Re-Examining Maine's Economic Position, Innovation Ecosystem and Prospects for Growth in Its Technology-Intensive Industry Clusters

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Prepared for:
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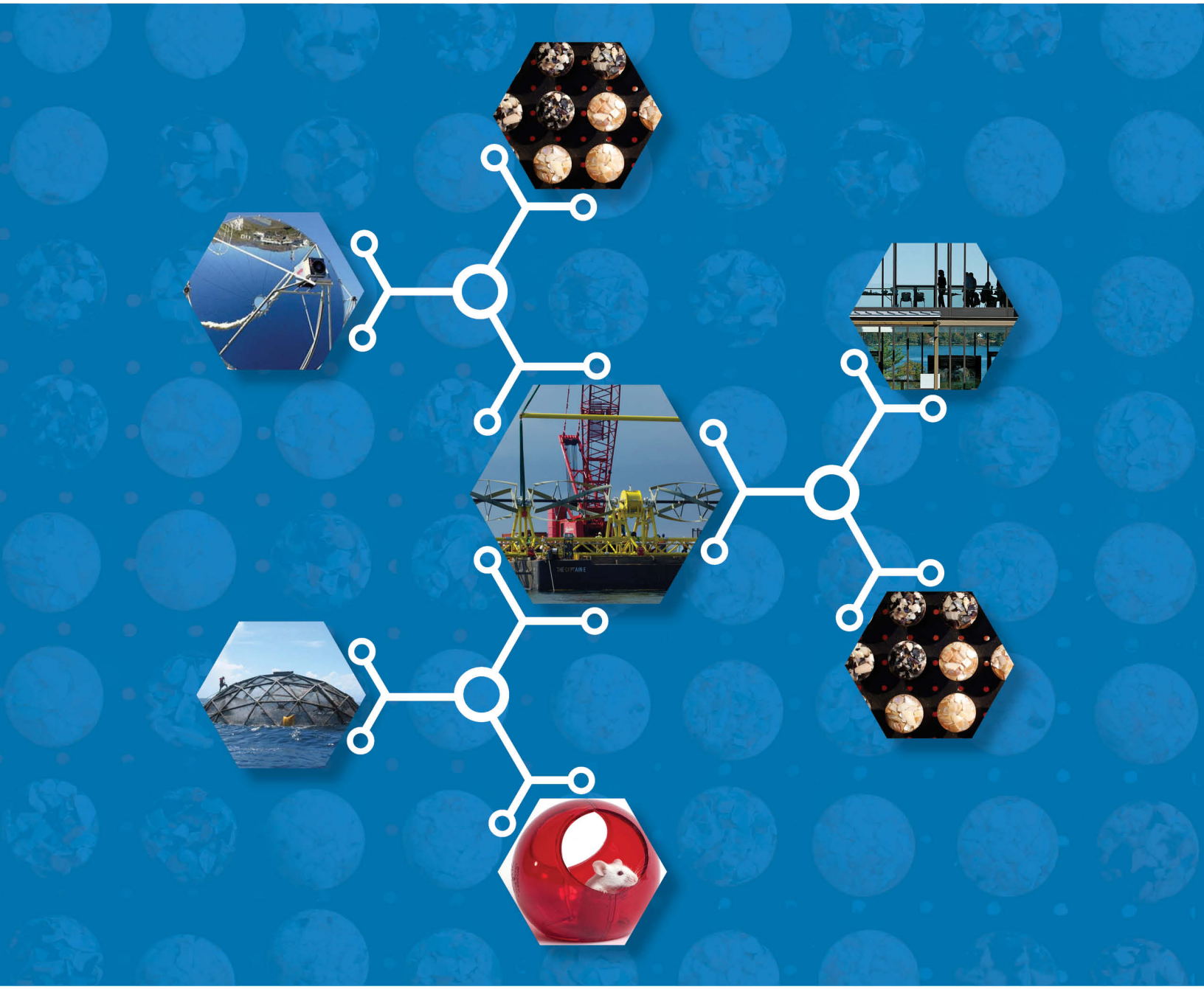
April 2014



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EXECUTIVE SUMMARY

Nearly five years after the Great Recession of 2008, the road to economic recovery has been sluggish nationwide – with employment and economic activity still below levels recorded before the severe recession hit. Of particular concern is that the growth in Maine, along with that of the rest of New England, continues to lag behind even the sluggish growth of the overall U.S. recovery. As the Federal Reserve Bank of Boston concluded at the end of 2013, "While New England's economy continued to make moderate advances in 2013, the region experienced smaller gains in economic activity than the nation."[1]

At the same time there is a growing recognition that economic challenges to advancing technology industries are rising. Increasing globalization, the fast pace of technological change, and the growing strength of developing nations in generating highly educated and skilled talent pose a threat to the economic competitiveness of all regions in the U.S.

This report was undertaken to provide the Maine Technology Institute (MTI) a forward-looking, comprehensive assessment on how Maine's technology industries are evolving and performing as drivers of economic growth. The report also assesses the gaps and weaknesses in Maine's "innovation ecosystem," which supports the ability of innovative firms to succeed in Maine.

This study had four specific objectives:

- ✓ Assessing the current position and recent trends in Maine's existing and emerging technology clusters based on industry performance and innovation capacity
- ✓ Identifying where Maine is positioned to grow in specific market niches relating to its existing and emerging technology clusters
- ✓ Assessing how the innovation ecosystem in Maine is currently advancing technology clusters in order to identify gaps and provide insights on how better to streamline, revamp, and integrate economic development efforts
- ✓ Developing forward-looking actions for MTI to further advance innovation, commercialization, and the overall strength of the state's existing and emerging technology-based industries.

To assist in this effort, the Battelle Technology Partnership Practice (TPP) was selected through a competitive process to conduct the analysis and offer insights into opportunities and actions needed to strengthen Maine's existing and emerging technology clusters. Battelle TPP is the economic development consulting arm of the world's largest independent non-profit research and development organization. Battelle TPP brings to this project a position as the national leader in advanced, technology-based and cluster-driven economic development practice with an established track record in developing and advising many of the most successful modern development programs in the U.S.

[1] Federal Reserve Bank of Boston, New England Economic Indicators, 4th Quarter 2013.

Identifying Specific Technology Clusters of Industries Driving Economic Growth in Maine

To effectively compete for innovation and technology development, it is well understood that each state has specific targeted economic drivers for innovation and economic growth. As the National Governor's Association set out in advising states across the nation on best practices for global competitiveness:

> *Each state must exploit the unique advantages it has relative to other states and build on the strengths found in its local "clusters of innovation"—distinct groups of competing and cooperating companies, suppliers, service providers and research institutions."*[2]

This focus on targeted economic drivers has been a hallmark of MTI's efforts and success over the years in investing in companies and technology development opportunities best positioned for commercialization and for new product and process development. In the legislation establishing the Maine Technology Institute, the State of Maine tasked MTI with focusing on seven broad targeted technology areas. These seven targeted technology areas are:

- Biotechnology
- Composites and Advanced Materials
- Environmental Technologies
- Forest Products and Agriculture
- Information Technology
- Marine Technology and Aquaculture
- Precision Manufacturing

While these targeted technology areas reflect where Maine is positioned to generate economic gains from the development and/or deployment of technologies, they are very broad categories that cut across many different industries in the state. For MTI to effectively consider how Maine's economy is recovering from the Great Recession, and as new growth opportunities in technology areas are emerging, it is important to conduct a more detailed examination of Maine's specific technology-related industry drivers found across the seven broad targeted technology areas.

In considering these more specific technology-related industry drivers found in Maine, it is now widely recognized in economic development best practice that individual industries that drive income and economic growth in a state do not stand alone, but are better understood as being part of a broader complex of industries that are inter-related, known as technology clusters. These technology clusters of inter-related industries provide a state with its unique competitive advantages, those most important in growing its economy. The growing importance of technology clusters for economic development is reflected in the emergence of the knowledge-based economy where technological advancements,

[2] National Governor's Association, "A Governor's Guide to Trade and Global Competitiveness," 2002.

innovation, and specialized skills have become pronounced factors for economic growth across both emerging and mature industries.

