts in 2016, even though exports to that country have declined 20% since 2011. Exports to Mexico (#2) and Switzerland (#4) have grown tremendously during the 2011-2016 period, in part due to large export growth in 2016. Exports to China (#3), the Netherlands (#8) and Ireland (#10) also experienced growth. **Massachusetts is 13th among the LTS in exports as a percentage of GDP the same as in 2015.**

MASSACHUSETTS & ...
EXPORTS

- **13th among LTS in Exports as % of the GDP in 2016**
- **Canada was the largest trading partner in 2016 - $3B**
- **$25.8B in exports in 2016**

U.S. exports continued to fall in 2016 for the second time since the Great Recession. After the decline from 2014-2015, total exports decreased by $111B from 2015-2016. National trends in declining export value have affected Massachusetts as well. Since reaching a post-recession peak of $27.9B in 2011, Massachusetts exports have averaged $26.2B annually over the following five years. The Commonwealth's 2016 exports were $25.8B which, although $500M higher than 2015, were $400M (-1.4%) lower than the five year average and $2.1B (-7.4%) lower than in 2011.

Massachusetts' top export commodities in 2016 consisted of Computer and Electronic Products, Machinery (except electrical), Chemicals and Miscellaneous Manufactured Commodities. Computer and Electronic Products have historically been the most exported commodity in the state and made up 26.9% of the state's exports in 2016. However, there has been a 4.9% drop in the value of computer and electronic products since 2015, which likely contributes to the job losses seen in this sector over the last year. Exports in machinery (except electrical) did experience an increase in value from 2015.

Despite an uptick in global economic growth, the increased purchasing power of the dollar continues to hinder state exports as it becomes more expensive for goods to be purchased by international trading partners. The major currencies of the Commonwealth's trading partners (Euro, Canadian dollar, Chinese yuan, Japanese yen, and Mexican peso) lost purchasing power against the dollar from 2015-2016. Massachusetts has also experienced a shift towards high tech services, which do not always show up in state-level export statistics. The U.S. as a whole has a positive trade balance in services exports.

Massachusetts Exports:
Top Ten Destinations and Value
($ Millions), 2011-2016

Country	2011	2016	% Change 2011-2016
Canada	$3,796	$3,025	-20.3%
Mexico	$1,437	$2,471	72.0%
China	$2,088	$2,165	3.7%
Switzerland	$563	$1,769	214.2%
Germany	$2,046	$1,635	-20.1%
United Kingdom	$3,285	$1,584	-51.8%
Japan	$2,043	$1,399	-31.5%
Netherlands	$1,106	$1,369	23.8%
South Korea	$1,030	$978	-5.0%
Ireland	$517	$948	83.4%

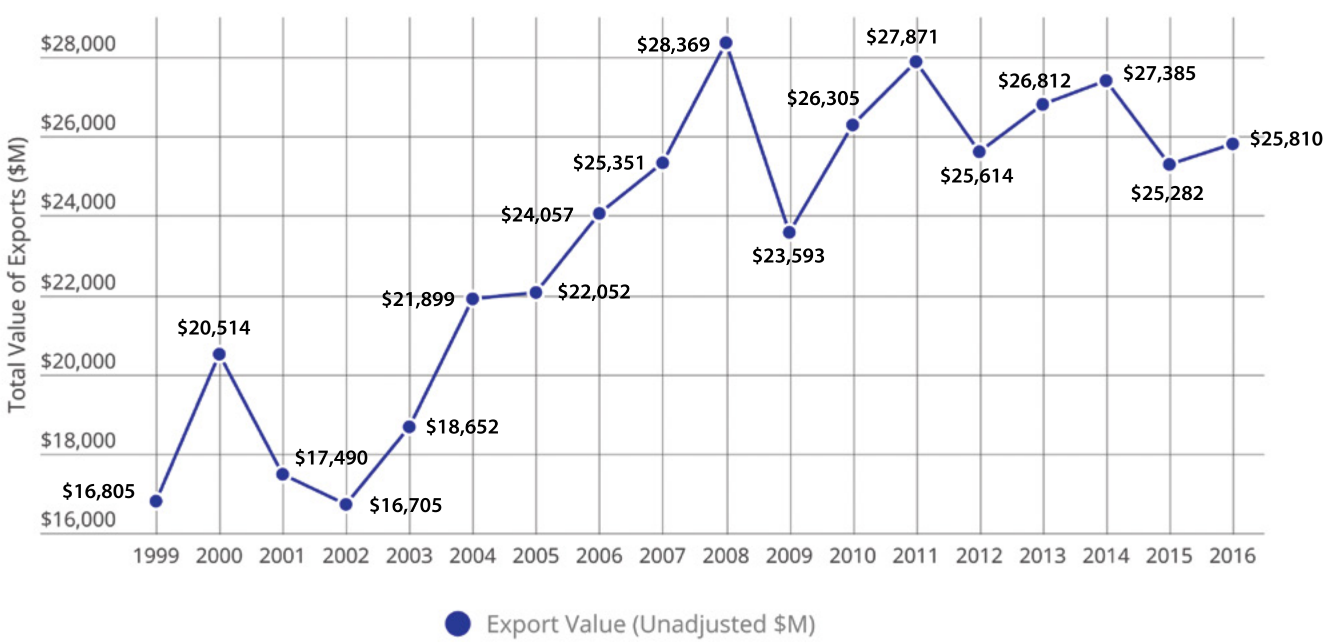
Data Source for Indicator 5: U.S. Census Bureau Foreign Trade Division, Staying Power II Report, xe.com

INDICATOR 5: Exports

Exports as a Percentage (%) of GDP
Massachusetts & LTS, 2011 & 2016

State	2011	2016
Texas	18.7%	14.3%
Ohio	8.8%	7.9%
Illinois	9.5%	7.5%
Wisconsin	8.4%	6.8%
California	7.8%	6.3%
North Carolina	6.3%	5.8%
Minnesota	7.3%	5.7%
Florida	8.8%	5.6%
Connecticut	6.9%	5.5%
New Jersey	7.7%	5.4%
New Hampshire	6.6%	5.3%
New York	6.9%	5.2%
Massachusetts	6.7%	5.1%
Pennsylvania	6.7%	5.0%
Rhode Island	4.6%	4.0%

Total Value of Exports
Massachusetts, 1999-2016
Unadjusted ($)



For additional charts on this indicator visit: masstech.org/index

Data Source for Indicator 5: U.S. Census Bureau Foreign Trade Division, Staying Power II Report, xe.com

Staff from the Woods Hole Oceanographic Institution (WHOI) deploy a REMUS autonomous underwater submersible to test its ability to track oil spills. The REMUS was developed by WHOI's Oceanographic Systems Lab. (Photo by Erin Koenig, WHOI)

Why are these Indicators Significant?

Indicator 6: Research & Development (R&D) - pp. 34-35

R&D performed in Massachusetts is an indicator of the size and health of the science and technology enterprise. Although not all new ideas or products emerge from defined R&D efforts, these data provide a basis for estimating a region's general capacity for knowledge creation. The distribution of R&D expenditures by type of performer illustrates the relationship that states have with the different types of R&D performers and how a differentiated list of performers can help produce an innovative and diverse ecosystem.

Indicator 7: Academic Article Output - p. 36

In contrast to R&D expenditures, which are inputs to research, academic article publication is a measure of research output and can be viewed as a leading indicator of patents and business development. In addition, the ratio of articles produced per dollar spent on research and articles produced per researcher measures the productivity of research activity.

Indicator 8: Utility Patents - p. 37

Patents are the leading form of legal codification and ownership of innovative thinking and its application. A patent award is particularly important for R&D-protecting products resulting from investments in R&D. High levels of patenting activity indicate an active R&D enterprise combined with the capacity to codify and translate research into ideas with commercial potential. U.S. Patent and Trademark Office (USPTO) patents represent one-fifth of global patents. Utility Patents are those for unique and novel inventions that have some practical purpose, as opposed to purely aesthetic Design Patents.

Indicator 9: Technology Patents - p. 38

The amount of patenting per capita by technology category indicates those fields in which Massachusetts' inventors are most active. The results suggest comparative strengths in knowledge creation, which is a vital source of innovation and business creation. The patent categories in this comparison are selected and grouped on the basis of their connection to key industries of the Massachusetts Innovation Economy.

INDICATOR 6: Research and Development

How Does Massachusetts Perform?

Massachusetts had the second highest overall level of R&D funding in the country in 2015 at $28.7B, ahead of Texas ($23.7B). R&D as a percentage of GDP in Massachusetts remained the highest among the LTS, at 5.86% in 2015, the same as 2014. While Massachusetts is the leader in R&D as a percentage of GDP, California still maintains a significant lead in total R&D funding ($125.06B in 2015).

The majority of R&D in 2015 was performed by private industry throughout the LTS. In 2015, 74.95% of R&D expenditures in Massachusetts were performed by private industry; placing Massachusetts eighth in the LTS. Massachusetts ranks fourth among the LTS in terms of R&D performed by universities, colleges, and other non-profit organizations with $5.2B, a 4.49% increase in R&D expenditures from universities and non-profits from 2010-2015. Massachusetts also has the second highest percentage of R&D performed at Federally Funded Research and Development Centers (4.79%) in the LTS, following Illinois.

MASSACHUSETTS & ... RESEARCH & DEVELOPMENT

- **$28.7B in R&D expenditures in 2015, 2nd nationally**
- **First among LTS in R&D expenditures as a % of GDP (5.86%)**
- **Business performs 75% of R&D in Massachusetts**

R&D Spending as a Percentage % of GDP
Massachusetts & LTS, 2010-2015

State	2010	2011	2012	2013	2014	2015
Massachusetts	5.02%	5.67%	5.59%	5.47%	5.86%	5.86%
California	4.12%	4.79%	4.59%	4.73%	4.67%	4.99%
Connecticut	3.17%	3.88%	3.57%	3.70%	3.95%	3.88%
New Hampshire	3.37%	3.90%	3.55%	3.53%	3.34%	3.12%
New Jersey	3.65%	3.18%	3.33%	2.95%	2.71%	2.82%
Rhode Island	2.92%	2.82%	2.50%	2.49%	2.27%	2.54%
Minnesota	2.74%	2.64%	2.47%	2.55%	2.47%	2.45%
North Carolina	2.10%	2.15%	2.07%	2.42%	2.27%	2.36%
Illinois	2.42%	2.38%	2.38%	2.34%	2.06%	2.12%
Pennsylvania	2.19%	2.35%	2.10%	2.30%	2.16%	2.10%
Wisconsin	2.11%	2.21%	2.09%	2.01%	1.89%	2.01%
Ohio	2.01%	2.11%	1.99%	1.98%	1.97%	2.00%
New York	1.42%	1.59%	1.42%	1.39%	1.44%	1.53%
Texas	1.57%	1.56%	1.41%	1.39%	1.42%	1.47%
Florida	1.08%	1.22%	1.08%	1.11%	1.08%	1.06%

For additional charts on this indicator visit: masstech.org/index

Data Source for Indicator 6: National Science Foundation (NSF), BEA, CPI

INDICATOR 6: Research and Development

Total R&D Expenditures
Massachusetts & LTS, 2010 & 2015
Millions of 2015 $

State	2010	2015	% Change 2010-2015
California	$87,958	$125,056	42.18%
Massachusetts	$21,928	$28,665	30.72%
Texas	$21,178	$23,668	11.76%
New York	$18,612	$22,401	20.36%
Illinois	$17,178	$16,502	-3.93%
New Jersey	$19,410	$15,865	-18.27%
Pennsylvania	$14,196	$14,839	4.53%
Ohio	$10,910	$12,233	12.12%
North Carolina	$9,497	$11,823	24.50%
Connecticut	$8,073	$9,918	22.85%
Florida	$8,635	$9,456	9.51%
Minnesota	$8,028	$8,053	0.32%
Wisconsin	$5,805	$6,132	5.64%
New Hampshire	$2,344	$2,333	-0.48%
Rhode Island	$1,563	$1,427	-8.67%

Distribution of R&D by Performer
Massachusetts & LTS, 2015

State	Federal	Federally Funded R&D Centers	Business	Universities and Colleges	Other Nonprofits
CA	1.89%	4.12%	86.35%	6.92%	0.67%
CT	2.52%	0.00%	86.04%	11.00%	0.21%
FL	11.27%	0.00%	61.51%	25.26%	1.48%
IL	1.73%	6.30%	77.02%	14.49%	0.45%
MA	2.20%	4.79%	74.95%	12.82%	5.20%
MN	0.76%	0.00%	84.69%	11.54%	2.98%
NC	2.59%	0.00%	72.50%	23.81%	0.98%
NH	1.67%	0.00%	82.81%	15.35%	0.17%
NJ	3.41%	0.51%	88.96%	6.97%	0.13%
NY	1.00%	2.62%	68.43%	25.45%	1.42%
OH	6.52%	0.00%	73.93%	17.60%	1.95%
PA	4.47%	0.88%	69.78%	22.62%	2.20%
RI	11.56%	0.00%	52.63%	31.74%	3.99%
TX	4.55%	0.05%	73.31%	21.48%	0.61%
WI	0.85%	0.00%	76.26%	22.41%	0.38%

Data Source for Indicator 6: National Science Foundation (NSF), BEA, CPI

INDICATOR 7: Academic Article Output

MASSACHUSETTS & … ACADEMIC ARTICLE OUTPUT

- **20,116 Academic Science & Engineering (S&E) Articles produced in 2013 (3rd nationally)**
- **First nationally and globally in Academic S&E Articles produced per-capita in 2013**

How Does Massachusetts Perform?

Massachusetts maintained a high rate of Science and Engineering (S&E) Academic Article Output relative to its population in 2013, the most recent year for which data are available. In 2013, S&E Academic Article Output climbed to 2,999 academic articles per million residents, three times the U.S. average (975). In 2013, Massachusetts ranked first internationally, outperforming second-place Switzerland by roughly 390 articles per million residents.

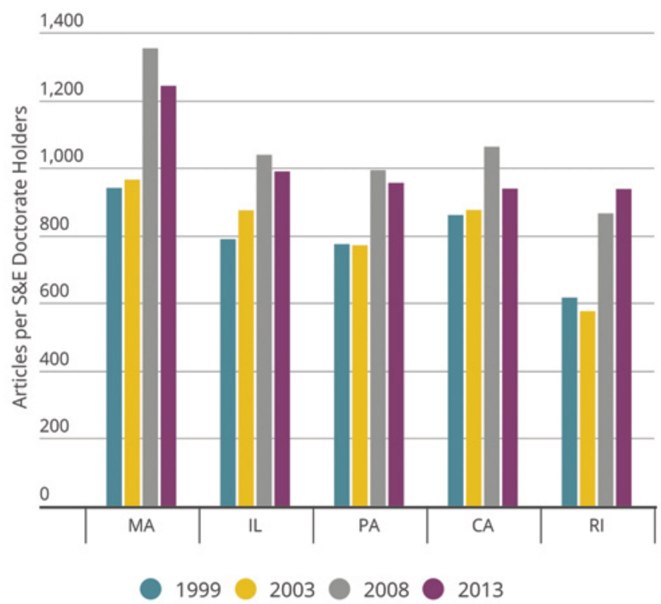
Massachusetts also performs well in terms of academic productivity. It continues to lead the LTS in article output per million dollars of academic R&D funding. In 2004, 2009, and 2013, Massachusetts produced more S&E Academic Articles per R&D dollar than all of the other LTS and the nation overall. In 2013, the state reported 6.0 articles per million academic R&D dollars spent. Massachusetts is also the leader in a second measure of research productivity, articles per 1,000 S&E Doctorate Holders. The median measure of the rest of the LTS (884) is 28.8% lower than Massachusetts' 1,452 figure, followed by Illinois which ranked second at 989.

Articles per researcher and articles per research dollar increased from 2012-2013 in both the U.S. and Massachusetts due to fairly stable academic spending on a national level. National academic funding was $63.4B in 2013, with Massachusetts receiving 5.0% of that spending. Although Massachusetts' population is only 2.1% of the U.S., Massachusetts' Life S&E sectors dominated the share of total U.S. academic R&D spending, together accounting for 21% of the Commonwealth's funding.