Of particular importance are those technology clusters that produce goods or services that generate new income flowing into the state – either by being exported outside of the state or by substituting for imports to the state – or what are commonly referred to as "*economic base industries."* These economic base industries generate the regional economic activity that supports "*sheltered*" or "*local serving*" industries that primarily serve the needs of the local population and business community, such as the local grocery or dry cleaners. While sheltered industries can involve the use of advanced knowledge and technologies, as is commonly found in local physician offices or local education providers, they depend upon the economic base industries to drive available incomes to support their services. Sheltered industries circulate the same dollars within the state, while economic base industries bring new dollars into the state and expand the state's economy.

A **technology cluster** is a grouping of industries that typically share common supply chains, markets, and technology competencies.

Battelle – in consultation with MTI and key stakeholders – identified thirteen specific technology clusters composed of the economic base industries that are currently driving the Maine economy across the seven broad technology targeted areas. Each technology cluster involves a grouping of industries that typically share common supply chains, markets, and technology competencies. These thirteen technology clusters are:

- Agriculture, Aquaculture, Fisheries and Food Production
- Alternative Energy and Turbines
- Biopharmaceuticals
- Boatbuilding and Related Industries
- Defense
- Electronics and Semiconductors
- Engineering and Other Scientific/Technical Services
- Environmental Services
- Finance and Business Support Services
- Forestry-Related Products
- Information Technology Services
- Materials for Textiles, Apparel, Leather and Footwear
- Medical Devices

The identification of the relevant Maine-specific technology clusters started with an analysis of all economic base industries in Maine that drive new income generation in the state and are aligned with the broad targeted technology areas, with a focus on understanding supply-chain inter-relationships and shared markets. The identification of technology clusters also involved a more detailed analysis of the

core technology competencies that link industries together. Core technology competencies reflect those detailed technology niches in which there is a "critical mass" of industry focus in the state. To understand the core technology competencies of Maine's industry, Battelle analyzed patent applications and awards associated with Maine inventors from 2008 to 2012. Patents represent the intellectual property being generated in Maine, and are a good means of identifying areas of critical mass in technology competencies being advanced specifically by Maine companies, universities, research institutions, and individual inventors. Battelle also considered the presence of emerging innovation companies found in Maine – those receiving Small Business Innovation Research (SBIR) funding and/or venture capital funding – across the patent innovation themes.

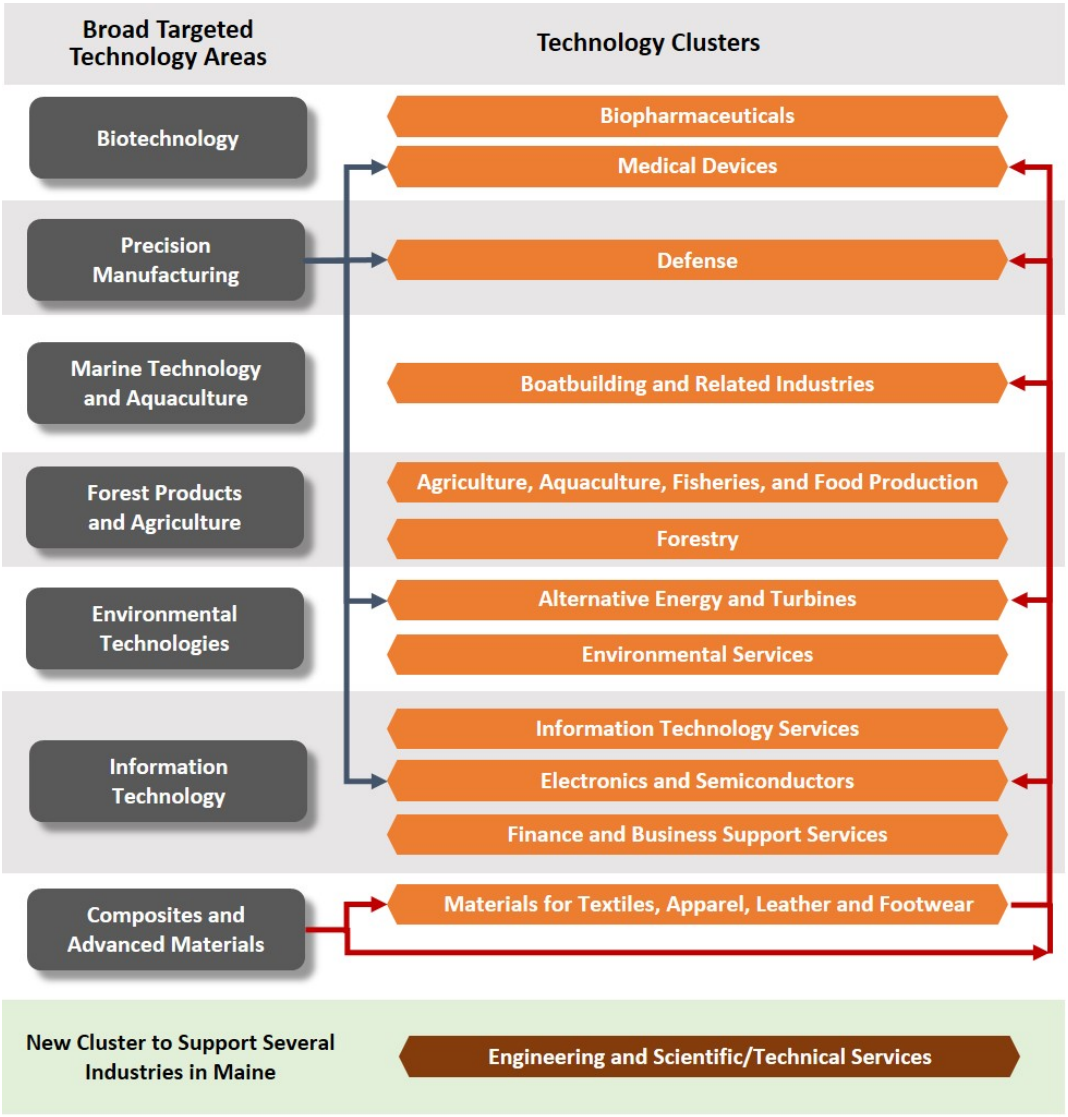
Three broad observations can be made in comparing the thirteen technology clusters identified as leading economic drivers for Maine to the broad targeted technology areas that define the technology focus of MTI's activities:

1. For the most part, the refreshed and more detailed technology clusters that were identified reflect a more distinct understanding of how the broad targeted technology areas in Maine are organized across industries from a market, supply chain, or technology driver perspective. Overall, eleven of the thirteen specific technology clusters that were identified map closely to one of the broad targeted technology areas.

2. Two specific technology clusters are characterized as more cross-cutting, and draw upon the technology know-how and/or markets found across a number of broad targeted technology areas. The Defense Technology cluster draws upon Maine's traditional technology strengths in precision manufacturing and in composites and advanced materials to serve our nation's military needs. The Engineering and Scientific/Technical Services technology cluster is an emerging set of industries that taps many of Maine's broad targeted technology areas and reflects a strong technology strength across the New England region.

3. Two of the broad targeted technology areas today are better understood as underlying technology strengths of Maine that support a number of specific technology clusters. In the case of the broad technology areas of both Composites and Advanced Materials as well as Precision Manufacturing, the pure-play industries typically found in those broad technology areas now have diminished. Still, the technology know-how and innovations present in those broad technology areas remain an important factor in Maine's competitiveness in many of the specific technology clusters, such as Boatbuilding and Related Industries, Defense, Alternative Energy and Turbines, and Electronics and Semiconductors.

Figure A. Mapping the Refined Technology Clusters for Maine across the State's Seven Broad Targeted Technology Areas



Note: Crosscutting targeted technology areas that impact several technology clusters include Precision Manufacturing and Composites and Advanced Materials.

Performance of Maine's Technology Clusters

The thirteen technology clusters shown in Figure A represent key drivers of economic activity and employment in the state of Maine. Thirteen of Maine's top fifty businesses, based on employment size, are found within these technology clusters, including Bath Iron Works, New Balance, and Anthem Health. As the core components of Maine's economic base industries, these thirteen technology clusters bring new income into the state and support economic activity across the state's economy. Battelle analyzed the economic impact of the thirteen technology clusters on the overall Maine economy and

found that the 84,305 jobs found in the thirteen technology clusters generate almost 100,000 additional total jobs in the state and generate over $15 billion in labor income.[3]

Given the major impact of these technology clusters on Maine's economy, a comprehensive assessment of the performance of these clusters is critical. While the generation of jobs is an important measure of success, there are many other measures of economic performance to be considered. Battelle analyzed the performance of Maine's technology clusters using eight performance criteria, including:

- Concentration of the technology cluster relative to the nation
- Job generation for the technology cluster
- Growth of the technology cluster relative to the nation
- Productivity
- Average wages
- Economic multiplier
- Projected national growth
- Position in the New England regional economy.

The definitions and importance of these measures is provided in the text box on the facing page.

Different individual technology clusters stand out because of a strong showing across the performance measures:

- Two technology clusters have no weak ratings across the eight performance measures
  - Biopharmaceuticals
  - Finance and Business Support Services
- Two technology clusters have only one weak rating across the eight performance measures
  - Agriculture, Aquaculture, Fisheries and Food Production
  - Alternative Energy and Turbines
- Four technology clusters have only two weak ratings across the eight performance measures
  - Boatbuilding and Related Industries
  - Engineering and Scientific/Technical Services
  - Environmental Services
  - Forestry.

[3] Battelle analyzed the economic impact of the 84,305 jobs in Maine's thirteen technology clusters using the IMPLAN model. Multiplier effects include the "induced" effects created by the in-state purchases of the industries analyzed and the "induced" effects of the resident incomes supported by these industries themselves and impacted industries.

Defining the Key Measures of Technology Cluster Performance for Maine

Relative concentration of the technology cluster – a measure of how specialized a technology cluster is in Maine relative to the nation, and so gauges "competitive advantage" for the technology cluster in Maine relative to the nation. The specific measurement of relative concentration is known as a location quotient. A location quotient is the share of Maine's employment found in a particular technology cluster divided by the share of total industry employment in that technology cluster for the nation. A location quotient greater than 1.0 indicates a higher relative concentration, whereas a location quotient of less than 1.0 signifies a relative underrepresentation. A location quotient greater than 1.20 denotes employment concentration significantly above the national average, and is considered "specialized".

Job generation for the technology cluster – a more straightforward measure of whether a technology cluster has been gaining or losing jobs in Maine.

Relative growth of the technology cluster – a measure of whether a local technology cluster is gaining or losing competitive share compared to the nation. It is measured as the difference between the percentage change in employment in a technology cluster in Maine minus the percentage change in employment in that same technology cluster for the nation.

Productivity – a measure of the economic output generated by each job. Comparing the level of productivity of Maine's technology cluster to its national level provides insights into whether the state's technology cluster is more or less productive, and therefore more or less competitive. Higher levels of productivity in Maine compared to national levels mean that, for each job, more economic output is generated; this suggests that the Maine technology cluster is better able to make use of advances in technology to produce goods and services and is able to produce more complex, higher value products.

Average wages of the technology cluster – a reflection of the overall quality of jobs found within a technology cluster. It is a measure that relates the contribution of the cluster to Maine's per capita income and ultimately to the economic well-being of the state. By comparing average wage levels across technology clusters, it is possible to learn which industries offer high-quality jobs. Average wage levels are measured by taking the total payroll reported by employers and dividing by the number of jobs. These data are reported by employers to federal and state agencies.

Economic multiplier of the technology cluster – a way to consider the broader economic impact of the cluster's economic activity on a local economy. Of particular importance for economic development is how inter-connected a technology cluster is to the broader regional (in this case New England) economy. These broader economic linkages consist of two types. The first type of local impacts consists of the presence of a local supply chain for that industry, often referred to as "indirect" impacts. Also important is the local income generated by an economic activity. Businesses pay wages and salaries to their workers, which are translated into local purchases of products ranging from housing, to medical care to groceries. These local income effects are termed "induced" impacts. Both the indirect and induced multipliers for each cluster were estimated using the IMPLAN input-output model of the inter-industry purchasing and income effects that occur on the national level. The model then considers the Maine industry structure in considering the opportunity for such inter-industry and personal consumption related purchases to happen in Maine. IMPLAN is one of the most widely used input-output models in the nation, and provides for each county in the nation its own customized input-output model based on national inter-industry purchases and the structure of the local industry base.

Projected national growth of the technology cluster – although past performance of technology clusters matters, it is critical also to have a view towards the expected future development of technology clusters. Of particular importance is whether technology clusters are expected to grow or decline in the next five to ten years. The long-term industry employment projection of national average annual employment growth developed by the U.S. Bureau of Labor Statistics (BLS) was used as the measure of national performance. The ten-year, long-term industry employment forecast generated by BLS has been a widely utilized tool for career guidance, educational and training program planning, and studying long-range employment trends. It is prepared every two years by BLS. The most recent period for which projections are available is for 2012 to 2022.

Position in the New England Regional Economy – since Maine is part of New England's dynamic regional economy, there are considerable economic linkages across these states. Understanding how Maine is positioned relative to other states in New England offers an important insight into the growth and development of its technology clusters. This measure considers Maine's position concerning the size of the cluster, level of cluster specialization, and the cluster's job generation, compared to the other New England states, for each of the thirteen technology clusters.

However, given the breadth of the performance measures in reflecting each technology cluster's strengths and weaknesses in the state, even those technology clusters doing well have a mixed economic performance profile within the cluster itself. The performance profile for each technology cluster – even those that generally are lagging across most of the performance measures – suggests how Maine might consider advancing the development of that cluster in the years ahead.

Battelle's insights into the development implications based on the technology cluster performance is set out below grouped into those well-performing technology clusters and those mixed-performing technology clusters.

Performance Profiles for Well-Performing Technology Clusters in Maine:

- ***Agriculture, Aquaculture, Fisheries and Food Production*** – This is a highly integrated technology cluster in Maine with strong supply-chain linkages and a sizable employment base of 10,352 jobs. This industry has shown promise in Maine with moderate job growth of 1.8% from 2007 to 2012, which slightly exceeds the average of 1.1% for the cluster nationally. Still, as an integrated technology cluster which runs from harvesting/fishing to processing, Maine is still not yet at national levels of employment concentration. By comparison, Maine still lags well behind the high specialization and strong growth found in Vermont, the leader in New England in this technology cluster. One particular sign of concern for Maine is its lower levels of productivity in this cluster relative to the nation, suggesting the need for more deployment of process technologies and for raising the value-added of its processing activities.
- ***Alternative Energy and Turbines*** – Although this is the smallest technology cluster in Maine, with just 948 jobs in 2012, it is one of the fastest growing with job gains of 11.9% from 2007 to 2012, and it is the most specialized with an impressive five times the national level of employment concentration. It also is one of the highest paying technology clusters in the state, with average annual wages of $74,091. The national growth prospects for this industry are strong and Maine appears to be well-positioned for growth. Both national and state policies and incentives are critical for the growth of this industry in Maine.
- ***Biopharmaceuticals*** – This technology cluster is performing particularly well in its recent employment growth compared to both the nation and the New England region, and also stands out in its future growth prospects. This future growth is particularly important for Maine given the cluster's high economic multiplier impacts in the state, reflecting both its high wages and good supply chain linkages. Still, it is only a moderately sized technology cluster in Maine, with just 3,950 workers, and lacks resources such as a strong academic medical center to help advance more translational and clinical research. Therefore, it is important to pursue efforts to connect Maine's biopharmaceuticals industry to the broader complex of academic resources found across New England.
- ***Boatbuilding and Related Industries*** – This is a specialized cluster in Maine, though it is one of the smaller clusters in the state, with1,003 jobs in 2012, and has undergone significant employment declines both in Maine and nationally from 2007 to 2012. Still, Maine's technology cluster appears to be competitive, with both lower declines in employment and higher productivity levels than those seen nationally. Looking to the future, national employment projections suggest only modest declines of 1% annually in the years ahead. This suggests this technology cluster, with its more competitive positioning, can perhaps hold its own and remain

a niche industry for Maine, though it is not expected to be a strong economic driver for the state.