Science and Engineering (S&E) Academic Article Output
per Million Residents
Massachusetts, International and LTS above U.S. Average, 2013

	S&E Article Output per million residents
Massachusetts	2,999
Switzerland	2,603
Denmark	2,223
Australia	2,068
Sweden	2,017
Singapore	1,974
Norway	1,940
Finland	1,867
Netherlands	1,810
Canada	1,644
New Zealand	1,631
Rhode Island	1,602
Connecticut	1,357
Pennsylvania	1,262
New York	1,142
North Carolina	1,021
U.S. Average	975

Science and Engineering (S&E) Academic Article Output
per 1,000 S&E Doctorate Holders
Massachusetts & Top 5 LTS, 1999, 2003, 2008, 2013



	1999	2003	2008	2013
MA	940	965	1,353	1,242
IL	789	874	1,038	989
PA	774	771	993	955
CA	860	875	1,062	938
RI	616	576	865	937

Data Source for Indicator 7: NSF, CPI

INDICATOR 8: Utility Patents

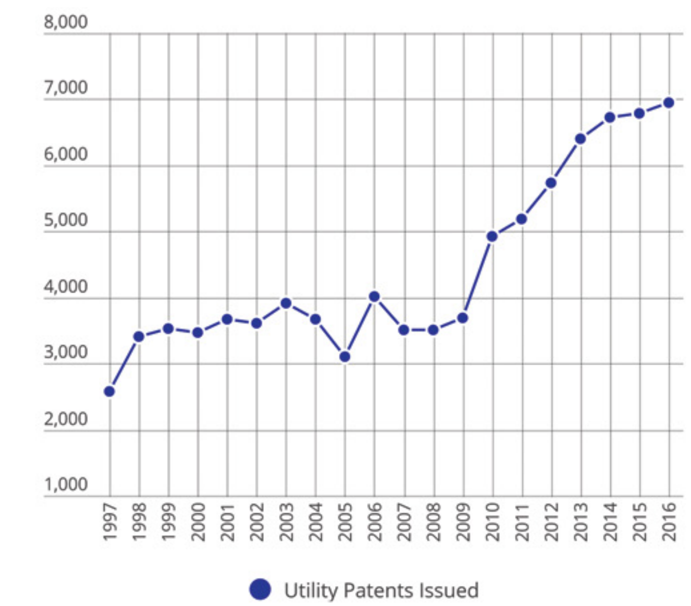
How Does Massachusetts Perform?

In 2016, Massachusetts again saw record numbers of utility patents granted, reaching a total of 6,946. Its share of U.S. utility patents was 4.8%, evidence that Massachusetts is a key state for translating research into products meant for commercialization. Massachusetts' growth rate in patents granted per million residents from 2011-2016 was 29.9%, placing it third among the LTS after California at 39.2% and Illinois at 31.0%. **Massachusetts ranks fourth among the LTS in total number of utility patents granted**, behind California, Texas and New York. It is **second only to California in utility patents granted per million residents, when compared to all 50 states**.

MASSACHUSETTS & ... UTILITY PATENTS

- **6,946 utility patents granted in 2016, a new high**
- **4th among LTS in utility patents granted**
- **2nd among LTS in utility patents granted per capita nationally**

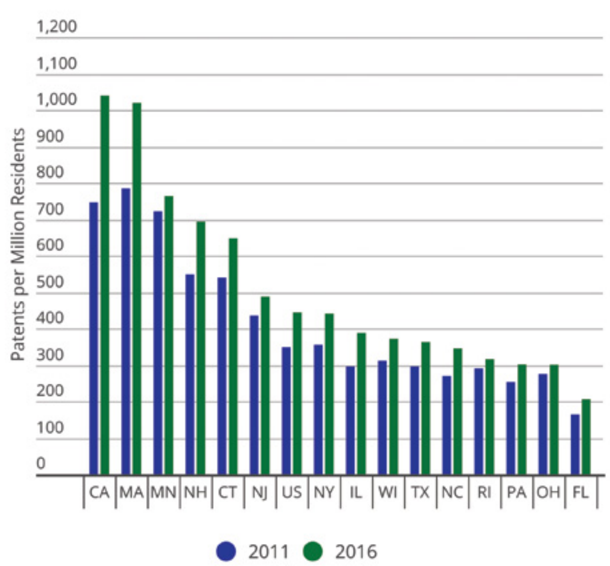
Utility Patents Issued
Massachusetts, 1997-2016



Year	Utility Patents Issued
1997	2,575
1998	3,413
1999	3,523
2000	3,463
2001	3,667
2002	3,608
2003	3,908
2004	3,672
2005	3,114
2006	4,011
2007	3,510
2008	3,516
2009	3,696
2010	4,923
2011	5,191
2012	5,734
2013	6,409
2014	6,725
2015	6,777
2016	6,946

Utility Patents per Million Residents
Massachusetts, LTS & U.S., 2011 & 2016

For additional charts on this indicator visit: masstech.org/index



State	2011	2016
CA	747	1,040
MA	785	1,020
MN	722	764
NH	549	694
CT	540	648
NJ	436	488
U.S. Average	349	445
NY	356	441
IL	296	388
WI	312	372
TX	296	363
NC	270	346
RI	291	316
PA	253	302
OH	275	301
FL	164	206

Data Source for Indicator 8: U.S. Patent and Trademark Office (USPTO), Census Bureau, World Intellectual Property Organization, U.S. Department of Commerce, World Bank

INDICATOR 9: Technology Patents

MASSACHUSETTS & ... TECHNOLOGY PATENTS

- **4,542 Tech Patents in 2015 (4th nationally)**
- **2nd nationally in Tech Patents per capita**
- **1st among LTS in Drugs and Medical Patents per capita**

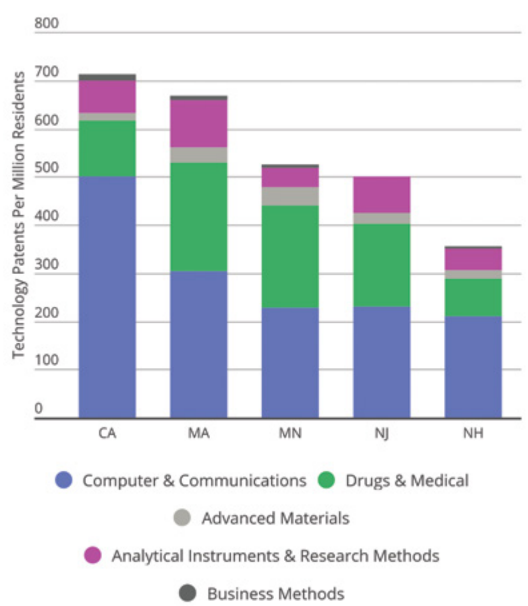
How Does Massachusetts Perform?

As of 2015, Massachusetts was the per-capita leader in two of the five technology patent categories tracked by the *Index*. It placed second among the LTS in the other three. The combination of Computer & Communications patents and Drugs & Medical patents accounted for 79.2% of all Massachusetts technology patents in 2015, with 303 and 227 patents per million residents respectively. California maintained its lead in Computer & Communication Patents (500 per million residents) and Massachusetts overtook Minnesota (212 per million residents) to lead the LTS in Drugs and Medical patents. Massachusetts ranked first in Analytical Instrument & Research Method patents for the sixth year in a row with 100 per million residents, approximately 50% more than California, the next highest state. Massachusetts' Business Method patents continued to fall in 2015, yet still ranked second among the LTS, trailing only California, where these patents also fell. Massachusetts' Advanced Materials patents increased from 26 to 30 per million state residents and ranked second among the LTS in this category. Technology patents have continued to steadily increase in the Commonwealth over the last decade and since 2005 have represented 62.9% of all patents issued in Massachusetts.

Technology Patents by Category
Massachusetts, 2015

Category	Percent of Patents	# of Patents
Computer & Communications	45.3%	2,056
Drugs & Medical	33.9%	1,540
Analytical Instruments & Research Methods	15.0%	681
Advanced Materials	4.4%	201
Business Methods	1.4%	64

Technology Patents
per Million Residents by Field
Massachusetts & Top 5 LTS, 2015



	Computer & Communications	Drugs & Medical	Advanced Materials	Analytical Instruments & Research Methods	Business Methods
CA	500	116	17	66	14
MA	303	227	30	100	9
MN	228	212	38	41	7
NJ	230	172	22	76	0
NH	209	80	18	44	5

For additional charts on this indicator visit: masstech.org/index

Data Source for Indicator 9: USPTO, Census Bureau

Why are these Indicators Significant?

Indicator 10: Technology Licensing - p. 40

Technology licenses provide a vehicle for the transfer of codified knowledge in the form of intellectual property (IP) from universities, hospitals, and non-profit research organizations to companies and entrepreneurs seeking to commercialize the technology. License royalties are evidence of the value of IP in the marketplace and are typically based on revenue generated from the sales of products and services using the licensed IP or from the achievement of milestones on the path to commercialization. Increases in royalty revenue totals are important, validating the original research and innovation, and generating funds that can be reinvested in new or follow-on R&D.

Indicator 11: SBIR/STTR - p. 41

The Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) Programs are highly competitive federal grant programs that enable small companies to conduct proof-of-concept (Phase I) research on technical merit and idea feasibility and prototype development (Phase II) that builds on Phase I findings. Unlike many other federal research grants and contracts, SBIR and STTR grants are reserved for applicant teams led by for-profit companies with fewer than 500 employees. Participants in the SBIR and STTR program are often able to use the credibility and experimental data developed through their research to design commercial products and to attract strategic partners and investment capital.

INDICATOR 10: Technology Licensing

How Does Massachusetts Perform?

Massachusetts has the fourth highest number of technology licenses and options executed in 2016, following California, New York, and Florida. Massachusetts was the leader in this category in 2014. LTS newcomer Florida had a significant percentage increase in technology licensing from 2006 (298%) and 2011 (133%) rising from what would have been 10th in the current LTS in 2006 to 3rd in 2016.

MASSACHUSETTS & ...
TECHNOLOGY LICENSING

- **513 Technology Licenses/Options Executed in 2016 (4th in LTS)**
- **$244M in Licensing Revenue in 2016**

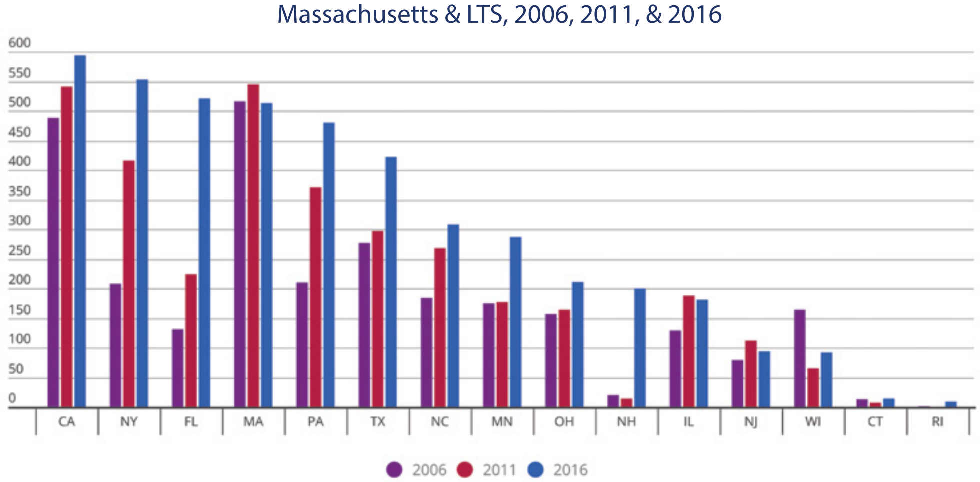
There has been a shift among the types of institutions in Massachusetts that comprise a majority of licenses and options executed from Universities to Research Institutions and Hospitals. From 2006-2016, licenses granted to Research Institutions and Hospitals decreased by 10% whereas for Universities they increased by 10%. Massachusetts Universities accounted for 53.8% of the technology licenses and options executed within the state in 2016. Licensing revenues to Research Institutions and Hospitals spiked in 2006-2007 due to a legal settlement in favor of Massachusetts General Hospital, accounting for much of the 70% decline from 2006-2016. However, licensing revenues are down from their post-2008 peaks for both Universities (2012, -47%) and Research Institutions/Hospitals (2011, -12%).

For additional charts on this indicator visit: masstech.org/index

Technology Licenses and Options Executed
Research Institutions, Hospitals & Universities
Massachusetts, 2006-2016

Year	Research Institutions & Hospitals	Universities
2006	264	252
2007	245	282
2008	242	234
2009	303	238
2010	286	228
2011	294	251
2012	376	248
2013	264	237
2014	292	254
2015	272	276
2016	237	276

Technology Licenses and Options Executed
Massachusetts & LTS, 2006, 2011, & 2016



	CA	NY	FL	MA	PA	TX	NC	MN	OH	NH	IL	NJ	WI	CT	RI
2006	488	208	131	516	210	277	184	175	157	20	129	79	164	13	1
2011	541	416	224	545	371	297	268	177	164	14	188	112	65	7	0
2016	594	553	521	513	480	422	308	287	211	200	181	94	92	14	9

Data Source for Indicator 10: Association of University Technology Managers (AUTM), CPI

INDICATOR 11: SBIR/STTR

How Does Massachusetts Perform?

There was a slight decline in the number of Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) awards in Massachusetts from 2015 to 2016, decreasing from 584 to 484 in 2016. SBIR and STTR award funding in the state also decreased from 2015 to 2016 by $19.4 million. The decline in awards since 2010, when they peaked following the Great Recession, was steep and Massachusetts received $108M in 2016, less than it did in 2010 ($353M). This reflects an overall trend in award funding nationally, which fell from $2.59 billion in 2010 to $1.95 billion in 2016, a $645 million decline. **Massachusetts is first in SBIR/STTR Award funding per $1M GDP among the LTS and ranks second in total funding amount, behind California**. Among the SBIR and STTR awards in Massachusetts in 2016, the Department of Health and Human Services accounted for the most funding (48%) while the Department of Defense accounted for the largest number of awards (225).

MASSACHUSETTS & ... SBIR/STTR

- **$245M in 2016 SBIR/STTR funding**
- **2nd in total funding among LTS**
- **1st in SBIR/STTR funding as a % of GDP**

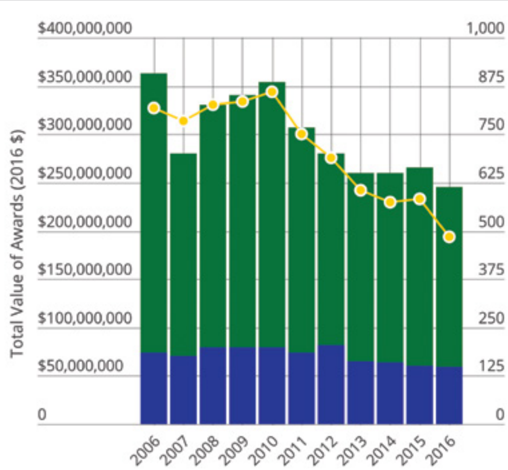
SBIR/STTR Awards Funding
Massachusetts & LTS, 2016

State	Total Funding Amount	Award Funding per $1 Million GDP
Massachusetts	$245,116,806	$482.60
New Hampshire	$30,412,848	$390.63
California	$479,513,404	$184.24
Pennsylvania	$99,523,099	$137.29
Rhode Island	$7,500,264	$130.59
Connecticut	$33,703,927	$127.97
North Carolina	$63,234,935	$122.10
Minnesota	$35,075,089	$104.66
Ohio	$63,353,201	$101.25
New Jersey	$49,311,488	$84.86
Illinois	$56,610,414	$71.51
New York	$96,279,732	$64.70
Texas	$101,577,122	$62.83
Wisconsin	$17,004,481	$54.94
Florida	$48,997,726	$52.87

SBIR & STTR Awards by Agency
Massachusetts, 2016

Agency	Funding	# of Awards
Health and Human Services	$116,690,598	166
Department of Defense	$69,858,099	225
Department of Energy	$21,103,836	52
National Aeronautics and Space Administration	$14,205,403	73
National Science Foundation	$13,576,038	38

SBIR & STTR Awards
Total Number of Awards and Value (by Phase) of Awards Granted
Massachusetts, 2006-2016



Year	Phase I Dollars	Phase II Dollars	Total Awards
2006	$74,251,208	$288,351,839	818
2007	$70,504,545	$209,958,696	785
2008	$79,064,788	$251,800,297	827
2009	$79,327,425	$260,902,267	834
2010	$79,718,769	$274,139,502	859
2011	$73,889,281	$233,533,507	752
2012	$81,978,180	$197,870,513	688
2013	$64,484,954	$195,155,351	604
2014	$63,393,799	$196,652,077	573
2015	$59,954,175	$205,277,236	584
2016	$59,286,477	$185,830,328	484

Data Source for Indicator 11: U.S. Small Business Administration, CPI

Why are these Indicators Significant?