- ***Engineering and Other Scientific/Technical Services*** – This is one of the moderately sized clusters in the state, with 3,928 jobs in 2012. Maine is gaining jobs in this technology cluster at a fast pace, with gains of 10.4% from 2007 to 2012 that more than doubled this cluster's national gains of 4.7%. This is most promising since future national projections suggest this will continue to be a high-growth industry, with expected annual average growth of 2.2% through 2022. Still, Maine is a follower in this technology cluster to Massachusetts, a national leader that appears to be driving the growth of this technology cluster for all of New England. This suggests that Maine needs to maintain close connections to this technology cluster at the regional level and find ways to competitively position itself to benefit from growth opportunities being driven by Massachusetts.
- ***Environmental Services*** – This is a smaller technology cluster, with 1,660 jobs in 2012, that is not yet specialized in Maine, but recording strong growth of 3.4% from 2007 to 2012 that outpaced the national growth of 1.7%. It is forecasted to continue to grow strongly at the national level with expected average annual growth of 2.6% through 2022. At the regional level, there appears to be a shift in this industry within New England, with Rhode Island and New Hampshire having gained employment, along with Maine, while the larger and more specialized states of Massachusetts and Connecticut lost employment from 2007 to 2012. This suggests that Maine needs to maintain close connections to this technology cluster at the regional level and find ways to competitively position itself to benefit from growth opportunities being driven by Massachusetts. One important competitive issue will be both national and state policies and incentives, according to industry stakeholders.
- ***Finance and Business Support Services*** – This is one of the largest technology clusters in Maine, with employment nearing 30,000. Maine also has significant momentum in this technology cluster, growing through the recession and economic recovery years of 2007 to 2012 even while the technology cluster's employment at the national and New England regional level declined and still remain below its 2007 levels. To continue to gain market share, Maine needs to be focused on growing talent, particularly for the more technical Information Technology jobs associated with this technology cluster.
- ***Forestry*** – This sizable technology cluster remains an anchor within Maine's economy, with 15,157 jobs in 2012, an industrial specialization that is three times the national level, and a high economic multiplier reflecting the most well-developed supply chain linkages among Maine's technology clusters. While employment declined from 2007 to 2012 in Maine and the U.S., the state appears highly competitive. Most outstanding is that Maine's productivity level for this technology cluster is 56% higher than the national average, suggesting that this industry is deploying technology and finding higher value-added at a level far greater than the industry across the nation. In addition, Maine's employment declines stood below that of the national average, and looking to the future national projections suggest small employment declines of less than 1% annually. So, while not a direct employment driver for the future, this competitive technology cluster remains important for Maine, and the continued output growth from the high productivity in this cluster adds significant value to Maine's economy through its supply chain linkages.

Performance Profiles for Mixed-Performing Technology Clusters in Maine:

- ***Defense*** – This is a sizable and specialized technology cluster in Maine, with 7,397 jobs in 2012, but a declining one. Even as employment in this industry grew from 2007 to 2012 nationally, it declined in Maine. Future prospects at the national level are not strong, with expected small annual employment declines of less than one percent through 2022. More importantly for Maine, this industry is driven by just a few major employers – including Pratt & Whitney and Electric Boat (General Dynamics) – and so the attention needs to be on ensuring their continued successful operations in the state.

  Despite the limited near-term growth prospects for this technology cluster, it is a viable target for state technology development efforts, because it is comprised of several of Maine's leading employers, it operates with strong linkages to the rest of the state's economy, and it generally pays high wages. As a result, efforts to stabilize the performance of this technology cluster even in the context of national declines represents an opportunity to protect and retain high wage employment opportunities both in this technology cluster itself and in its local supplier community.

- ***Electronics and Semiconductors*** – This is a smaller technology cluster, with 2,055 jobs in 2012, that is not specialized in the state and lost jobs faster in Maine than nationally from 2007 to 2012. Future employment prospects at the national level are weakly negative with expected annual average declines of 1.3% through 2022.

  Still, this technology cluster is led by major companies with operations in Maine, particularly Fairchild Semiconductor Corporation and Texas Instruments. Similar to the Defense technology cluster, the attention needs to be on ensuring that these major employers have continued successful operations in the state.

- ***Information Technology Services*** – This is a moderately sized technology cluster in Maine, with 4,065 jobs in 2012, but is surprisingly a declining one, with job losses of 11.1% from 2007 to 2012, despite strong national growth of 16.4% and growing employment levels for all of the other New England states during that same period.

  Still, this industry's national growth projections are outstanding at over 3% average annual growth through 2022 and it is a high wage technology cluster in Maine, with average annual wages of $73,168 in 2012. So this technology cluster is hard to ignore, but clearly struggling in Maine. Perhaps this cluster is best viewed for Maine as a critical enabler to the state's Finance and Business Support Services technology cluster. They share a need for specialized talent and many of the growth opportunities are in related markets.

- ***Materials for Textiles, Apparel, Leather and Footwear*** – This is a moderately sized technology cluster in Maine, with 4,194 jobs in 2012, and is highly specialized with over two times the national average concentration in the state.

  While a declining technology cluster in Maine and nationally, it is a competitive cluster in Maine with productivity standing 3% higher in the state than in the nation, and job losses at a much lower level from 2007 to 2012 than nationally. Still, the national projections are for continued major employment declines of more than 3% annually through 2022. So, while a clear niche for Maine, this technology cluster will not be a strong economic driver.

- ***Medical Devices*** – This is a small technology cluster, with total employment of 1,036 in 2012, and a much lower level of industry concentration found in Maine than in the nation (unlike the Biopharmaceuticals cluster, which is specialized in Maine).

  While Maine has enjoyed job gains mirroring the national average of 1.5% from 2007 to 2022, this cluster in Maine has a low level of productivity and low average salary of $44,602. Future national employment projections are forecasted to be relatively flat with average annual declines of less than 0.5% through 2022. So this technology cluster is not expected to be a major economic driver for the state. Still, across New England Medical Devices are an industry specialization, led by large and highly specialized technology clusters in Massachusetts and Connecticut. From an economic development perspective, it appears that Maine needs to maintain close connections to this technology cluster at the regional level – especially to fill in a lack of translational and clinical research drivers in the state – and continue to look for ways to competitively position itself within the region.

More Targeted Focus on Line of Sight to Growth Opportunities

This report also examines where Maine is positioned for targeted growth opportunities over the next three to five years by applying a "line of sight" analysis to market opportunities. This line of sight analysis examines the focus areas of strength in Maine today based on the detailed industry strengths found within each technology cluster, together with a forward-looking assessment of core technology competencies based on the patent cluster analysis developed for this study (see Figure B).

Figure B. Identification of Growth Opportunities based on Target Product/Service Markets and Presence of Core Technology Competencies

While the thirteen technology clusters in Maine are economic drivers for the state, they vary considerably in how they are positioned for economic and employment growth. More importantly, even in technology clusters that were hard hit by the recession, key component industries or sub-sectors may offer important growth opportunities, even when the overall technology cluster has limited overall growth potential based on national or international economic trends. As a result, it is important to analyze Maine's technology clusters in more depth to examine how they are positioned.

Battelle reviewed each of the thirteen technology clusters using three key steps to identify likely growth opportunities:

- **Step One:** Identified, for each of the 13 technology clusters, those detailed product/service markets in which Maine has a strong or growing presence and are economic drivers. In this context, a detailed product/service market is defined very narrowly in order to be able to specifically identify the high-performing detailed industries within a cluster.
- **Step Two:** Assessed how these detailed product/service market drivers align with technology competencies or specific assets found in Maine.
- **Step Three:** Surveyed market research studies at the detailed industry and project level to identify, for the most attractive product/service market opportunities, the market growth potential and critical technology and market advances required.

From this three-step process, Battelle identified a promising set of growth opportunities that take advantage of Maine's position over a range of detailed product/service markets over the next several years. These growth opportunities range from those that draw upon technology competencies in Maine, such as turbine-powered energy and molecular-based diagnostics, to those that build upon assets found in Maine that have fueled traditional industries, such as aquaculture and functional foods.

These identified **detailed product/service market growth opportunities** across Maine's thirteen technology clusters include:

- Aquaculture
- Electronic components
- Engineering services
- Enterprise and data hosting services
- Financial transaction processing and telemarketing
- Functional foods
- Molecular-based diagnostics and genomics
- Remediation and environmental consulting
- Turbines for energy production
- Wireless sensor networks.

Assessment of Maine's Innovation Ecosystem

Economic development is not easy to achieve in general, while technology-based economic development is an even greater challenge. For economic development to occur an entire inter-connected sequence of positive factors has to be in place. For development of technology-based business sectors the chain of factors is particularly complex and challenging to develop and manage. If any link in the chain in missing, a sustainable technology cluster is unlikely to develop.

For this assessment of Maine, Battelle considered three broad areas that encompass the key functional areas involved in technology development, including:

- Research and Development – including basic and applied research through the process of technology transfer
- Commercialization/Market Entry – focusing on product development, new business formation, and access to capital
- Growth/Scalability – involving the range of issues for growing, retaining, and attracting technology companies to Maine and advancing overall technology clusters

This assessment relied on several sources, including the following:

- Analysis of available databases on Maine's activities in R&D, venture funding, SBIR awards, STEM (science, technology, engineering and math) occupations, entrepreneurial activities, business tax climate, and broadband technology infrastructure
- Detailed interviews conducted with over 20 Maine stakeholder groups and individuals representing a cross-section of the broad targeted technology areas
- Results from a Maine Department of Economic and Community Development survey of companies receiving assistance from MTI.

The analysis of available databases on Maine's key factors shaping technology development suggests the following:

- The state's university and industry levels of research and development are still well behind the national average per capita, but are growing. In particular, growth in Maine's university research expenditures has significantly outpaced the nation's since 2001, growing by 90 percent, compared to 73 percent nationally.[4]
- New business start-up levels in Maine are higher than those in other New England states but lag the national average. Where Maine appears to fall short compared to other New England states is in high-growth small businesses.
- Formal venture capital funding in Maine has increased since 2007, while it has declined nationally, but its level remains well behind other New England states and the national average.
- Maine is also lagging in federal SBIR awards to innovative small business.

[4] Battelle analysis of National Science Foundation data.

- While high-skilled talent specializations are limited, Maine has been recording strong growth in high-skilled occupations.
- Maine's general business tax climate falls in the middle range of states across the U.S., and within New England it is neither the lowest nor the highest.
- Broadband technology infrastructure, involving the adoption and download speeds of broadband, is at about the national average for Maine, but lags other New England states.

From the more qualitative information garnered through the stakeholder interviews and company survey results, a number of gaps were identified across the innovation ecosystem in Maine. These gaps, which point to possible areas for future program efforts by MTI, include the following:

- Lack of a connection between Maine's base of industry and university based research capabilities
- Maine has successfully increased the level of support for entrepreneurial activity in urban areas, but there exists unmet needs in rural areas
- Technology based development in Maine is hampered by a lack of access to capital and a shortage of skilled labor.

In order for the state to achieve success in its technology-based development efforts, there is general consensus among the key stakeholders interviewed that:

- Efforts to link the industry-driven research base in the state to the targeted technology clusters are critical
- Continued investments in entrepreneurial development remain important
- Cluster-based initiatives to enhance access to capital and promote talent generation will be vitally important.

Implications for the Future

This refined analysis of technology industries, together with the assessment of Maine's innovation ecosystem, points to some important implications for MTI going forward. The analysis points to five major implications for MTI to consider as it moves forward in the years to come relating to either supporting technology cluster development in Maine or to strengthening the broader innovation ecosystem in Maine, as summarized below.

Implications Focused on Supporting Technology Cluster Development in Maine

Implication #1: The use of specific technology clusters offers insights into industries driving Maine's economy and growth opportunities.

Efforts in the past have focused on the seven broad targeted technology areas, but this analysis shows that a more precise examination of technology clusters focused on industries that typically share common supply chains, markets, and technology competencies can offer more helpful insights into how Maine's technology-related economy is performing and a more refined line of sight to growth opportunities. For example, within the Agriculture, Aquaculture, Fisheries and Food Production cluster further engagement on aquaculture is indicated, but MTI may also consider advancing functional foods, linking its wild blueberry production with its traditional frozen food industry. Furthermore, even within struggling technology clusters in Maine, such as Information Technology Services, there are promising opportunities. In this case the continued rapid adoption of IT into the Finance and Business Support Services cluster provides a more effective driver for Maine to take advantage of the high projected national growth in areas such as financial transaction processing.

Implication #2: Raising productivity is a crosscutting challenge for nearly all of Maine's technology clusters and can lead to higher wages, helping to address the lower average wages found in Maine's technology clusters compared to the nation and the New England region.

Maine's level of productivity – a key measure of technology deployment and activities in higher value-added products – stands generally well below the U.S. average. Only three of the thirteen technology clusters outpace the U.S. average in productivity, most notably Forestry-related Products, with productivity which is 56 percent higher in Maine than the U.S. average. Not surprisingly, Maine's average wages are below the U.S. average for twelve of the thirteen technology clusters, and only exceed the U.S. average for the Forestry-related Products. This partially reflects the lower cost of living in Maine, but also reflects the generally lower productivity of Maine's technology clusters. Increased productivity increases the wealth and value of the companies in a cluster, and usually results in increased wages, as some of the increased wealth is passed on to employees. While increased productivity does not guarantee increased wage levels, it is a necessary component.

What will be critical for raising productivity levels is addressing the deployment of technology as well as raising the value-added to the goods and services being produced in Maine across its technology clusters.

Implication #3: Technology cluster development in Maine needs to continue to find the right balance between defined measurable projects to realize growth opportunities and broader outreach, increased innovation, and networking to create a more closely knit and collaborative business environment.

Often there is a common tension in technology cluster development on whether to support projects involving a group of companies within a technology cluster or to support the industry or trade organizations that help to bring the cluster together through networking and broader outreach. This tension is clearly articulated in a case study of Arizona's cluster activities in the 1990s by Mary Jo Waits, currently Division Director of Economic, Human Services and Workforce at the National Governors Association: "During the early years of strategy implementation, the focus was on keeping the cluster organizations together, connected to each other, and visible to economic development organizations and the broader community … Arizona economic development leaders soon learned, however, that such intelligence might be moot without the ability to modify services accordingly, provide them in a timely holistic manner, and reach enough firms to make an impact. In other words, the full formula to help firms compete in global markets is the identification of their needs *plus* development of an effective system for meeting their needs." [5]

From the stakeholder discussions, it is clear that there is an uneven pattern to the organizational engagement across the broad targeted technology areas in Maine. In some cases, too few resources and too little attention have been paid to particular technology clusters. In other cases, Maine might actually have too many industry groups, none of which has sufficient resources to support the needed networking services for the industry. This uneven infrastructure can inhibit the ability of MTI to advance needed collaborative efforts.

As MTI seeks to be more pro-active in pursuing growth opportunities in the state, rather than expending resources addressing a multitude of different industry groups' requests and needs, some of which may duplicate others, MTI may find it useful to offer a more centralized "shared" service. The mission of this shared service would be to offer a suite of resources – such as web site development, mailing capacity, company directories, and production of materials – that can support multiple industry networking efforts. The users of this service could come and go as MTI probes the opportunities to realize the potential for growth opportunities set out in this report and others that it identifies over time. These industry networking efforts would typically need a facilitator that could be jointly supported through MTI and industry organizations. This can allow MTI to be agile in its industry consortium work, while acknowledging that while industry

[5] Mary Jo Waits, The Added Value of the Industry Cluster Approach to Economic Analysis, Strategy Development, and Service Delivery, *Economic Development Quarterly*, February 2000, page 47

organizations need to identify the efforts needed to move forward, they cannot always self-organize.

Implications Focused on Strengthening Maine's Broader Innovation Ecosystem

Implication #4: Regional context matters.