Indicator 12: Business Formation - p. 43

New business formation is a key source of job creation and cluster growth, typically accounting for 30 to 45 percent of all new jobs in the U.S. It is also important to the development and commercialization of new technologies. The number of 'spin-out' companies from universities, teaching hospitals, and non-profit research institutes (including out-licensing of patents and technology) is an indicator of the overall volume of activity dedicated to the translation of research outcomes into commercial applications.

Indicator 13: IPO and M&A - p. 44

Initial Public Offerings (IPOs) and Mergers and Acquisitions (M&As) represent important business outcomes with which emerging companies can access capital, expand operations, and support business growth. IPOs and M&As are opportunities for early-stage investors to liquidate their investments and free up capital for future investment. IPOs of venture-backed companies can reflect investor confidence in the market. Overall figures are relatively low so it is expected that year-over-year figures will fluctuate, which is why it is important to review trends over multiple years.

INDICATOR 12: Business Formation

How Does Massachusetts Perform?

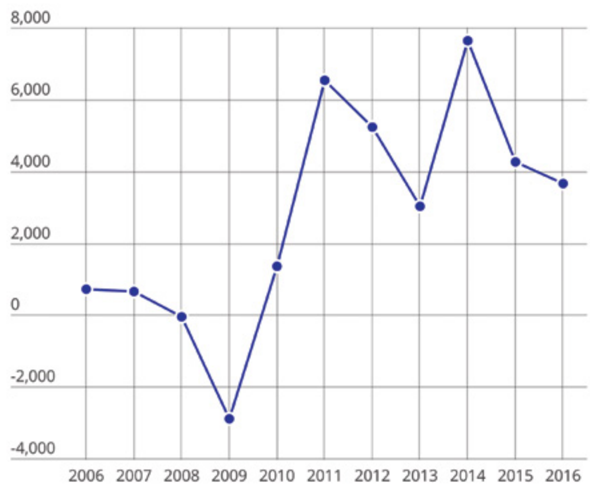
In 2016 Massachusetts experienced its 7th consecutive year of business establishment growth, with a net gain of 3,653 establishments. While close to the average annual gain over this period (+4,525 establishments), it represents a 52% decline from the peak of 7,630 net new establishments in 2014.

In 2016, start-up formation from universities, hospitals, research institutions, and technology investment firms in Massachusetts increased to 75. From 2011-2016, Massachusetts has averaged 67 start-ups initiated per year from universities, hospitals, research institutions, and technology investment firms. Of the LTS, only New York and California lead Massachusetts in start-up formation. New York rapidly increased at a 41.0% rate from 2014-2016, climbing to second in the LTS. Both Texas and Pennsylvania worsened in this category by 7.8% and 3.4% respectively, from 2015-2016.

MASSACHUSETTS & … BUSINESS FORMATION

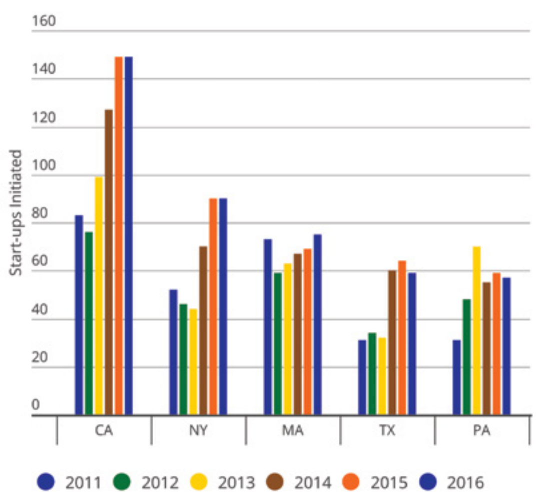
- **Net gain of 3,653 Business Establishments in 2016**
- **75 Start-ups Initiated from Universities, Hospitals, Research Institutions and Technology Licensing Firms in 2016 (3rd in LTS)**

Net Change in Number of Business Establishments
Massachusetts, 2006 -2016



Year	Net Change in Number of Business Establishments
2006	725
2007	639
2008	-47
2009	-2,909
2010	1,363
2011	6,538
2012	5,213
2013	3,033
2014	7,630
2015	4,248
2016	3,653

Start-up Companies Initiated
From Universities, Hospitals, Research Institutions, and Technology Investment Firms
Massachusetts & Top 4 LTS, 2011-2016



State	2011	2012	2013	2014	2015	2016
CA	83	76	99	127	149	149
NY	52	46	44	70	90	90
MA	73	59	63	67	69	75
TX	31	34	32	60	64	59
PA	31	48	70	55	59	57

Data Source for Indicator 12: BLS Business Employment Dynamics, QCEW, Census Bureau, AUTM, 2010 Kauffman Index of Entrepreneurial Activity

INDICATOR 13: Initial Public Offerings (IPO) & Mergers and Acquisitions (M&A)

How Does Massachusetts Perform?

California, Texas, New York, and Massachusetts are traditionally major generators of IPOs due to their focus on advanced technology cluster development and large economies. Massachusetts recorded twice as many IPOs in 2017 (18) as in 2012 (9).

Massachusetts IPOs were dominated by biotech and pharmaceutical companies in 2017, of which there were eleven. The average dollar amount raised in the IPO of these companies in Massachusetts in 2017 was $134.6M. For 10 of the LTS, the number of M&As decreased from 2016 to 2017. However, there was a 61% increase in the number of companies acquiring others and a 81% increase in the number of companies being acquired in Massachusetts from 2012 to 2017.

MASSACHUSETTS & ... IPO AND M&A

- **18 IPO's in 2017**
- **Average amount raised: $134.6M**
- **168 Massachusetts companies acquired in 2017 (3rd in LTS)**
- **171 Massachusetts companies acquired another company in 2017 (4th in LTS)**

Number of Initial Public Offerings (IPO)
Massachusetts & LTS, 2012-2017

State	2012	2013	2014	2015	2016	2017
CA	33	44	57	45	30	41
CT	2	1	9	3	6	2
Fl	4	6	4	9	2	6
IL	3	9	3	4	5	2
MA	9	13	23	18	12	20
MN	2	1	0	1	1	4
NC	1	5	5	2	6	5
NJ	4	11	9	8	3	3
NY	4	15	12	26	21	26
OH	2	0	3	2	3	1
PA	5	8	11	9	7	8
TX	19	24	22	24	27	30
WI	2	1	0	2	7	1

Number of Companies Being Acquired
Massachusetts & LTS, 2012-2017

No. of Companies being Acquired by State	2012	2013	2014	2015	2016	2017	2012-2017 Growth Rate
CA	379	427	536	534	721	651	72%
TX	83	73	93	109	169	190	129%
MA	93	69	132	101	176	168	81%
NY	95	93	106	112	179	143	51%
FL	39	53	65	67	117	134	244%
IL	48	41	65	73	101	96	100%
PA	27	48	43	67	99	94	248%
NJ	23	43	41	53	78	76	230%
OH	21	26	32	35	67	67	219%
MN	16	19	26	24	61	63	294%
NC	17	23	41	45	57	55	224%
CT	9	13	25	21	34	36	300%
WI	4	11	22	14	40	36	800%
NH	6	5	5	7	17	17	183%
RI	3	1	6	3	7	4	33%

Number of Companies Acquiring Others
Massachusetts & LTS, 2012-2017

No. of Companies Acquiring Others by State	2012	2013	2014	2015	2016	2017	2012-2017 Growth Rate
CA	401	484	542	503	698	648	62%
NY	117	110	181	189	310	301	157%
TX	92	81	118	109	182	204	122%
MA	106	79	127	120	170	171	61%
IL	80	78	117	129	183	157	96%
FL	39	44	71	95	120	120	208%
NJ	45	36	73	58	114	108	140%
PA	32	41	63	43	115	105	228%
OH	21	34	33	32	70	88	319%
MN	15	29	37	40	62	67	347%
NC	24	15	32	26	46	52	117%
CT	19	26	35	52	69	49	158%
WI	9	14	13	13	48	43	378%
RI	2	5	7	6	12	7	250%
NH	6	6	13	5	9	5	-17%

Data Source for Indicator 13: Renaissance Capital, IPO Home, National Venture Capital Association (NVCA), Ipomonitor.com, Crunchbase.com

Why are these Indicators Significant?

Indicator 14: Federal Funding for Academic & Health R&D - pp. 46-47

Universities and other non-profit research institutions are critical to the Massachusetts Innovation Economy. They advance basic science and create technologies and know-how that can be commercialized by the private sector. This R&D also contributes to educating the highly-skilled individuals that make up one of Massachusetts' greatest economic assets. The National Institutes of Health (NIH) is the federal government's main source of funding for medical research. Awards from the NIH help fund the Commonwealth's biotechnology, medical device, and health services industries which together comprise the Life Sciences cluster.

Indicator 15: Industry Funding of Academic Research - pp. 48-49

Industry funding of academic research is one measure of industry-university relationships and the ability to transfer academic research into the commercial market. Industry-university research partnerships may result in advances in technology industries by promoting basic research that may have commercial applications. Moreover, university research occurring in projects funded by industry helps educate individuals in areas directly relevant to industry needs.

Indicator 16: Venture Capital - pp. 50-51

Venture capital (VC) firms are an important source of funds for the creation and development of innovative new companies. VC firms also typically provide valuable guidance on strategy as well as oversight and governance. Trends in venture investment can indicate emerging growth and recruiting opportunities in the Innovation Economy. Empirical research suggests that the amount of VC in a region has a positive effect on economic growth.

INDICATOR 14: Federal Funding for Academic and Health R&D

How Does Massachusetts Perform?

Due to federal budget cuts, **federal funding for academic R&D declined in all the LTS in 2015**, with every state falling below its 2010 level. Massachusetts **remains second among the LTS in federal R&D funding awarded to universities and non-profit institutions**. Massachusetts received $3.1B in federal R&D funding in 2015, roughly 1/3rd less than California's total ($4.7B), an impressive statistic considering the Commonwealth's population, which is 1/6th that of the Golden State.

Massachusetts continues to maintain a lead in federal funding for Academic R&D per $1,000 GDP at $7.07. This is almost twice as much as second ranked Rhode Island, which also benefits from a large concentration of research hospitals and medical schools as well as a small population base. Despite leading the LTS, Massachusetts has suffered a 29% decrease in federal funding for Academic R&D per $1,000 GDP since 2010.

Of the 52,470 awards from the National Institute of Health (NIH) in the U.S. in 2016, Massachusetts accounts for 5,029 or 9.6%. Massachusetts also had a 10.5% share of NIH funding in 2015. Eleven Massachusetts research organizations attracted more than $100M in NIH funding in 2016, combining for 3,637 awards and over $1.4B in NIH funding. Boston and Cambridge together combined for a total of 2,855 awards and more than $1.9B in NIH funding in 2015 due to the high density of hospitals, universities, and pharmaceutical companies in these cities.

MASSACHUSETTS & ... FEDERAL FUNDING FOR ACADEMIC & HEALTH R&D

- **$3.1B in federal funding for academic R&D in 2015, 2nd nationally**
- **Also 2nd in NIH funding in 2016, with $2.6B**
- **11 Research Organizations received more than $100M in NIH funding in 2016**

Massachusetts continues to attract the largest share of NIH funding per $1 million GDP among the LTS and nationally. Massachusetts' amount of NIH funding per $1M GDP ($5,065) is unparalleled in the LTS, reaching more than 3 times the median share for the LTS. Massachusetts received the second highest number of NIH awards (5,029 in 2016) following only California (7,720). In terms of the absolute amount of NIH funding, Massachusetts ranked second ($2.5B) to California ($3.7B). Per million dollars of GDP, however, Massachusetts ranks first ($378) ahead of second place Connecticut ($143).

Federal Funding for R&D
Universities, Colleges and Non-Profit Organizations
Massachusetts & LTS, 2005, 2010, 2015

	Absolute Funding (Millions $)			Funding per $1000 GDP		
State	2005	2010	2015	2005	2010	2015
California	$5,374	$6,119	$4,664	$2.81	$3.16	$2.09
Connecticut	$680	$774	$526	$2.94	$3.33	$2.30
Florida	$1,013	$1,008	$837	$1.31	$1.38	$1.06
Illinois	$1,247	$1,439	$1,161	$1.93	$2.23	$1.69
Massachusetts	$3,219	$3,950	$3,095	$8.55	$9.89	$7.07
Minnesota	$601	$775	$620	$2.25	$2.91	$2.12
New Hampshire	$176	$165	$148	$2.80	$2.59	$2.21
New Jersey	$541	$575	$421	$1.10	$1.19	$0.84
New York	$2,849	$3,226	$2,532	$2.54	$2.71	$2.00
North Carolina	$1,351	$1,605	$1,339	$3.44	$3.89	$3.03
Ohio	$1,440	$1,223	$943	$2.81	$2.48	$1.73
Pennsylvania	$2,409	$2,448	$1,985	$4.30	$4.15	$3.08
Rhode Island	$489	$272	$206	$9.71	$5.57	$4.15
Texas	$1,830	$2,001	$1,551	$1.75	$1.67	$1.04
Wisconsin	$621	$702	$568	$2.48	$2.80	$2.10
United States	$38,243	$41,267	$32,991	$2.69	$2.82	$2.05

Data Source for Indicator 14: NSF, BEA, National Institutes of Health (NIH), Census Bureau

INDICATOR 14: Federal Funding for Academic and Health R&D

National Institutes of Health (NIH) R&D Funding
per $1 million GDP
Massachusetts & LTS, 2016

NIH R&D Funding by State	Number of Awards	Absolute Funding (Millions $)	Funding per $1 Million GDP
Massachusetts	5,029	$2,573	$5,064.94
Rhode Island	443	$151	$2,626.26
North Carolina	2,221	$1,154	$2,228.88
Pennsylvania	3,464	$1,570	$2,165.92
Connecticut	1,179	$511	$1,938.69
Minnesota	1,029	$520	$1,552.23
New York	4,953	$2,206	$1,482.50
California	7,720	$3,686	$1,416.25
Wisconsin	902	$422	$1,362.61
New Hampshire	211	$99	$1,269.77
Ohio	1,694	$734	$1,173.31
Illinois	1,995	$818	$1,033.38
Texas	2,633	$1,098	$678.91
Florida	1,196	$532	$573.71
New Jersey	571	$240	$413.23
United States	52,470	$24,593	$1,332.48

Massachusetts Research Organizations Receiving $100M+ in NIH Funding
2016

Organization	Awards	Funding
Massachusetts General Hospital	796	$364,981,379
Brigham And Women's Hospital	570	$349,521,979
Harvard Medical School	373	$195,160,545
University Of Mass Medical School Worcester	344	$153,892,824
Children's Hospital Corporation	331	$147,762,034
Boston University Medical Campus	254	$135,953,012
Beth Israel Deaconess Medical Center	256	$132,229,333
Dana-Farber Cancer Institute	217	$128,050,993
Harvard School Of Public Health	183	$123,090,691
Massachusetts Institute Of Technology	243	$107,764,386
Broad Institute, Inc.	70	$101,382,185

Data Source for Indicator 14: NSF, BEA, National Institutes of Health (NIH), Census Bureau

INDICATOR 15: Industry Funding for Academic Research

How Does Massachusetts Perform?

After a decline in 2010, industry funding for academic research and development in science and engineering (S&E) in Massachusetts recovered, reaching $224M in 2015, a $3M increase over 2010. Over the last five years, Massachusetts' share of the U.S. total has remained relatively steady, averaging 5.9% a year. Massachusetts' share of the U.S. total in 2015 was 5.75%.

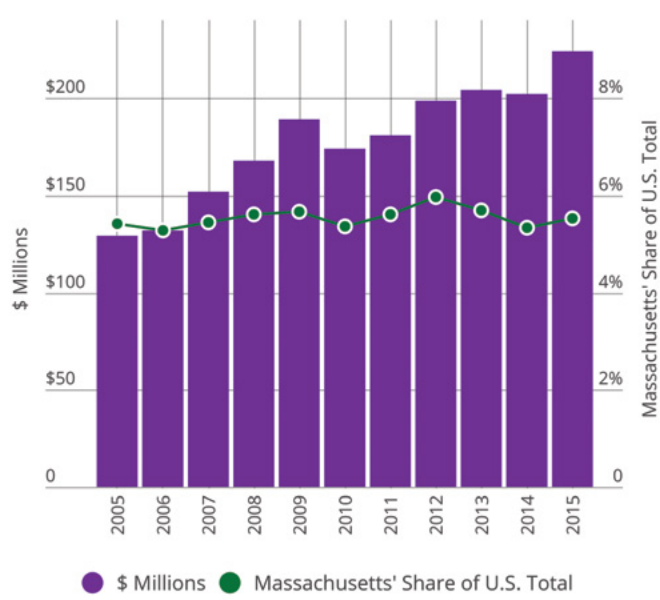
Since 2013, the majority of the LTS have experienced considerable growth in industry funded academic research in S&E as a percentage of GDP, beginning to reverse the decline that began in 2009. Eight LTS experienced a growth rate above 24%. In 2015, Massachusetts experienced an increase of $22M of Industry Funded academic research from the previous year. North Carolina leads the LTS in industry funding for academic research in S&E per $100,000 GDP with $67.50, followed by Massachusetts in second ($54.50). The remaining LTS are substantially behind the two leaders. In 2015, industry funding as a share of total academic S&E research funding increased to 7.2% in Massachusetts, an increase from 2014 (6.8%). North Carolina was the leader in 2015 at 11.98%, followed by Ohio (8.60%), and New York (7.59%).

MASSACHUSETTS & ...
INDUSTRY FUNDING FOR ACADEMIC RESEARCH

- **$227M in 2015 Industry Funding for Academic Science & Engineering Research (5th nationally)**
- **Second highest level of Industry Funding for Academic and Science Research as a % of GDP**

Industry funding for academic research in S&E for each of the LTS is relatively small compared with the total research enterprise in each state thus funding amount percentages can change dramatically from year to year.

Industry Funding for Academic Research in Science & Engineering
Massachusetts, 2005-2015



Year	$ Millions	Massachusetts' Share of U.S. Total
2005	$129	5.64%
2006	$132	5.49%
2007	$152	5.68%
2008	$168	5.84%
2009	$189	5.90%
2010	$174	5.59%
2011	$181	5.85%
2012	$199	6.23%
2013	$204	5.93%
2014	$202	5.57%
2015	$224	5.75%

Data Source for Indicator 15: NSF, BLS, Census Bureau

INDICATOR 15: Industry Funding for Academic Research

Industry Share of States' Total Academic R&D Funding in Science & Engineering
Massachusetts & LTS, 2015

State	Share
North Carolina	11.98%
Ohio	8.60%
New York	7.59%
Massachusetts	7.24%
Texas	6.93%
California	6.40%
Pennsylvania	5.86%
Illinois	5.43%
Florida	5.11%
Connecticut	4.95%
New Hampshire	4.24%
New Jersey	3.44%
Wisconsin	2.93%
Minnesota	2.84%
Rhode Island	1.39%

Amount in 2015 and Growth Rate in Industry Funding for Academic Research in Science & Engineering per $100,000 GDP
Massachusetts & LTS, 2010-2015

State	2015	Growth Rate 2010-2015
North Carolina	$67.50	4.35%
Massachusetts	$54.50	43.84%
Ohio	$30.49	11.60%
New York	$29.92	64.15%
Pennsylvania	$27.75	24.82%
California	$22.24	12.64%
Texas	$21.85	34.28%
Connecticut	$21.06	88.11%
New Hampshire	$20.45	-19.01%
Illinois	$16.82	61.71%
Florida	$13.81	51.94%
Wisconsin	$13.37	55.50%
Rhode Island	$11.35	5.69%
Minnesota	$8.07	-12.29%
New Jersey	$6.74	-7.12%

Data Source for Indicator 15: NSF, BLS, Census Bureau

INDICATOR 16: Venture Capital (VC)

How Does Massachusetts Perform?

Massachusetts' average share of annual U.S. VC investment from 2006 to 2016 was 10.18%, ranging from around 8% to 12% annually. The Commonwealth's VC investment increased to 9.89% of the U.S. total in 2016. California continued to be the number one destination for VC investment despite an 18% decrease from 2015-2016. The largest gain from 2015-2016 was in Rhode Island, which experienced a 75% increase in VC investment, from $12M to $21M. The Commonwealth continued to trail California in VC funding as a share of GDP, despite funding increasing from $12.16 to $12.20 per $1,000 GDP in 2016.

Healthcare and Internet were by far the largest target industries for VC funding in Massachusetts in 2016, representing 56.9% and 19.8% respectively, of total VC funding for the state. This reflects the Commonwealth's strengths in these sectors as well as their broader appeal to investors. Although Venture Capital Investments in Massachusetts dropped by 7% ($6.7B to $6.2B) from 2015-2016, investment levels in the biopharmaceutical and biotech sector in Massachusetts continue to increase. Venture investment in biopharma companies in the state rose to $2.9B in 2016, a significant increase from the previous year.[1] Massachusetts is also home to 7 "unicorn" companies (private companies with valuations above $1B) with 7 additional national unicorns companies having a presence in Boston.[2]

Seed funding from VC firms in Massachusetts has increased by $175M from 2006 to 2016, rising to $200M. Early stage financing increased by $52M from 2015. Expansion financing increased by 73% from 2006 to 2016, the lowest percentage increase compared to other stages of financing. From 2015 to 2016, expansion financing dropped to $1.989B, a drop of $750M from 2015. Late stage financing is the largest category of VC funding in the state and has grown 268% since 2006. Apart from expansion financing by VC firms, VC investment at every stage peaked in 2016.

MASSACHUSETTS & ... VENTURE CAPITAL

- **$6.2 billion in VC investment in 2016 (3rd nationally)**
- **VC funding dropped 7% over 2015**
- **Trailed only California ($34.6B) and New York ($7.5B)**
- **Healthcare ($3.5B) & Internet ($1.2B) were largest VC targets**
- **Home to 7 'unicorn' companies (over $1B valuation)**
- **Seed funding has nearly doubled over last decade, rising to $200M**

[1] Telegram, 2017
[2] AmericanInno, 2017

VC Investment by Sector
Massachusetts
Millions of 2016 $

Sector	VC Investment (Millions of 2016 $)
Healthcare	$3,527
Internet	$1,228
Mobile & Telecommunications	$557
Computer Hardware & Services	$290
Software (non-internet/mobile)	$203
Industrial	$106
Consumer Products & Services	$92
Energy & Utilities	$79
Electronics	$50
Other	$42
Leisure	$17
Food & Beverages	$8

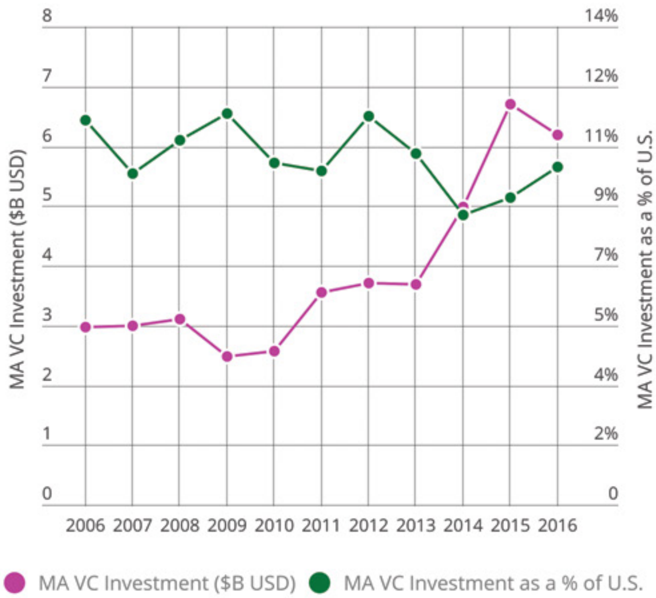
Venture Capital Investment
Massachusetts & LTS, 2011-2016
Millions of 2016 $

State	2016 $	2015-2016 % Change	2011-2016 % Change	2016 VC Investment per $1000 GDP
CA	$34,558	-18%	73%	$13.28
NY	$7,642	2%	155%	$5.14
MA	$6,199	-7%	64%	$12.20
TX	$1,398	-30%	-23%	$0.86
FL	$1,206	38%	254%	$1.30
IL	$1,103	-2%	-11%	$1.39
PA	$693	-19%	22%	$0.96
NC	$605	-32%	113%	$1.17
NJ	$539	-56%	-14%	$0.93
MN	$341	-14%	-7%	$1.02
OH	$254	-36%	47%	$0.41
CT	$193	-44%	-38%	$0.73
WI	$112	-7%	35%	$0.36
NH	$50	-52%	-45%	$0.64
RI	$21	75%	-40%	$0.37

Data Source for Indicator 16: Kauffman Foundation, PricewaterhouseCoopers MoneyTree Report, CPI, BEA, NVCA

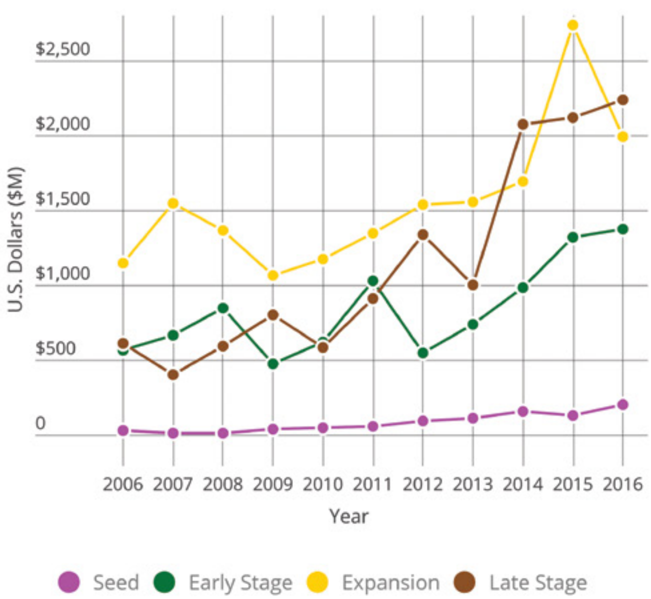
INDICATOR 16: Venture Capital

VC Investment
Total ($ Billions) & as % of U.S.
Massachusetts, 2006-2016



Year	MA VC Investment ($B USD)	MA VC Investment as a % of U.S.
2006	$2.97	11.26%
2007	$3.00	9.68%
2008	$3.11	10.68%
2009	$2.47	11.47%
2010	$2.58	10.02%
2011	$3.55	9.79%
2012	$3.72	11.38%
2013	$3.69	10.27%
2014	$4.99	8.50%
2015	$6.70	9.01%
2016	$6.20	9.89%

VC Investment by Stage
Massachusetts, 2006-2016



Year	Seed	Early Stage	Expansion	Late Stage
2006	$25	$563	$1,148	$608
2007	$11	$661	$1,548	$403
2008	$6	$844	$1,364	$589
2009	$34	$476	$1,064	$798
2010	$42	$614	$1,172	$583
2011	$59	$1,031	$1,349	$909
2012	$95	$549	$1,533	$1,332
2013	$110	$740	$1,559	$1,000
2014	$153	$983	$1,687	$2,074
2015	$126	$1,322	$2,739	$2,116
2016	$200	$1,374	$1,989	$2,239

Data Source for Indicator 16: Kauffman Foundation, PricewaterhouseCoopers MoneyTree Report, CPI, BEA, NVCA

TALENT - Indicators 17-22

Why are these Indicators Significant?

Indicator 17: Educational Attainment - pp. 53-54

A well-educated workforce constitutes an essential component of a region's capacity to generate and support innovation-driven economic growth. Without a trained workforce, businesses will not expand or relocate to an area and, in some cases, may move away. Challenges to maintaining a suitably trained labor force in Massachusetts include the need to continually increase skill levels and the technical sophistication of workers. A highly educated workforce often results in a lower-than-average unemployment rate.

Education plays an important role in preparing Massachusetts residents to succeed in their evolving job requirements and adapt to shifting career trajectories. A strong education system also helps attract and retain workers who want excellent educational opportunities and skills for themselves and their children. Economic growth in Massachusetts is highly dependent upon maintaining a high level of skills, as well as diverse skills, within the workforce.

Indicator 18: Public Investment in Education - p. 55

Investments in elementary, middle, and high schools are important for preparing a broadly educated and innovation-capable workforce. Investments in public, post-secondary education are critical to increase the ability of public academic institutions to prepare students for skilled and well-paying employment. In addition, well-regarded, public higher education programs enhance Massachusetts' distinctive ability to attract students from around the globe, some of whom choose to work in the Commonwealth after graduation.

Indicator 19: STEM Career Choices and Degrees - p. 56

Science, technology, engineering, and math (STEM) education provides the skills and know-how that can help increase business productivity, create new technologies and companies, and establish the basis for higher-paying jobs. STEM degree holders are also important to the wider economy, as nearly 75% of them work in non-STEM occupations.

Indicator 20: Talent Flow and Attraction - pp. 57-58

Migration patterns are a key indicator of a region's attractiveness. Regions that are hubs of innovation have high concentrations of educated, highly-skilled workers and dynamic labor markets refreshed by inflows of talent. In-migration of well-educated individuals fuels innovative industries by bringing in diverse and high-demand skill sets.

Indicator 21: Housing Affordability - pp. 59-60

Assessments of 'quality of life', of which housing affordability is a major component, influence Massachusetts' ability to attract and retain talented people. Availability of affordable housing for both essential service providers (i.e. teachers, emergency services, etc) and entry-level workers can enable individuals to move to the area, thus facilitating business' ability to fill open positions and fuel business expansion in the region. One measure for housing affordability is the Housing Price Index which is a weighted index measuring the movement of housing prices.

Indicator 22: Infrastructure - pp. 61-62

A state's infrastructure is more than just the sum of its roads and bridges. Infrastructure is comprised of the transportation, communication, and energy systems within a state. It plays a crucial role in allowing goods and services to be moved into, within, and out of Massachusetts, whether physically or electronically. Energy is the unseen input that allows business to operate. Everything from data centers and offices to factories and hospitals consume it. Fast broadband connections increase business productivity and allow consumers to access a wider range of goods and services online. Additionally, the amount of time people spend commuting to and from work imposes a hidden cost on the economy, consuming time that could otherwise be spent productively elsewhere and affecting the overall quality of life. The more productive workers become, the more the cost of this lost time increases.

INDICATOR 17: Educational Attainment

How Does Massachusetts Perform?

Massachusetts continues to be the 'best in class' when it comes to the percentage of adults with a bachelor's degree or higher (47.3%) when compared to the LTS average (37.0%) or that of the U.S. (34.2%) during the 2014-2016 timeframe. Massachusetts remains competitive among the LTS in workforce educational attainment with 67.5% of its working age population having achieved at least some college (3rd in the LTS) and is virtually tied with 2nd and 4th ranked New Hampshire and Connecticut. Minnesota leads in overall college attainment, due largely to its strong performance with students having less than a four-year degree. One possible explanation for this is the continued strength of Advanced Manufacturing in the Midwest, as many of these jobs require post-secondary credentials, but not a full bachelor's degree. Midwest peer Wisconsin posts similarly strong percentages with such students.

MASSACHUSETTS & ... EDUCATIONAL ATTAINMENT

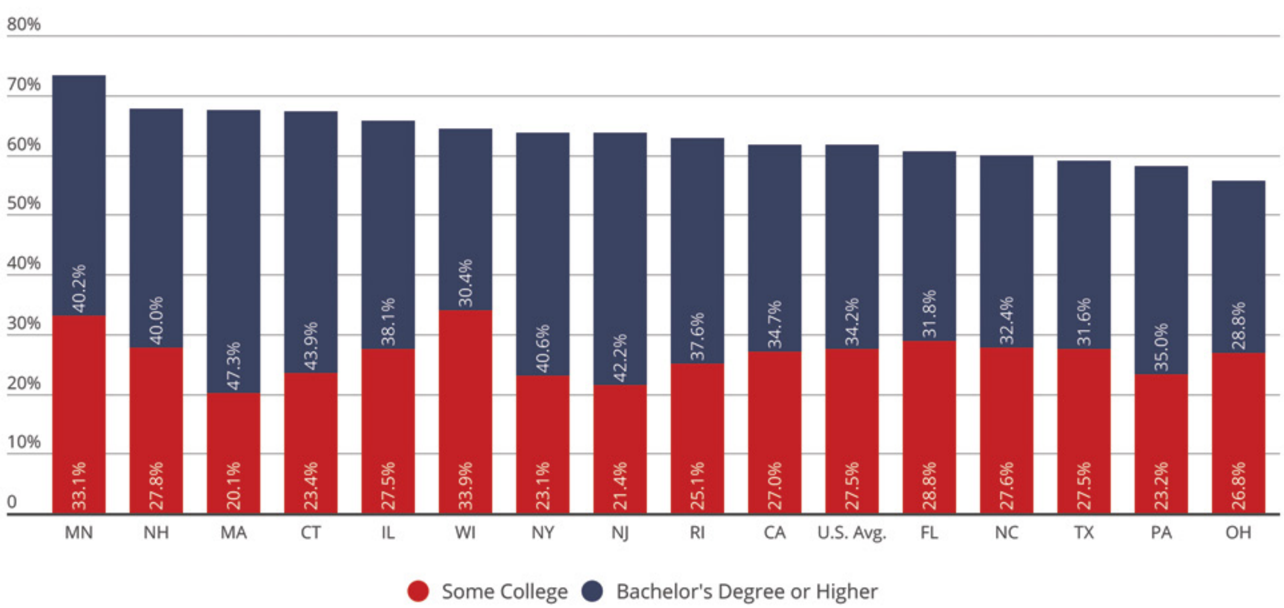
- **47.3% of workforce with at least a Bachelor's Degree in 2016 (1st nationally)**
- **118,348 Postsecondary Degrees conferred in 2015, (10th nationally)**

The employment rate among adults with at least a bachelor's degree in Massachusetts (75.5%) has remained comparatively high, but it has remained relatively stagnant since the Great Recession of 2009 (76.7%). Over the same period, the gap between the employment rates of holders of Bachelor's degree and above holders compared to those with only a high school diploma has fallen from 20 percentage points to 13.5, mainly due to increases in the employment rate of high school graduates. The significant improvement in the state's unemployment rate since 2009 can be attributed to the more than 5% increase in employment among high school graduates during the 2009-2015 time period.