Many of the refined technology clusters within Maine's broad targeted technology areas are not strong in Maine and need to be connected to regional efforts for development. Where Maine is not a regional leader but is rather either a regional player or regional follower, simply trying to grow these technology clusters outside of the regional context will be difficult. Efforts to advance improved supply chains, talent development, and technology advancements outside of the broader New England states will not be as successful as looking to work on a multi-state basis. This does not necessarily mean having to create government-to-government collaborations. Instead, it is more about how to work across the industrial base found in New England. Regional approaches are also needed to address some of Maine's most difficult ecosystem challenges:

- Financing challenges, particularly for emerging biopharmaceutical and Information Technology services firms, where Maine is a regional player and regional follower, respectively, requires leveraging the private financial institutions that are more prevalent in other New England states . A more regional approach to engaging existing regional financial institutions to support the later stages of financing needs in Maine would greatly compliment MTI's efforts in early stage development and commercialization and is more realistic than Maine establishing its own private financial institutions.
- Entrepreneurial/C-level management talent is another opportunity area for Maine to tap the expertise found across New England. Interestingly, technology organizations in other states that are focused on growing start-up ventures have hit upon a strategy of rooting an emerging company's operations locally but bringing in experienced management talent from outside of the state to see the company through its later stages of development. This is now being done by the Louisiana Fund and the Virtual Incubator Company in Arkansas.
- Talent development may also offer opportunities. Many other New England states that are regional leaders or regional players in specific technology clusters have developed more advanced university programs and research capabilities. There is no reason not to seek ways to collaborate. This is already being done in Maine through its collaborations with the University of Massachusetts, Lowell's advanced materials programs. Universities, even public ones, do not see state boundaries as they advance industry partnerships. Creating collaborations through multi-institutional research institutes might be a way to also establish greater strengths in Maine's universities in areas that are lacking today.

Implication #5: The lack of emerging companies' ability to scale is a critical gap across Maine's innovation ecosystem which must be addressed.

MTI has done an excellent job in its technology development efforts in generating "more shots on goal" through its early-stage investment and commercialization assistance efforts. This is critical to having an effective innovation ecosystem and must diligently be pursued.

Still, MTI may need to consider how to address, on its own or in partnership with other development organizations in the state, the critical factors holding back the ability of companies to scale. Noted from the stakeholder interviews and DECD survey of MTI-assisted companies were the following key factors holding back the ability of emerging technology companies to scale:

- Access to capital, particularly later stage venture capital ($750,000 to $5 million) and expansion capital for equipment
- Finding the right workers, which combines needs for both specific skills and experience
- Reaching markets.

Some of these issues can be addressed through regional New England approaches, but state efforts targeting incentives and programs to grow the talent base and focusing more on opening markets for targeted product markets are crucial. Together these implications can help guide the next generation of activities of MTI by reflecting the new economic realities facing the state, the line of sight to new growth opportunities, and the situation confronting its overall innovation ecosystem.

TABLE OF CONTENTS

LIST OF TABLES

Page

LIST OF FIGURES

Page

INTRODUCTION

The Maine Technology Institute (MTI) was formed in 1999 to foster and accelerate innovation and growth of Maine's technology industries into thriving technology clusters. A hallmark of MTI's efforts and success over the years has been bringing a focus on those industries and technology opportunities best positioned for commercialization, new product and process development and ultimately high quality job creation in Maine.

The time is now critical for a refreshed examination of Maine's technology-industry drivers and their growth opportunities. The last time a comprehensive analysis of Maine's technology- clusters, innovation ecosystem and growth opportunities was undertaken in 2008, just as the most severe recession since the Great Depression of the 1930s was beginning to take hold.

Nearly five years after this recent recession, the road to economic recovery has been sluggish nationwide – with employment and economic activity still below that recorded before the severe recession hit. Of particular concern is that Maine, along with the rest of New England, continues to lag behind even the sluggish growth of the overall U.S. recovery. As the Federal Reserve Bank of Boston concludes at the end of 2013, "While New England's economy continued to make moderate advances in 2013, the region experienced smaller gains in economic activity than the nation."[6]

Maine Technology Institute's Legislative Charge

The 1999 legislation creating MTI charged it with the mission to "promote, stimulate and support research and development activity leading to the commercialization of new products and services in Maine's technology-intensive sectors to increase the likelihood that one or more of the sectors will develop into an economic cluster of activity."

At the same time there is a growing recognition that the economic challenges to advancing technology industries are rising. Increasing globalization, the fast pace of technological change, and the growing strength of developing nations in generating highly educated and skilled talent are threatening the economic competitiveness of all regions in the U.S. As the 2013 report by the National Research Council Report, *Rising to the Challenge*, notes:

> *U.S. regional economies face mounting global competitive challenges. No longer do U.S. states and cities primarily compete among themselves for talent, investment, and entrepreneurs in technology industries. They also compete against [foreign] national and regional governments that are executing comprehensive strategies that seek to create innovation clusters in many of the same important, emerging industries.*[7]

Competing in the 21st Century Global Knowledge-Based Economy

While the bar for advancing innovation-based, competitive industries has been raised, the fundamentals for competing in today's 21st century global, knowledge-based economy remain the same. To effectively

[6] Federal Reserve Bank of Boston, *New England Economic Indicators, 4th Quarter 2013*.

[7] Charles W. Wessner and Alan Wm. Wolff, Eds. *Rising to the Challenge: U.S. Innovation Policy for the Global Economy*. 2012. The National Academies Press, Washington, DC., page 431

compete for innovation and technology development, it is well understood that each state has specific targeted economic drivers for innovation and economic growth. As the National Governor's Association set out in advising states across the nation on best practices for global competitiveness:

> "*Each state must exploit the unique advantages it has relative to other states and build on the strengths found in its local "clusters of innovation"—distinct groups of competing and cooperating companies, suppliers, service providers and research institutions*."[8]

This focus on targeted economic drivers has been a hallmark of MTI's efforts and success over the years in investing in companies and technology development opportunities best positioned for commercialization and for new product and process development. In the legislation establishing the Maine Technology Institute, the State of Maine tasked MTI with focusing on seven broad targeted technology areas. These seven targeted technology areas are:

- Biotechnology
- Composites and Advanced Materials
- Environmental Technologies
- Forest Products and Agriculture
- Information Technology
- Marine Technology and Aquaculture
- Precision Manufacturing

While these targeted technology areas reflect where Maine is positioned to generate economic gains from the development and/or deployment of technologies, they are very broad categories that cut across many different industries in the state. For MTI to effectively consider how Maine's economy is recovering from the Great Recession, and as new growth opportunities in technology areas are emerging, it is important to conduct a more detailed examination of Maine's specific technology-related industry drivers found across the seven broad targeted technology areas.

Of particular importance are those technology clusters that produce goods or services that generate new income flowing into the state – either by being exported outside of the state or by substituting for imports to the state – or what are commonly referred to as "*economic base industries"*. These economic base industries generate the regional economic activity that supports "*sheltered*" or "*local serving*" industries that primarily serve the needs of the local population and business community, such as the local grocery or dry cleaners. While sheltered industries can involve the use of advanced knowledge and technologies, as is commonly found in local physician offices or local education providers, they depend upon the economic base industries to drive available incomes to support their services. Sheltered industries circulate the same dollars within the state, while economic base industries bring new dollars into the state and expand the state's economy.

[8] National Governor's Association, "A Governor's Guide to Trade and Global Competitiveness," 2002

It is also critical to focus on those areas of industry development where a state's industry and research base is positioned to build specialized areas of expertise where it can be a world leader. The ability of a region to lead in technology innovation and deployment in particular areas of industry is becoming a critical and defining driver of economic competitiveness. It is at the intersection between technology cluster development and the advancement of specialized areas of technology know-how that competitive advantage is defined to fuel future growth. As Michael Best, a leading scholar chronicling the growth and development of industries across states and broader regions, explains in *The New Competitive Advantage:*

> "*[Each state and regional economy] can be thought of as developing specialized and distinctive technology capabilities, which give them unique global market opportunities. The successful pursuit of these market opportunities in turn reinforces and advances their unique regional technological capabilities. Regional specialization results from cumulative technological capability development and the unique combinations and patterns of intra- and inter-firm dynamics that underlie enterprise and regional specialization*." [9]

From a state economic development perspective, specialized know-how can be identified where there is a "critical mass" of expertise and activities across product development and productivity in industry as well as research activities in universities, hospitals, and non-profit research centers. As defined by Gary Hamel and C.K. Prahalad in *Competing for the Future*,[10] a "competence is a bundle of skills and technologies representing the sum of learning across individual skill sets and organizational units."