Since the onset of the Great Recession, Massachusetts has maintained a lower unemployment rate than the U.S. as a whole. Meanwhile college attainment has remained relatively stable in Massachusetts since 2008 with 65.0-67.5% of the state's working age population having at least some college education. The employment situation for high school graduates seems to be improving and could signal future economic growth. Growth in the employment rate of college-educated adults may reach a plateau as baby boomers age out of the workforce and there is more room for growth in the employment rate among high school graduates.

Massachusetts is second to Rhode Island among the LTS in Postsecondary Degrees conferred per 1,000 residents in 2015. In each of the top five LTS, aside from Minnesota, the majority of post-secondary graduates go to private non-profit schools.

Educational Attainment of Working Age Population
Massachusetts, LTS & U.S., Three Year Rolling Average, 2014-2016

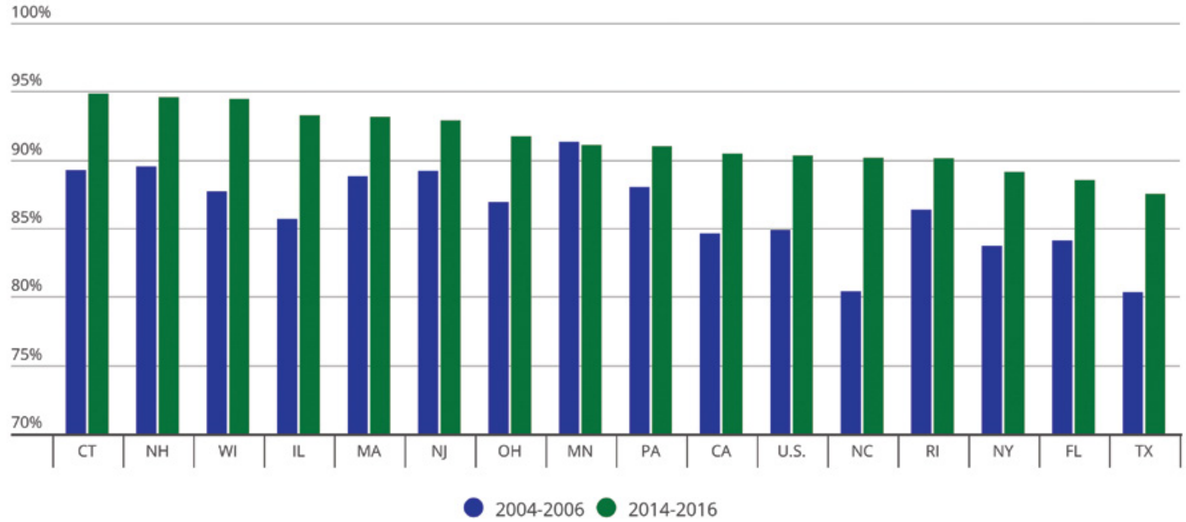


Indicator 17 continued on next page-->

Data Source for Indicator 17: Census Bureau Current Population Survey (CPS) , National Center for Education Statistics (NCES), American Community Survey (ACS)

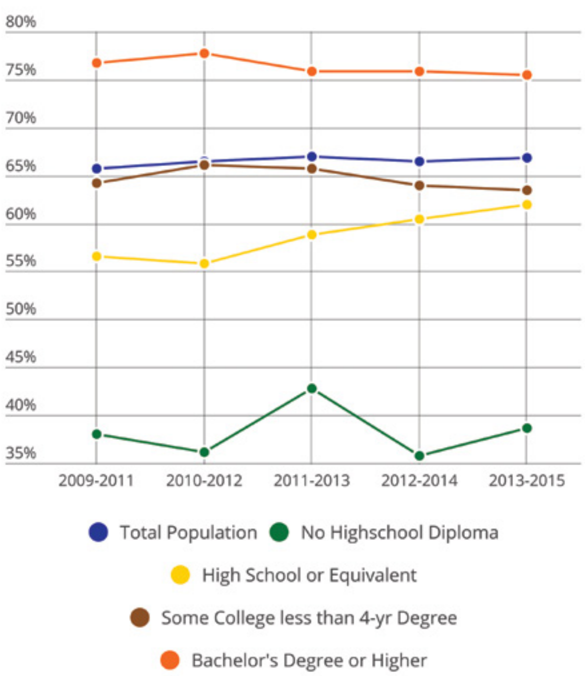
INDICATOR 17: Educational Attainment

High School Attainment of Persons aged 19-24
Massachusetts, LTS & U.S., Three Years Rolling



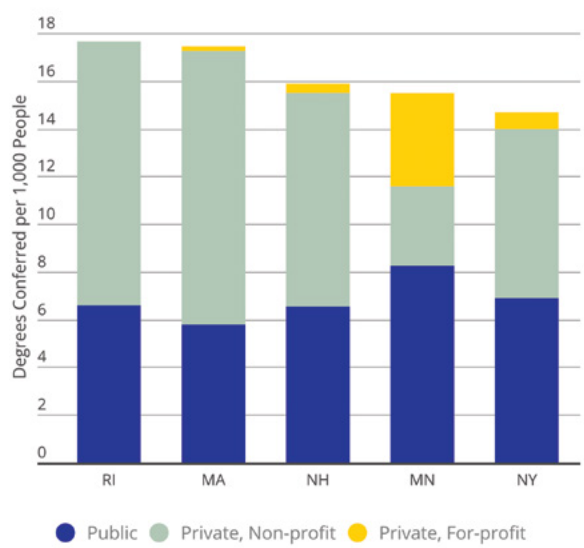
	CT	NH	WI	IL	MA	NJ	OH	MN	PA	CA	U.S.	NC	RI	NY	FL	TX
2004-2006	89.26%	89.52%	87.70%	85.69%	88.80%	89.19%	86.92%	91.32%	88.02%	84.61%	84.89%	80.38%	86.36%	83.71%	84.10%	80.33%
2014-2016	94.85%	94.59%	94.46%	93.25%	93.14%	92.88%	91.73%	91.08%	91.00%	90.46%	90.32%	90.15%	90.11%	89.12%	88.52%	87.51%

Employment Rate by Educational Attainment
Massachusetts, Three Year Rolling Average, 2009-2015



	2009-2011	2010-2012	2011-2013	2012-2014	2013-2015
Total Population	65.7%	66.4%	67.0%	66.4%	66.9%
No Highschool Diploma	38.0%	36.1%	42.8%	35.7%	38.6%
High School or Equivalent	56.6%	55.8%	58.8%	60.4%	62.0%
Some College less than 4-yr Degree	64.2%	66.1%	65.7%	64.0%	63.5%
Bachelor's Degree or Higher	76.7%	77.8%	75.9%	75.9%	75.5%

Post-Secondary Degrees Conferred per 1,000 People
Massachusetts & Top 5 LTS, 2014-2015



State	Public	Private, Non-profit	Private, For-profit
RI	6.60	11.05	0.00
MA	5.80	11.46	0.19
NH	6.52	8.98	0.39
MN	8.26	3.32	3.89
NY	6.91	7.08	0.70

For additional charts on this indicator visit: masstech.org/index

Data Source for Indicator 17: Census Bureau Current Population Survey (CPS), National Center for Education Statistics (NCES), American Community Survey (ACS)

INDICATOR 18: Public Investment in Education

How Does Massachusetts Perform?

Massachusetts continues its above-average spending per pupil on public elementary and secondary school systems ($15,592 per student). Of the LTS, New York, Connecticut, and New Jersey invest more per student than Massachusetts, which spends approximately $4,000 more per student than the national average.

In terms of higher education, appropriations per full-time-equivalent (FTE), student in Massachusetts ($6,334) is slightly above the LTS average ($5,985) but remains below the U.S. average ($7,116). In this measure Massachusetts places 6th among the LTS, when cost of living is taken into account, but 5th with unadjusted figures. The fall in ranking likely reflects the relatively high cost of living in the state, which leads to higher expenses for colleges and universities providing similar services as elsewhere, mostly in the form of higher wages.

Massachusetts' state higher education appropriations per student ($6,334) have increased by 12.8% since 2011. North Carolina had the highest level of state higher education appropriations per student in 2016, leading the LTS at $8,750, 5.7% more than in 2011.

MASSACHUSETTS & ...
PUBLIC INVESTMENT IN EDUCATION

- **$15,592 in 2015 public school spending per student (7th nationally)**
- **$6,334 in 2016 higher education appropriations per student (21st nationally)**

Per Pupil Spending
Public Elementary/Secondary School Systems
Massachusetts, LTS, & U.S., 2015

State	Per Pupil Spending
New York	$21,206
Connecticut	$18,377
New Jersey	$18,235
Massachusetts	$15,592
Rhode Island	$15,179
Pennsylvania	$14,717
New Hampshire	$14,697
Illinois	$13,755
Minnesota	$11,949
Ohio	$11,637
U.S. Average	$11,392
Wisconsin	$11,375
California	$10,467
Florida	$8,881
Texas	$8,861
North Carolina	$8,687

State Higher Education Appropriations
Per Full-Time Equivalent Student
Adjusted for Inflation, Enrollment Mix and Cost of Living
Massachusetts, LTS, & U.S., 2016

State	2016	2011-2016 % Change
North Carolina	$8,750	5.7%
Connecticut	$8,000	1.1%
Texas	$7,159	-2.8%
California	$7,122	16.2%
U.S. Average	$7,116	3.3%
New York	$7,106	4.0%
Massachusetts	$6,334	12.8%
Minnesota	$6,267	13.3%
New Jersey	$5,709	-10.7%
Florida	$5,693	0.9%
Wisconsin	$5,537	-18.8%
Ohio	$5,365	11.3%
Rhode Island	$4,681	5.5%
Pennsylvania	$3,576	-18.7%
New Hampshire	$2,489	-9.9%

Data Source for Indicator 18: State Higher Education Office, Census Bureau, ACS

INDICATOR 19: STEM Career Choices and Degrees

How Does Massachusetts Perform?

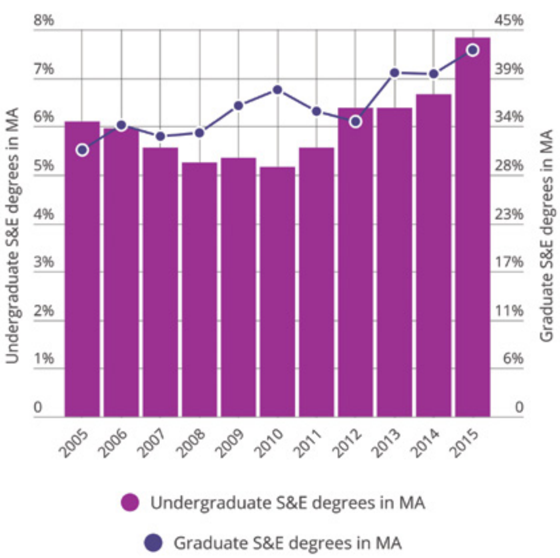
Massachusetts leads the LTS in degrees (graduate & undergraduate) granted in STEM fields per one million residents (2,877) a figure 29.1% greater than the second state, Rhode Island. Among the STEM fields, engineering and biological & biomedical science are the most popular majors, together comprising 62.9% of STEM degrees granted in Massachusetts; this compared with 59.1% on average in the LTS. Computer and Information Sciences was the third most popular degree granted in STEM, accounting for 21.4% in Massachusetts and 24.6% on average in the LTS. Degrees granted in STEM fields to non-permanent residents in Massachusetts rose in all fields except for Engineering Technologies and Engineering Related Fields, where it fell slightly over the period from 2006-2015. **Total STEM degrees granted from 2006 to 2015 in Massachusetts rose by 54.4%**.

MASSACHUSETTS & ... STEM CAREER CHOICES AND DEGREES

- **19,518 graduates in STEM fields in 2015 (10th nationally)**
- **Highest number of 2015 STEM graduates per capita nationally**

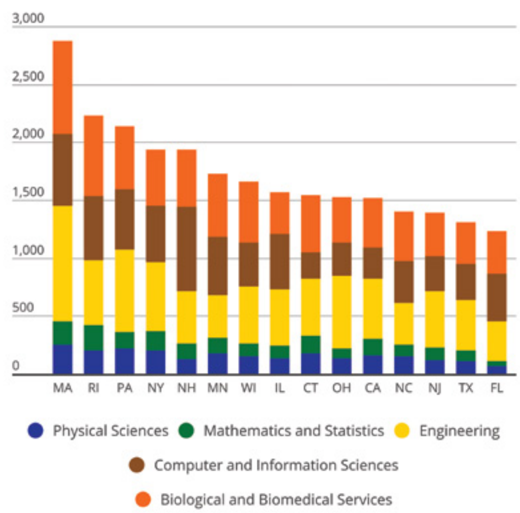
Foreign students attracted to the Commonwealth's high quality universities and colleges are an important source of STEM talent for Massachusetts' companies and research institutions. Graduate degrees granted in Science and Engineering (S&E) to temporary, non-permanent residents reached a 10-year peak in 2015 at 42.6%. Undergraduate S&E degrees conferred to temporary, non-permanent residents matched a ten-year peak in 2015 (7.8%). However, these are comparably small numbers with Massachusetts' institutions granting 183 additional undergraduate degrees to foreign students in S&E in 2015, for a total of 925. This is in contrast to the 3,002 graduate S&E degrees granted to foreign students in 2015, which increased by 391 between 2014 and 2015.

S&E Degrees Conferred to Temporary Non-permanent Residents
Universities in Massachusetts, 2005-2015



Year	Undergraduate S&E degrees conferred in MA	Graduate S&E degrees conferred in MA
2005	6.11%	31.07%
2006	5.97%	33.92%
2007	5.55%	32.57%
2008	5.26%	32.95%
2009	5.36%	36.19%
2010	5.17%	37.96%
2011	5.55%	35.56%
2012	6.38%	34.28%
2013	6.37%	39.95%
2014	6.66%	39.87%
2015	7.83%	42.61%

Degrees Granted in STEM Fields All Degree Levels
per 1 Million Residents
Massachusetts & LTS, 2014-2015



State	Physical Sciences	Mathematics and Statistics	Engineering	Computer and Information Sciences	Biological and Biomedical Services
MA	253.68	196.93	1002.47	615.99	807.90
RI	197.04	224.51	555.13	559.87	691.55
PA	218.73	141.57	709.04	525.33	539.17
NY	198.86	171.46	589.45	488.83	491.11
NH	127.80	127.80	458.61	723.25	499.21
MN	172.37	137.16	371.37	501.05	543.92
WI	154.65	104.02	496.19	377.43	526.71
IL	135.91	110.91	479.32	480.25	359.30
CT	172.40	152.59	498.22	222.61	499.90
OH	137.09	82.64	626.45	285.05	392.59
CA	158.20	144.77	515.52	270.68	427.99
NC	149.07	102.74	361.13	355.35	433.38
NJ	116.50	112.25	482.46	301.50	377.49
TX	111.19	87.24	437.30	308.83	363.55
FL	69.20	41.04	344.38	411.86	365.33

Data Source for Indicator 19: College Board, ACS, NCES, IPEDS

INDICATOR 20: Talent Flow and Attraction

How Does Massachusetts Perform?

In recent years, net migration in the LTS has been concentrated in so-called "Sun Belt" states such as Florida, Texas, North Carolina, and California, all of which place in the Top 5 LTS in net migration as a percentage of the population. Minnesota is an outlier in this respect, placing 4th in the LTS. Massachusetts places 6th, in this measure, although it has declined every year since 2013. Massachusetts track record in attracting the college-educated is much better as, in 2016, Massachusetts regained the top spot among the LTS for relocation for college-educated adults as a percentage of the population 25 years and older. As companies scramble to take advantage of the talent in Greater Boston, college-educated adults are incentivized to relocate to a city offering opportunities, creating a self-perpetuating effect.

MASSACHUSETTS & ...
TALENT FLOW & ATTRACTION

- **+15,000 in Net Migration in 2016**
- **Positive Net Migration every year since 2008**

In 2016, Massachusetts' net migration levels were around 15,000, after dropping substantially from their ten-year peak in 2013 (32,251). International migration decreased 1.5% between 2015-2016, reaching 40,898, while domestic migration dropped -15.9% from the previous year to - 25,606. This is in part due to the increasing cost of living in the state. Despite the state's many amenities, the high cost of housing and the issues that come with it are driving some people away. In addition, Massachusetts and other cold climate states typically lose retirees to balmier locations.

Despite the slowdown, **Massachusetts has had positive net migration every year since 2008, representing a strong rebound from the early-to mid-2000's when the state experienced six consecutive years of negative net migration.**

Relocation by College-Educated Adults
To the LTS from Out-of-State or Abroad
Massachusetts & LTS, 2011-2016

State	2011	2012	2013	2014	2015	2016	Percentage Point Change 2011-2016
MA	1.10%	1.08%	1.20%	1.13%	1.12%	1.18%	0.08
RI	1.14%	1.02%	1.06%	1.05%	0.94%	1.14%	0.00
IL	0.96%	1.05%	1.10%	1.07%	1.03%	1.12%	0.16
CT	1.07%	1.00%	1.01%	1.06%	1.13%	1.11%	0.04
CA	0.96%	1.02%	1.02%	1.04%	1.07%	1.09%	0.13
NJ	1.00%	1.03%	1.10%	1.07%	1.09%	1.07%	0.07
NY	1.02%	0.83%	1.05%	1.11%	1.09%	1.07%	0.05
NH	0.96%	0.97%	1.07%	0.90%	1.21%	1.07%	0.10
MN	0.86%	0.92%	0.99%	0.94%	0.95%	1.00%	0.13
OH	0.83%	0.86%	0.85%	0.89%	0.86%	0.94%	0.12
PA	0.91%	0.89%	0.91%	0.93%	0.93%	0.92%	0.00
NC	0.74%	1.14%	0.87%	0.85%	0.90%	0.90%	0.17
TX	0.79%	0.76%	0.82%	0.85%	0.89%	0.87%	0.08
WI	0.94%	0.82%	1.00%	0.93%	0.85%	0.87%	-0.07
FL	0.70%	0.67%	0.69%	0.74%	0.74%	0.74%	0.04

Indicator 20 continued on next page -->

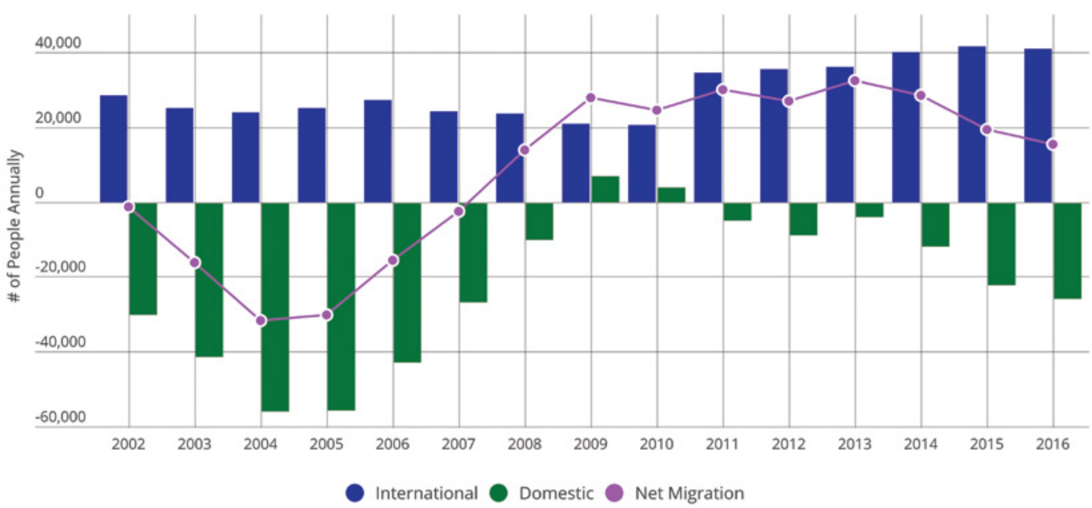
Data Source for Indicator 20: Census Bureau, ACS

INDICATOR 20: Talent Flow and Attraction

Net Migration as a % of Population
Massachusetts & LTS, 2011-2016

Net Migration as a Percent of Population by State	2011	2012	2013	2014	2015	2016	Percentage Point Change 2011-2016
FL	1.30%	1.28%	1.21%	1.54%	1.76%	1.78%	0.49
TX	1.57%	1.63%	1.52%	1.75%	1.77%	1.55%	-0.01
NC	0.95%	0.98%	0.97%	0.93%	1.00%	1.10%	0.15
MN	0.70%	0.59%	0.71%	0.63%	0.53%	0.68%	-0.02
CA	0.91%	0.88%	0.85%	0.89%	0.80%	0.65%	-0.26
MA	0.70%	0.69%	0.73%	0.64%	0.51%	0.40%	-0.30
NH	0.12%	0.21%	0.11%	0.46%	0.10%	0.35%	0.23
WI	0.34%	0.29%	0.29%	0.27%	0.16%	0.19%	-0.15
NJ	0.42%	0.36%	0.29%	0.29%	0.12%	0.10%	-0.32
OH	0.03%	0.05%	0.17%	0.21%	0.09%	0.08%	0.05
RI	-0.08%	0.04%	0.01%	0.14%	0.11%	0.08%	0.16
NY	0.60%	0.42%	0.36%	0.23%	0.15%	-0.01%	-0.61
PA	0.25%	0.22%	0.07%	0.07%	0.01%	-0.06%	-0.31
CT	0.28%	0.11%	0.06%	-0.11%	-0.20%	-0.23%	-0.51
IL	0.14%	0.08%	0.07%	-0.09%	-0.22%	-0.29%	-0.44

Domestic & International Migration
Massachusetts, 2002-2016



	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
International	28,517	24,961	23,944	25,220	27,123	24,226	23,643	20,866	20,659	34,572	35,460	35,960	40,091	41,526	40,898
Domestic	-29,936	-41,300	-55,788	-55,426	-42,821	-26,666	-9,799	6,843	3,720	-4,679	-8,675	-3,709	-11,569	-22,087	-25,606
Net Migration	-1,419	-16,339	-31,844	-30,206	-15,698	-2,440	13,844	27,709	24,379	29,893	26,785	32,251	28,522	19,439	15,292

Data Source for Indicator 20: Census Bureau, ACS

INDICATOR 21: Housing Affordability

How Does Massachusetts Perform?

The percentage of Massachusetts' renters qualifying as "burdened" (spending more than 30% of their income on housing) by housing costs decreased by 1.3 percentage points from 2015 to 2016, falling to 46.8%. Massachusetts ranks 11th in the U.S. for burdened renters and 6th in the LTS after California, Florida, New York, New Jersey, and Connecticut. Massachusetts and the U.S. as a whole have seen little change in these figures over the last five years. **In every LTS, over 40% of renters spend more than 30% of their income on housing.** The percentage of burdened homeowners in Massachusetts decreased to 29.8% from 32.5% between 2015 and 2016, U.S. homeowners have also become less burdened in the past six years, with 28.1% of homeowners spending more than 30% of their income on housing, down from 37.8% in 2011.

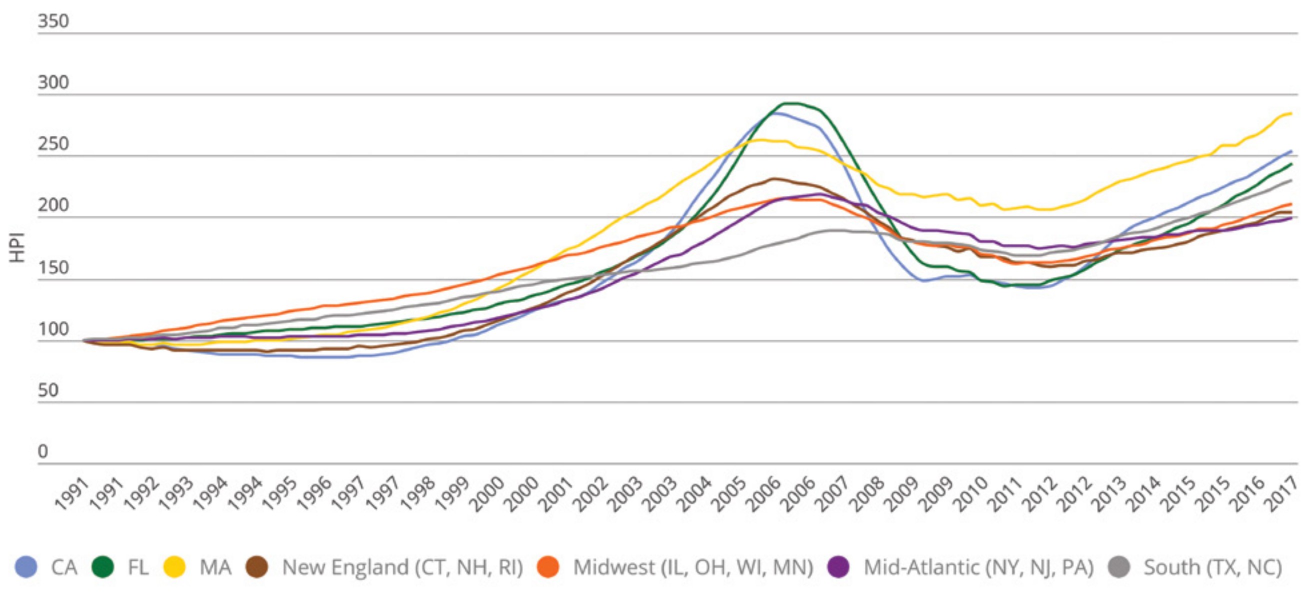
MASSACHUSETTS & ...
HOUSING AFFORDABILITY

- **Highest FHA Housing Price Index among LTS as of Q2 2017**
- **48.6% of MA renters are housing cost burdened in 2016 (6th in LTS, 11th nationally)**
- **29.8% of MA homeowners are housing cost burdened in 2016 (7th in LTS, 12th nationally)**

Overall, homeowners are significantly less likely to be burdened by housing costs than renters. Homeowners face differing rates of housing cost burden with over 35% of homeowners in California and New Jersey spending more than 30% of their income on housing, and fewer than 25% doing so in Wisconsin, Ohio and Minnesota. On the surface, the situation seems to be improving in Massachusetts, yet home prices and rents are increasing. Demand for more housing is, however, having a positive effect on the Commonwealth's economic growth and driving a boom in construction jobs. Around 7,500 construction jobs were created from 2015 to 2016 in Massachusetts, a 5.0% increase in construction employment.

Rising housing costs could potentially be a setback for the Massachusetts economy in the future as the lack of affordable housing and increasing commuting times may result in job losses to regions with more affordable housing stock. **Over the last decade, housing prices have risen dramatically in Massachusetts, which currently ranks highest on the Federal Housing Finance Authority Housing Price Index (HPI) among the LTS**. While HPI in the state has just recovered to mid-2000s levels, it has risen by 32.8% from Q4 2012 (when the market bottomed out) to Q2 2017. California has experienced an especially sharp rise in prices (58.9%) within the same time period. Florida (54.7%) and Texas (37.3%) also experienced relatively fast increases in the HPI, although both from much lower starting points.

Housing Price Index
CA, FL, MA, New England, Midwest, Mid-Atlantic, South
Q1 1991-Q2 2017



Indicator 21 continued on next page-->

Data Source for Indicator 21: Federal Housing Finance Agency, Census Bureau, The Boston Globe, U.S. Department of Labor, Corelogic

INDICATOR 21: Housing Affordability

Percent of Households that Spend at least 30% of Income on Housing
Massachusetts & U.S., 2011-2016

	2011	2012	2013	2014	2015	2016
MA Renters	48.9%	46.8%	47.5%	47.8%	48.1%	46.8%
US Renters	49.3%	48.1%	47.6%	47.9%	46.8%	46.1%
MA Homeowners	38.6%	35.1%	33.7%	32.5%	32.5%	29.8%
US Homeowners	37.8%	33.7%	31.6%	30.7%	29.4%	28.1%

Households Spending 30% or more of Income on Housing Costs
Massachusetts, LTS & U.S., 2016

	Renters	Homeowners	Household Income
CA	52.6%	38.6%	$67,739
FL	52.1%	34.0%	$50,860
NY	49.8%	33.8%	$62,909
NJ	49.1%	36.4%	$76,126
CT	48.1%	30.7%	$73,433
MA	46.8%	29.8%	$75,297
U.S. Average	46.1%	28.1%	$57,617
RI	45.7%	31.6%	$60,596
IL	45.3%	28.2%	$60,960
TX	43.9%	26.4%	$56,565
MN	43.3%	22.3%	$65,599
PA	43.1%	25.4%	$56,907
NC	42.6%	25.7%	$50,584
OH	42.0%	21.9%	$52,334
NH	41.8%	27.7%	$70,936
WI	41.8%	23.9%	$56,811

Data Source for Indicator 21: Federal Housing Finance Agency, Census Bureau, The Boston Globe, U.S. Department of Labor, Corelogic

INDICATOR 22: Infrastructure

How Does Massachusetts Perform?

Massachusetts has the fastest average broadband speed among the LTS (23.8 Megabits per second or Mbps). This is almost the same as Rhode Island's (23.7 Mpbs), but almost 2.0 Mbps faster than New Jersey, the next closest state. Broadband speeds have increased dramatically since 2012 when Massachusetts, then the top ranked state among the LTS, had an average speed of 9.1 Mbps. Rhode Island has the highest level of access to broadband speeds above 15 Mbps among the LTS, a benchmark for high quality broadband (available to 66.2% of population). Access to broadband is improving, as Massachusetts has improved the access to connection speeds over 15 Mbps by 14.0% relative to 2015. Increased access to faster broadband speeds is a pattern throughout the LTS, as every state increased its access to 15 Mbps broadband in 2016.

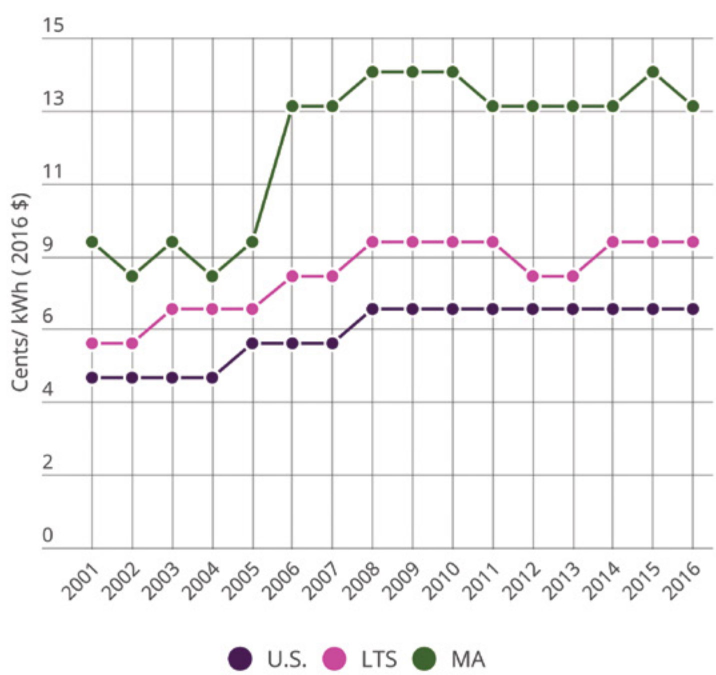
MASSACHUSETTS & … INFRASTRUCTURE

- **23.8 Mbps average broadband speed, fastest among LTS (3rd nationally) as of Q1 2017**
- **Industrial electricity prices were 51% and 94% higher than the LTS and U.S. averages in 2016**
- **5th longest Large Metro Commute Time (250 hours/year) among LTS**

Since 1990, Massachusetts has consistently sustained higher industrial electricity prices than either the LTS or the U.S. as whole. After a trend of declining prices from 1990 to 2006, Massachusetts has since experienced a relatively large increase in industrial electricity prices compared to the LTS and the U.S. The difference in prices between Massachusetts and much of the country is due to a number of persistent factors, including a relative lack of generating capacity in New England, a lack of interconnections with other regions, and a mix of energy sources with higher input costs. The other New England states also have higher industrial electricity prices than the LTS average.