In today's global, knowledge-based economy, it is particularly important to recognize that all economic base industries that face global competition are increasingly competing through improved processes and products requiring technology advances and deployment. So, the advancement and deployment of technology is critical for more mature and established industries, and not just for emerging technology industries. Consider that more than six of every ten IT workers are employed outside of computer and telecommunications industries, with high concentrations found in finance, insurance, logistics, and manufacturing. Similarly, the employment of other key technology-related occupations is distributed across the broader economy. For example, 69 percent of engineers are employed outside of the professional, scientific, and technical services sector, with their employment distributed across a broad spectrum of industries. In fact more engineers are employed in the manufacturing sector, 34 percent of all engineers, than in the professional, scientific, and technical services sector, 31 percent. Moreover, established products such as energy, industrial machinery, plastics, and measuring and control devices have growing high-technology content embedded in them and their production processes.

By linking a state's core technology competencies to its technology clusters, it is possible for the state to identify how to position an existing technology cluster for future development and to identify the potential for advancing emerging technology clusters. Bringing together an assessment of where

9 Michael Best, *The New Competitive Advantage*, Oxford University Press, 2001.

10 G. Hamel and C.K. Prahalad. *Competing for the Future*. Harvard Business School Press: Boston, MA, 1994, pp. 90 and 217.

Maine's technology industry base stands today across existing and emerging technology clusters with an assessment of how it is positioned for future growth offers a "line of sight" to growth opportunities.

Report Purpose and Objectives

This report was undertaken to provide the Maine Technology Institute (MTI) a forward-looking, comprehensive assessment on how Maine's technology industries are evolving and performing as drivers of economic growth. The report also assesses the gaps and weaknesses in Maine's "innovation ecosystem", which supports the ability of innovative firms to succeed in Maine.

To assist in this effort, the Battelle Technology Partnership Practice (TPP) was selected through a competitive process to conduct the analysis and offer insights into opportunities and actions needed to strengthen Maine's existing and emerging technology clusters. Battelle TPP is the economic development consulting arm of the world's largest independent non-profit research and development organization. Battelle TPP brings to this project a position as the national leader in advanced, technology-based and cluster-driven economic development practice with an established track record in developing and advising many of the most successful modern development programs in the U.S.

The specific objectives of this study include:

- ✓ Assessing the current position and recent trends in Maine's existing and emerging technology clusters based on industry performance and innovation capacity;
- ✓ Identifying where Maine is positioned to grow in specific market niches relating to its existing and emerging technology clusters;
- ✓ Assessing how the innovation ecosystem in Maine is currently advancing technology clusters in order to identify gaps and provide insights on how better to streamline, revamp, and integrate economic development efforts; and
- ✓ Developing forward-looking actions for MTI to further advance innovation, commercialization, and the overall strength of the state's existing and emerging technology-based industries.

In presenting the findings of this forward-looking assessment of Maine's technology clusters, the report is organized into six sections:

- Section I identifies the specific technology clusters driving Maine's economy today.
- Section II, then, considers how these technology clusters are performing across a comprehensive set of measures.
- Section III focuses on where Maine's technology-based economy is positioned for growth through an assessment of specific product/service market strengths and core technology competencies found in Maine's economy, the state's position in the critical development assets needed to advance and sustain growth, and the strengths and weaknesses of Maine's innovation ecosystem, and develops a line of sight analysis.
- Section IV addresses the implications of the report's findings and suggests approaches for MTI to advance technology-based economic development in Maine.

SECTION I:
IDENTIFYING SPECIFIC TECHNOLOGY CLUSTERS DRIVING ECONOMIC GROWTH IN MAINE: A REFRESHED AND REFINED EXAMINATION OF MAINE'S BROAD TARGETED TECHNOLOGY AREAS

The concept of industry clusters has been present in economic theory for many decades, but has only taken hold as a best practice for economic development in the past two decades. The growing importance of industry clusters for economic development reflects the emergence of the knowledge-based economy where technological advancements, innovation, and specialized skills have become pronounced factors for economic growth across both emerging and mature industries. The National Research Council identifies technology clusters or innovation clusters as "localized groups of companies developing creative products and services within an active web of collaboration that includes specialized suppliers and service providers, universities, and research institutes and organizations [that are] now widely associated with higher levels of economic growth and competitiveness."[11] According to the NRC report, "at present, most state and regional development efforts in technology-intensive industries are based on cluster formation."[12]

Approach to Identifying Specific Technology Clusters of Industries Driving Economic Growth in Maine

In consultation with MTI – including its board and key stakeholders – Battelle identified the technology clusters that are currently driving the Maine economy by augmenting traditional regional economic analysis with a more forward-looking view on the core technology competencies found across Maine's industry.

The traditional regional economic analysis employed a rigorous, data-driven process that examined:

- How Maine's industry structure was evolving at the most detailed industry levels (6-digit NAICS) to understand specific economic base industry activities based on size, relative concentration/specialization, and recent trends, particularly against national performance;
- The activities of leading firms in specific economic base industries, learned by leveraging information from corporate databases, visiting company websites, and calling companies to understand their products, services, and applied technologies and where they fit relative to other related companies in the state; and
- Supply chain relationships using the IMPLAN input/output model for Maine to learn about key inter-relationships between the detailed industries found in Maine.

[11] National Research Council, Best Practices in State and Regional Innovation Initiatives: *Competing in the 21st Century*, 2013.

[12] *IBID*, p. 33.

The concept of core competencies, meanwhile, is now widely understood as a critical factor by which industry advances competitive advantage. Gary Hamel and C.K. Prahalad in their landmark study, *Competing for the Future,* explain how a focus on core competencies can improve competitiveness:

> "To successfully compete for the future…requires top management to conceive of the company as a portfolio of core competencies rather than a portfolio of individual business units…core competencies are the gateways to future opportunities."[13]

From a state and regional economic development perspective, core competencies represent a "critical mass" of know-how found in industry. Linking core competencies to strengthen existing targeted technology areas is important, but it is also the case that it is from core competencies that gaining a position in knowledge and technology driven markets can best be realized. To understand the core technology competencies of Maine's industry, Battelle analyzed patent applications and awards associated with Maine inventors from 2008 to 2012. Patents represent the intellectual property being generated in Maine, and are a good means of identifying areas of critical mass in technology competencies being advanced specifically by Maine companies, universities, research institutions, and individual inventors. Battelle also considered the presence of emerging innovation companies found in Maine, receiving Small Business Innovation Research funding and venture capital funding, across the patent innovation themes. See Appendix A for the results of the core competency analysis.

From Broad Targeted Technology Areas to More Refined Technology Clusters

Within each state, technology clusters come in many varieties. Many technology clusters share a common market that they serve through their supply chain, while others draw on the natural resource endowments of a state or region in which they are located. Increasingly, technology clusters are based more on shared "know-how" involving core technology competencies to advance competitive advantage that leads to growth in the global marketplace.