Finally, Boston is well known for its heavy rush hour traffic and indeed, Massachusetts metropolitan areas with more than 250,000 commuters ("large metros") have similar commutes to those in California. However, New York, New Jersey, and Illinois commuters spend even more time in traffic. New York has experienced a large increase in annual commute time for large metros since 2014 (23 hours). This is largely driven by New York City, which has suffered from an outbreak of breakdowns on the Metropolitan Transit Authority. Massachusetts has also experienced a significant increase in annual commute times from 239 hours to 250 hours from 2014-2016. While not as large as New York's, this is evidence that continued investments in the transportation system matter. Metropolitan areas in Connecticut, Wisconsin, North Carolina, Minnesota, Rhode Island, and Ohio have shorter commutes than the U.S. average.

Industrial Electricity Prices
Massachusetts, LTS & U.S., 2001-2016
Cents per Kilowatt Hour



Year	U.S.	LTS	MA
2001	$0.05	$0.06	$0.09
2002	$0.05	$0.06	$0.08
2003	$0.05	$0.07	$0.09
2004	$0.05	$0.07	$0.08
2005	$0.06	$0.07	$0.09
2006	$0.06	$0.08	$0.13
2007	$0.06	$0.08	$0.13
2008	$0.07	$0.09	$0.14
2009	$0.07	$0.09	$0.14
2010	$0.07	$0.09	$0.14
2011	$0.07	$0.09	$0.13
2012	$0.07	$0.08	$0.13
2013	$0.07	$0.08	$0.13
2014	$0.07	$0.09	$0.13
2015	$0.07	$0.09	$0.14
2016	$0.07	$0.09	$0.13

Indicator 22 continued on next page-->

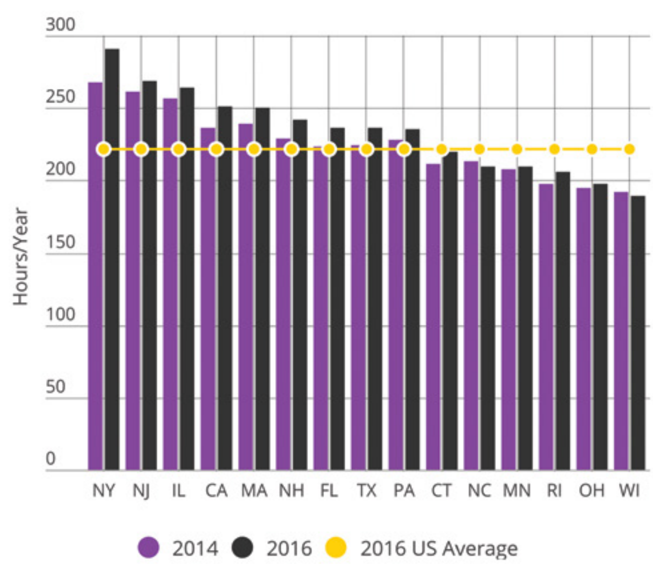
Data Source for Indicator 22: Census Bureau, ACS, Akamai, Energy Information Administration

INDICATOR 22: Infrastructure

Broadband Speed and Access
Massachusetts & LTS, Q1 2017

State	Average Connection Speed (Mbps)	15 Mbps Broadband Access (% of Population)	Speed Rank (in U.S.)	Access Rank (in U.S.)
MA	23.8	61.5%	3	4
RI	23.7	66.2%	4	1
NJ	22.2	61.8%	6	3
NY	22.0	58.0%	7	7
PA	20.8	53.8%	9	9
CA	20.1	49.4%	11	15
CT	19.5	51.1%	13	11
NH	19.4	51.5%	14	10
IL	18.6	46.3%	18	19
FL	18.2	49.4%	20	14
TX	17.9	44.9%	25	21
MN	17.6	43.7%	26	27
NC	17.5	45.5%	27	20
WI	16.9	42.9%	30	29
OH	15.7	39.8%	37	37

Average Metropolitan Commute Time
Large Metros (above 250K commuters)
Hours/Year
Massachusetts & LTS, 2014 & 2016



State	2014 Hours/Year	2016 Hours/year
NY	268	291
NJ	261	269
IL	257	264
CA	236	251
MA	239	250
NH	229	242
FL	223	236
TX	224	236
PA	228	235
U.S. Average	214	222
CT	211	220
NC	213	210
MN	208	210
RI	198	206
OH	195	198
WI	192	189

Data Source for Indicator 22: Census Bureau, ACS, Akamai, Energy Information Administration

APPENDIX

The *2017 Index* tracks a selection of 22 indicators that MassTech and its *Index* Advisory Committee (page 71) view as being the most comprehensive set of data for benchmarking the Innovation Economy. Indicators can change from year-to-year as new data sources become available and best-practices in tracking economic data are updated. MassTech and the *Index* Advisory Committee review the selection of indicators each year to determine whether to add or remove any and whether or not better sources of data are available.

DATA SOURCES FOR INDICATORS AND SELECTION OF LEADING TECHNOLOGY STATES (LTS)

I. Note on Data Availability

Indicators are calculated with data from proprietary and other existing secondary sources. In most cases, data from these sources were organized and processed for use in the *Index*. Since these data are derived from a wide range of sources, content of the data sources and timeframes are not identical and cannot be compared without adjustments. This appendix provides information on the data sources for each indicator.

The *Index* always displays the most recent year of data available for each indicator at the time of writing.

II. Note on Price Adjustment

The *Index* uses inflation-adjusted figures for most indicators. Dollar figures represented in this report, where indicated, are 'chained' (adjusted for inflation) to the latest year of data unless otherwise indicated. Price adjustments are according to the Consumer Price Index for all Urban Consumers, U.S. City Average, All Items, Not Seasonally Adjusted. Bureau of Labor Statistics, U.S. Department of Labor (www.bls.gov/data).

III. Note on Per-Capita Comparisons

The *Index* makes frequent use of per-capita metrics in order to make meaningful comparisons between states of vastly different sizes since the Leading Technology States range from roughly 1 million people to nearly 40 million. Per-capita or "as a % of" metrics allow the *Index* to make comparisons on density in certain measures, which MassTech views as crucial to cluster formation and growth. Where performance is less tied to a state's population, the *Index* includes absolute figures as well.

IV. Note on Selection of Leading Technology States (LTS) for Benchmarking Massachusetts' Performance

The *Index* benchmarks Massachusetts' performance against other leading states and nations to provide the basis for comparison. The LTS for this year's *Index* includes the 10 states used every year since 2012; California, Connecticut, Illinois, Massachusetts, Minnesota, New Jersey, New York, Ohio, Pennsylvania, and Texas. This edition of the *Index* also includes five additional states: Florida, New Hampshire, North Carolina, Rhode Island, and Wisconsin. In 2017, the LTS were chosen using three criteria: (i.) by the number of select key industry sectors with a high concentration (10% above average) of employment, (ii.) the percent of employment in these sectors, and (iii.) the size of each states' innovation economy (measured by number of employees). The sectors used to represent the Innovation Economy include: Advanced Materials, Biopharma & Medical Devices, Business Services, Computer & Communication Hardware, Defense Manufacturing & Instrumentation, Diversified Industrial Manufacturing, Financial Services, Healthcare Delivery, Postsecondary Education, Scientific, Technical, & Management Services, and Software & Communications Services. The sector employment concentration for each state measures sector employment as a percent of total employment to the same measure for the U.S. as a whole. This ratio, called the 'location quotient' (LQ), is above average if greater than one. The three criteria are assessed simultaneously and with equal weighting. The score assigned to each state for each criterion is between 0 and 1, with 1 going to the leading state and 0 going to the bottom state. The scores for the rest of the states are determined by their relative position within the spread of data. The criteria scores are added together to get an overall score. The states with the 15 highest overall scores are then chosen for the LTS.

The Innovation Economy (IE) Score is used only to select the LTS as described above, it does not reflect performance on all 22 indicators used in the *Index*.

2017 Leading Technology States (LTS)

State	LTS Selection Score
Massachusetts	2.27
California	2.15
Pennsylvania	2.00
New York	1.71
Illinois	1.66
Ohio	1.63
Connecticut	1.56
Minnesota	1.54
North Carolina	1.40
Texas	1.40
New Jersey	1.39
New Hampshire	1.39
Rhode Island	1.35
Florida	1.33
Wisconsin	1.32

Source: BLS QCEW

APPENDIX

Sources for the LTS Initiatives from pages 17-22:

1. https://www.masstech.org/innovation-institute/projects-and-initiatives/collaborative-research-matching-grant-program
2. http://www.masslifesciences.com/
3. http://boston.masschallenge.org/
4. https://biotechconnection-losangeles.org/about
5. http://www.sfmade.org/services/about-us/
6. http://www.connect.org/
7. http://www.catalystconnection.org/about/
8. http://www.sep.benfranklin.org/
9. https://www.sciencecenter.org/
10. https://tech.cornell.edu/about
11. http://www.sunycnse.com/Home.aspx
12. https://esd.ny.gov/nystar/centersforadvtechnolgy.asp
13. http://innovation.uconn.edu/tech-park/
14. http://ctnext.com/
15. http://ct.org/signature-event/connecticut-skills-challenge/
16. http://researchpark.illinois.edu/
17. http://www.illinoisinnovation.com/
18. http://www.illinoistreasurer.gov/Businesses/Technology_Development_Accounts
19. https://www.bioenterprise.com/
20. https://ewi.org/
21. http://www.competitiveworkforce.com/
22. https://mndrive.umn.edu/
23. http://www.enterpriseminnesota.org/
24. http://minnesota.uli.org/advisory-services/prospect-north-partnership/
25. http://www.rtp.org/
26. http://www.ncbioimpact.org/about_us.html
27. http://www.ncidea.org/content/about/945
28: http://gov.texas.gov/ecodev/guri/home
29. https://texaswideopenforbusiness.com/services/texas-enterprise-fund
30. http://biohouston.org/about/
31. http://njii.com/
32. http://www.njeda.com/real_estate/properties/tcnj
33. http://centers.njit.edu/njiac/students/challenge/index.php
34. http://www.nhirc.unh.edu/
35. https://gameassembly.org/
36. http://www.futuretechwomen.org/
37 http://www.underseatech.org/
38. http://commerceri.com/finance-business/taxes-incentives/innovation-vouchers/
39: http://stac.ri.gov/innovate-ri-fund/
40. http://fl-ate.org/programs/high-school-technology-initiative/
41. https://www.innovationflorida.co/
42. http://www.scripps.edu/
43: http://inwisconsin.com/entrepreneurs/assistance/qualified-new-business-venture/
44. http://thewatercouncil.com/
45. http://uwmrealestatefoundation.org/innovationcampus/overview/vision.aspx

V. Note on Selection of Comparison Nations

For all the indicators that include international comparisons, countries displayed on the graph are the top performers for that measure. Some countries were excluded from comparison due to a lack of data reported for required years.

VI. Note on Data Timeframes

The *Index* uses multiple time intervals when looking at data within the indicators, but generally shows five years or ten years of change from a base year (i.e. 2010-2015 or 2005-2015). Depending upon space and data availability, sometimes all data collected by MassTech from a series are displayed.

APPENDIX

INDICATOR 1: INDUSTRY SECTOR EMPLOYMENT AND WAGES

Data on sector wages are from the Bureau of Labor Statistics' Quarterly Census of Employment and Wages (www.bls.gov/cew). This survey derives employment and wage data from workers covered by state unemployment insurance laws and federal workers covered by the Unemployment Compensation for Federal Employees program. Wage data denote total compensation paid during the four calendar quarters regardless of when the services were performed. Wage data include pay for vacation and other paid leave, bonuses, stock options, tips, the cash value of meals and lodging, and contributions to deferred compensation plans.

INDICATOR 2: OCCUPATIONS AND WAGES

The U.S. Bureau of Labor Statistics, Occupational Employment Estimates (OES) (www.bls.gov/oes/oes_dl.htm) program estimates the number of people employed in certain occupations and wages paid to them. The OES data include all full-time and part-time wage and salary workers in non-farm industries. Self-employed persons are not included in the estimates. The OES uses the Standard Occupational Classification (SOC) system to classify workers. MassTech aggregated the 22 major occupational categories of the OES into 10 occupational categories for analysis.

The occupational categories in the *Index* are:

- Arts & Media: Arts, design, entertainment, sports and media occupations.
- Construction & Maintenance: Construction and extraction occupations; Installation, maintenance and repair occupations.
- Education: Education, training and library occupations.
- Healthcare: Healthcare practitioner and technical occupations; Healthcare support occupations.
- Computer and Mathematical: Computer and mathematical occupations.
- Science, Architecture and Engineering Occupations: Architectural and engineering occupations; life, physical and social science occupations.
- Business, Financial and Legal Occupations: Management occupations; Business and financial operations occupations; and Legal occupations.
- Production: Production occupations.
- Sales & Office: Sales and related occupations; Office and administrative support occupations.
- Community and Social Service: Community and social service occupations.
- Other Services: Protective service occupations; Food preparation and serving related occupations; Building and grounds cleaning and maintenance occupations; Personal care and service occupations; Transportation and material moving occupations; Farming, fishing and forestry occupations.

INDICATOR 3: HOUSEHOLD INCOME

Median Household Income

Median household income data are from the U.S. Census Bureau, American Community Survey.

Income Distribution

Data for Distribution of Income are from the American Community Survey from the U.S. Census Bureau. Income is the sum of the amounts reported separately for the following eight types of income: wage or salary income; net self-employment income; interest, dividends, or net rental or royalty income from estates and trusts; Social Security or railroad retirement income; Supplemental Security Income; public assistance or welfare payments; retirement, survivor, or disability pensions; and all other income.

INDICATOR 4: OUTPUT

Output

Industry output data are obtained from the Moody's economy.com Data Buffet. Moody's estimates are based on industry output data for 2 and 3 digit NAICS produced by the Bureau of Economic Analysis.

INDICATOR 5: EXPORTS

Exports data are from the U.S. Census Bureau, Foreign Trade Division. Currency data from xe.com.

INDICATOR 6: RESEARCH AND DEVELOPMENT

Research and Development (R&D) Performed

Data are from the National Science Foundation (NSF), "Table: U.S. Research and Development Expenditures, by State, Performing Sector and Source of Funding". Data used are the totals for all R&D, Federal, FFRDCs, Business, U&C and Other Nonprofit.

Industry Performed Research and Development (R&D) As a Percent of Industry Output

Data on Industry Performed R&D are from the NSF Science & Engineering Indicators, "Table 8-45: Business-Performed R&D as a Percentage of Private-Industry Output, by State."

Research and Development (R&D) as a Percent of Gross Domestic Product (GDP)

Data for Massachusetts' R&D as a percent of GDP are from the NSF, "Table: U.S. Research and Development Expenditures, by State, Performing Sector, and Source of Funding" and the Bureau of Economic Analysis (bea.gov).

Data for the LTS are from the NSF National Patterns of R&D Resources, "Table - Research and Development Expenditures, by State, Performing Sector, and Source of Funds". Data used are the totals for all R&D, Federal, FFRDCs, Business, U&C and Other Nonprofit. www.nsf.gov/statistics.

APPENDIX

INDICATOR 7: ACADEMIC ARTICLE OUTPUT

LTS data are from the NSF "Table 8-49 - Academic Science and Engineering Article Output per $1 million of Academic S&E R&D, by State and Table 8-48- Academic S&E Articles per 1,000 S&E Doctorate Holders in Academia by state". International data is from the NSF. "Table 5-27 - S&E Articles in All Fields, by Region/Country/Economy". The NSF obtained its information on science and engineering articles from the Thomson Scientific ISI database. LTS population data are from the U.S. Census Bureau (www.census.gov/popest/data/index.html).

INDICATOR 8: PATENTS

United States Patent and Trademark Office (USPTO) Patents Granted

The count of patents granted by state are from the U.S. Patent and Trademark Office (USPTO). Patents granted are a count of Utility Patents only. The number of patents per year are based on the date patents were granted (www.uspto.gov). Population estimates are from the U.S. Census Bureau, Population Estimates Branch (www.census.gov/popest/data/index.html).

INDICATOR 9: TECHNOLOGY PATENTS

The count of patents granted by state and patent class are from the U.S. Patent and Trademark Office (www.uspto.gov), Patenting By Geographic Region, Breakout by Technology Class. State population data come from the U.S. Census Bureau, Population Estimates Branch. (www.census.gov/popest/data/index.html). The number of patents per year is based on the date the patents were granted. Patents in "computer and communications" and "drugs and medical" are based on categories developed in Hall, B. H., A. B. Jaffe, and M. Tratjenberg (2001), "The NBER Patent Citation Data File: Lessons, Insights and Methodological Tools." NBER Working Paper 8498. Patents in "advanced materials" and "analytical instruments and research methods" are based on categories developed by the Innovation Institute at MassTech. The "business methods" category has its own USPTO patent class.

INDICATOR 10: TECHNOLOGY LICENSING

Data on licensing agreements are from the Association of University Technology Managers website (AUTM) (www.autm.net). Institutions participating in the survey are AUTM members.

INDICATOR 11: SMALL BUSINESS INNOVATION RESEARCH (SBIR) AND TECHNOLOGY TRANSFER (STTR) AWARDS

This indicator includes SBIR award and STTR award data. SBIR/STTR award data are from U.S. Small Business Administration (www.sbir.gov/sbirsearch/technology), state population data come from the U.S. Census Bureau, Population Estimates Branch (www.census.gov/popest/data/index.html) and GDP Data is from U.S. Bureau of Economic Analysis (www.bea.gov).

INDICATOR 12: BUSINESS FORMATION

Business Establishment Openings

Data are from the Business Employment Dynamics database of the Bureau of Labor Statistics'(BLS) Business Employment Dynamics (www. bls.gov/bdm).

Start-up Companies

Data on spinout "start-up" companies are from the Association of University Technology Managers (AUTM). Institutions participating in the survey are all AUTM members (www.autm.net).

INDICATOR 13: INITIAL PUBLIC OFFERINGS AND MERGERS AND ACQUISITIONS

Initial Public Offerings (IPOs)

The number and distribution by industry sector of filed IPOs from 2015 on by state and for the U.S. are from IPO Monitor (https://www.ipomonitor.com/pages/ipo-filings.html). Data previous to 2015 are from Renaissance Capital's, IPOs Near You (www.renaissancecapital.com/IPOHome/Press/MediaRoom.aspx#). Data on venture-backed IPOs for 2012 are from the National Venture Capital Association (NVCA) (www.nvca.org).

Mergers & Acquisitions (M&As)

Data on total number of M&As are from Factset Mergerstat, deals include acquired company by location. Data on M&As are from Crunchbase.com. Crunchbase.com data tends to focus more on Innovation Economy companies and is less likely to capture mergers of financial holding companies.

INDICATOR 14: FEDERAL FUNDING FOR ACADEMIC AND HEALTH R&D

Federal Expenditures For Academic And Nonprofit Research And Development (R&D)

Data are from the NSF, "Federal obligations for research and development for selected agencies, by state and other locations and performer" (www.nsf.gov/statistics). Data used are the entries for federal funding for universities and nonprofits, excluding university and nonprofit federally funded research and development centers (FFRDCs).

National Institutes of Health (NIH) Funding per Capita, per GDP and Average Annual Growth Rate

Data on federal health R&D are from the NIH (http://report.nih.gov/award/). The NIH annually computes data on funding provided by NIH grants, cooperative agreements and contracts to universities, hospitals and other institutions. The figures do not reflect institutional reorganizations, changes of institutions, or changes to award levels made after the data are compiled. Population data are from U.S. Census Bureau (http://www.census.gov/popest/data/index.html). GDP data are from Bureau of Economic Analysis (bea.gov), U.S. Department of Commerce.

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INDICATOR 15: INDUSTRY FUNDING OF ACADEMIC RESEARCH

Data are from the NSF Survey of Research and Development Expenditures at Universities and Colleges and Survey of Research and Development Expenditures at Universities and Colleges, Business Financed Higher Education R&D Expenditures for S&E (http://www.nsf.gov/statistics/srvyrdexpenditures/). Since FY 1998, respondents have included all eligible institutions. Population data are from U.S. Census Bureau (http://www.census.gov/popest/data/index.html).

INDICATOR 16: VENTURE CAPITAL (VC)

Data for total VC investments, VC investments by industry activity, and distribution by stage of financing are provided by PricewaterhouseCoopers (PwC) in the MoneyTree Report (https://www.pwcmoneytree.com/MTPublic/ns/nav. jsp?page=historical). Industry category designations are determined by PwC. Definitions for the industry classifications and stages of development used in the MoneyTree Survey can be found at the PwC website (http://www.pwcmoneytree.com/moneytree/nav. jsp?page=definitions). GDP data are from Bureau of Economic Analysis (bea.gov), U.S. Department of Commerce.

PWC Stage Definitions: https://www.pwcmoneytree.com/MTPublic/ns/nav.jsp?page=definitions#stage

INDICATOR 17: EDUCATIONAL ATTAINMENT

For this indicator, the workforce is defined as the population ages 25-65. Data on educational attainment of this population are from the U.S. Census Bureau (http://www.census.gov/cps/data/cpstablecreator.html), Current Population Survey, Annual Social and Economic Supplement. Figures are three-year rolling averages. Data on employment rate by educational attainment are based on the full-time employment rate of the workforce.

High School Attainment by the Population Ages 19-24

Data on high school attainment are from the US Census Bureau, Current Population Survey (http://www.census.gov/cps/data/cpstablecreator.html), Annual Social and Economic Supplement. Figures are three year rolling averages.

College Degrees Conferred

Data for the U.S. states comes from the National Center for Education Statistics using the sum of all degrees conferred at the bachelor's level or higher.

INDICATOR 18: PUBLIC INVESTMENT EDUCATION

Per Pupil Spending in K-12

Public elementary & secondary school finance data are from the U.S. Census Bureau, Table 19, "Per Pupil (PPCS) Amounts and One-Year Percentage Changes for Current Spending of Public Elementary-Secondary School Systems by State". Figures are presented in current dollars. Data exclude payments to other school systems and non K-12 programs.

State Higher Education Appropriations per Full-Time Equivalent (FTE)

Data on public higher education appropriations per full-time equivalent (FTE) student is provided by the State Higher Education Executive Office (http://www.sheeo.org/finance/shef-home.htm). The data consider only educational appropriations—state and local funds available for public higher education operating expenses, excluding spending for research, agriculture, and medical education and support to independent institutions and students. The State Higher Education Finance Report employs three adjustments for purposes of analysis: Cost of Living Adjustment (COLA) to account for differences among the states', Enrollment Mix Index (EMI) to adjust for the different mix of enrollments and cost among types of institutions across the states' and the Higher Education Cost Adjustment (HECA) to adjust for inflation over time. More detailed information about each of these adjustments can be found on the State Higher Education Executive Officers (SHEEO) website.

INDICATOR 19: SCIENCE, TECHNOLOGY, ENGINEERING, AND MATH (STEM) CAREER CHOICES AND DEGREES

STEM Degrees

Data about degrees conferred by field of study are from National Center for Education Statistics (NCES), Integrated Postsecondary Education Data System (IPEDS) Completions Survey using the NSF population of institutions. Data were accessed through the NSF WebCASPAR (http://caspar.nsf.gov). Fields are defined by 2-digit Classification of Instructional Program (CIP), listed below.

- Biological & Biomedical Sciences
- Physical Sciences
- Computer & Information Science & Support Services
- Engineering
- Mathematics & Statistics

Science & Engineering Talent by Categories

Data for Science & Engineering (S&E) Talent are provided by the U.S. Census Bureau, Decennial Census and American Community Survey Public Use Microdata Samples (PUMS). A list of S&E occupations was divided into six categories: Computer, Physical Engineers, Design, Biological, Mathematics and Aerospace Engineers & Scientists. Design includes Designers and Artists & Related Workers. Both were added to the S&E occupations to try to capture the employment in Graphic Designers and Multi-Media Artists & Animators. According to BLS Occupation Employment Statistics (May 2009), both occupations represent almost 60 percent of employment in both Designers and Artists & Related Workers.

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Science & Engineering Doctorates

Data for S&E doctorates come from the Science and Engineering Doctorates report, table 9, published by the NSF.

INDICATOR 20: TALENT FLOW AND ATTRACTION

Relocations to LTS by College Educated Adults

Data on population mobility come from the U.S. Census Bureau, American Community Survey; Table B07009-Geographic Mobility in the Past Year by Educational Attainment, 1-year estimate. This is the number of people moving in and includes no information about the number moving out. It can be used as a measure of the ability to attract talent.

Net Migration

Net Migration figures are derived from the U.S. Census Bureau's population estimates program using annual data.

INDICATOR 21: HOUSING AFFORDABILITY

Housing Price Index

Housing price data are from the Federal Housing Finance Agency's Housing Price Index (HPI) (http://www.fhfa.gov/). Figures are four-quarter percent changes in the seasonally adjusted index. The HPI is a broad measure of the movement of single-family house prices. The HPI is a weighted, repeat-sales index that is based on repeat mortgage transactions on single-family properties whose mortgages have been purchased or securitized by Fannie Mae or Freddie Mac since January 1975.

Housing Affordability

Housing affordability figures are from the U.S. Census Bureau, American Community Survey, R2513: "Percent of Mortgaged Owners Spending 30 Percent or More of Household Income on Selected Monthly Owner Costs" and R2515: "Percent of Renter-Occupied Units Spending 30 Percent or More of Household Income on Rent and Utilities".

Median Household Income

Median household income data are from U.S. Census Bureau, American Community Survey, B19013: "Median Household Income in the Past 12 Months", 3-year estimate.

INDICATOR 22: INFRASTRUCTURE

Broadband Speed

Data are taken from Akamai Technologies State of the Internet Q1, 2017 report.

Industrial Electricity Rates

Data are taken from the U.S. Energy Information Administration, Average Retail Price of Electricity Annual Survey.

Median Commute Time

Data are taken from the U.S. Census Bureau American Community Survey County Level Statistics. Metro area median commutes were determined using the median commute time of each component county and its proportion of total metro area commuters. Only "Large Metro Areas", defined as having more than 250,000 commuters are included.

APPENDIX

The *Index* makes use of 4, 5 and 6 digit North American Industry Classification System (NAICS) codes to define key industry sectors of the Massachusetts Innovation Economy. The *Index's* key industry sector definitions capture traded-sectors that are known to be individually significant in the Massachusetts economy. Consistent with the innovation ecosystem framework, these sector definitions are broader than 'high-tech'. Strictly speaking, clusters are overlapping networks of firms and institutions which would include portions of many sectors, such as Postsecondary Education and Business Services. For data analysis purposes the *Index* has developed NAICS-based sector definitions that are mutually exclusive.

Modification to Sector Definitions

The 11 key industry sectors as defined by the *Index* reflect the changes in employment concentration in the Massachusetts Innovation Economy over time. For the purposes of accuracy, several sector definitions were modified for the 2007 edition. The former "Healthcare Technology" sector was reorganized into two new sectors: "Biopharmaceuticals, Medical Devices and Hardware" and "Healthcare Delivery." The former "Textiles & Apparel" sector was removed and replaced with the "Advanced Materials" sector. While "Advanced Materials" does not conform to established criteria, it is included in an attempt to quantify and assess innovative and high-growing business activities from the former "Textiles & Apparel" sector.

With the exception of Advanced Materials, sectors are assembled from those interrelated NAICS code industries that have shown to be individually significant according to the above measures. In the instance of the Business Services sector, it is included because it represents activity that supplies critical support to other key sectors. In the 2009 *Index*, the definition of Business Services was expanded to include 5511-Management of Companies and Enterprises. According to analysis by the Bureau of Labor Statistics, this category has at least twice the all-industry average intensity of technology-oriented workers. All time-series comparisons use the current sector definition for all years, and, as such, may differ from figures printed in prior editions of the *Index*. The slight name change in 2009 of the Biopharma and Medical Devices sector does not reflect any changes in the components that define the sector.

Advanced Materials

3133 Textile and Fabric Finishing and Fabric Coating Mills
3222 Converted Paper Product Manufacturing
3251 Basic Chemical Manufacturing
3252 Resin, Synthetic Rubber and Artificial and Synthetic Fibers and Filaments Manufacturing
3255 Paint, Coating and Adhesive Manufacturing
3259 Other Chemical Product and Preparation Manufacturing
3261 Plastics Product Manufacturing
3262 Rubber Product Manufacturing
3312 Steel Product Manufacturing from Purchased steel
3313 Alumina and Aluminum Production and Processing
3314 Nonferrous Metal (except Aluminum) Production and Processing

Biopharmaceuticals, Medical Devices & Hardware

3254 Pharmaceutical and Medicine Manufacturing
3391 Medical Equipment and Supplies Manufacturing
6215 Medical and Diagnostic Laboratories
42345 Medical Equipment and Merchant Wholesalers
42346 Ophthalmic Goods Merchant Wholesale
541711 R&D in Biotechnology
334510 Electro Medical Apparatus Manufacturing
334517 Irradiation Apparatus Manufacturing

Business Services

5411 Legal Services
5413 Architectural, Engineering and Related Services
5418 Advertising and Related Services
5511 Management of Companies
5614 Business Support Services

Computer & Communications Hardware

3341 Computer and Peripheral Equipment Manufacturing
3342 Communications Equipment Manufacturing
3343 Audio and Video Equipment Manufacturing
3344 Semiconductor and Other Electronic Component Manufacturing
3346 Manufacturing and Reproducing Magnetic and Optical Media
3359 Other Electrical Equipment and Component Manufacturing

Defense Manufacturing & Instrumentation

3329 Other Fabricated Metal Product Manufacturing
3336 Engine, Turbine and Power Transmission Equipment Manufacturing
334511 Search, Detection, Navigation, Guidance, Aeronautical and Nautical System and Instrument Manufacturing
334512 Automatic Environmental Control Manufacturing for Residential, Commercial and Appliance Use
334513 Instruments and Related Products Manufacturing for Measuring, Displaying and Controlling Industrial Process Variables
334514 Totalizing Fluid Meter and Counting Device Manufacturing
334515 Instrument Manufacturing for Measuring and Testing Electricity and Electrical Signals
334516 Analytical Laboratory Instrument Manufacturing
334518 Watch, Clock and Part Manufacturing
334519 Other Measuring and Controlling Device Manufacturing
3364 Aerospace Product and Parts Manufacturing

Diversified Industrial Manufacturing

3279 Other Nonmetallic Mineral Product Manufacturing
3321 Forging and Stamping
3322 Cutlery and Handtool Manufacturing
3326 Spring and Wire Product Manufacturing
3328 Coating, Engraving, Heat Treating and Allied Activities
3332 Industrial Machinery Manufacturing
3333 Commercial & Service Industry Machinery Manufacturing
3335 Metalworking Machinery Manufacturing
3339 Other General Purpose Machinery Manufacturing
3351 Electric Lighting Equipment Manufacturing
3353 Electrical Equipment Manufacturing
3399 Other Miscellaneous Manufacturing

Financial Services

5211 Monetary Authorities - Central Bank
5221 Depository Credit Intermediation
5231 Securities and Commodity Contracts Intermediation and Brokerage
5239 Other Financial Investment Activities
5241 Insurance Carriers

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5242 Agencies, Brokerages and Other Insurance Related Activities
5251 Insurance and Employee Benefit Funds
5259 Other Investment Pools and Funds

Healthcare Delivery

6211 Offices of Physicians
6212 Offices of Dentists
6213 Offices of Other Health Practitioners
6214 Outpatient Care Centers
6216 Home Health Care Services
6219 Other Ambulatory Health Care Services
622 Hospitals

Postsecondary Education

6112 Junior Colleges
6113 Colleges, Universities and Professional Schools
6114 Business Schools and Computer and Management Training
6115 Technical and Trade Schools
6116 Other Schools and Instruction
6117 Educational Support Services

Scientific, Technical & Management Services

5416 Management, Scientific and Technical Consulting Services
5417 Scientific Research and Development Services*
*Minus the portion apportioned to the Bio sector
5419 Other Professional, Scientific and Technical Services

Software & Communications Services

5111 Newspaper, Periodical, Book and Directory Publishers
5112 Software Publishers
5171 Wired Telecommunications Carriers
5172 Wireless Telecommunications Carriers (except Satellite)
5174 Satellite Telecommunications
5179 Other Telecommunications
5182 Data Processing, Hosting and Related Services
5415 Computer Systems Design and Related Services
8112 Electronic and Precision Equipment Repair and Maintenance

51913 Internet Publishing and Broadcasting and Web Search Portal

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