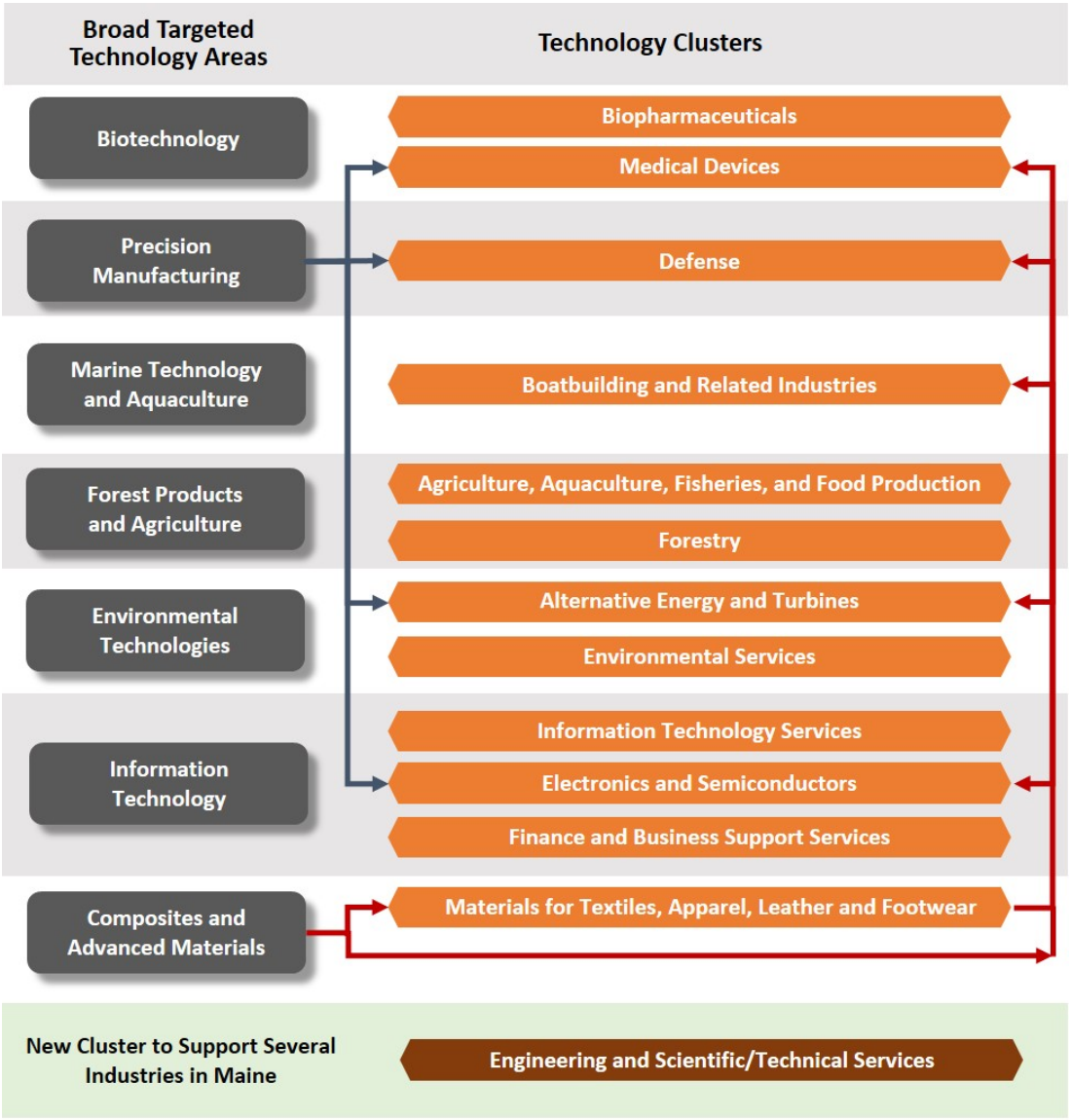
The analysis undertaken by Battelle suggests that within the existing seven broad targeted technology areas that MTI is charged with advancing, there is a more refined set of thirteen technology clusters driving Maine's economy today. Figure 1 depicts how the more refined technology clusters for Maine relate to the existing seven broad targeted technology areas. The rationale for analyzing these specific technology clusters is based on the post-recession changes occurring in the Maine and national economy as well as the broader industry and technology strengths found in the state. Appendix A provides a detailed description and overview of each of these technology clusters and Appendix B lists the detailed industries encompassing each technology cluster. The thirteen refined technology clusters, include:

- Agriculture, Aquaculture, Fisheries and Food Production
- Alternative Energy and Turbines
- Biopharmaceuticals
- Boatbuilding and Related Industries

[13] Hamel and Prahalad, Competing for the Future, Harvard Business Press, 1994, pg 90 and 217.

- Defense
- Electronics and Semiconductors
- Engineering and Scientific/Technical Services
- Environmental Services
- Finance and Business Support Services
- Forestry
- Information Technology Services
- Materials for Textiles, Apparel, Leather and Footwear
- Medical Devices

Figure 1. Mapping the Refined Technology Clusters for Maine across the State's Seven Broad Targeted Technology Areas



Note: Crosscutting targeted technology areas that impact several technology clusters include Precision Manufacturing and Composites and Advanced Materials.

Below is a discussion of each of the original seven broad targeted technology areas and how the thirteen technology clusters relate to them. The Core Technology Competencies from Table 1 that are associated with each technology cluster are identified in italics.

- **The Biotechnology targeted technology area** has two technology clusters with significant differences – the Biopharmaceuticals technology cluster and the Medical Devices technology cluster. A main difference is in the technology competencies advancing these two technology clusters:
    - Biopharmaceuticals draws upon the state's significant base of technology focus on *Biologics and Biotechnology* as well as *Pharmaceutical Formulation and Delivery*.
    - Medical Devices in Maine is a much less technology-driven sector, with a limited presence in patent areas such as *Electromechanical Components and Systems* and *Fluid Handling and Filtering* technologies and a particularly low output per employee, suggesting less use of technology in production and less complex product manufacturing.

  These two technology clusters also differ significantly in their size and level of specialization found in Maine, though both serve the market for biomedical treatments.
- **The Composites and Advanced Materials targeted technology area** stands out in Maine less for having a strong presence of pure-play materials industries than for the significant technology competency in *Coatings and Composite Materials* used in a wide range of technology clusters, including Boatbuilding and Related Industries, Defense, and Electronics and Semiconductors.

  However, one pure-play materials industry that had been overlooked in the past technology industry studies and that is highly specialized in Maine, reflecting its long-standing presence in the state, is Materials for Textiles, Apparel, Leather and Footwear. This technology cluster is one of the few in which Maine's productivity exceeds the national average, suggesting a strong focus on technology deployment and higher value-added products. There are innovative firms involved with fiber materials and next generation textiles, and one of Maine's top 50 private employers, New Balance Athletic Shoe, Inc., is found in this technology cluster.
- **The Environmental Technologies targeted technology area** comprises two very distinct technology clusters that both relate to the broad theme of "cleantech" but draw upon different technologies, supply chains, and markets.
    - One technology cluster is found in Alternative Energy and Turbines, which aligns strongly to Maine's technology competency in *Engines and Turbines* for wind-power, and to Maine's technology competency in *Chemistry and Organic Compounds* for biofuels.
    - The other technology cluster is in Environmental Services, which is led in Maine by environmental consulting services and draws on technology competencies in *Fluid Handling and Filtering* for environmental and storm water management.
- **The Forest Products and Agriculture targeted technology area** maps to two separate and distinct technology clusters – each with significant employment – because of the different markets served and supply chain relationships found across industries in this sector:
    - The Agriculture, Aquaculture, Fisheries and Food Production technology cluster represents a vertically integrated system with strong local supply chain linkages that goes from fishing and agricultural production to processing and production. Within this technology cluster, the state's technology focus on *Aquaculture* driven by emerging innovation companies is

critical to advancing the seafood market. Another key technology competency found in Maine that supports this industry is *Fluid Handling and Filtering* for beverage systems.

- Forestry is a more sizable and highly specialized technology cluster in Maine. The cluster is highly vertically integrated with strong supply chin linkages that include growing, harvesting, processing, and manufacturing end-products from Maine's substantial timber resources. Technology competencies that help advance this technology cluster include *Chemistry and Organic Compounds* for wood treatment processes and improved growth characteristics.

- The **Information Technology targeted technology area** in Maine turns out to be one of the more diverse sectors in the state with three distinct technology clusters drawing upon an equally diverse base of state technology competencies:
  - The Electronics and Semiconductors technology cluster is led by large employers in Maine, including Fairchild Semiconductor Corporation and Texas Instruments, and while communications equipment and electronic component instrument manufacturing is in decline, semiconductors and integrated circuit manufacturing continue and are sizable, growing, and almost specialized in Maine. This technology cluster has significant technology presence in Maine through its industry leaders involving *Semiconductors, Electronic Signal Conversion and Power Switches,* and *Networking, Signal Processing and Communications*.
  - The Information Technology Services technology cluster is a sizable but not very specialized cluster in Maine. Still, there is a significant presence among Maine's technology competencies found in *Data Processing, Management and Analysis*.
  - Finance and Business Support Services is the largest technology cluster in Maine. This technology cluster is becoming a highly specialized user of information technology across the nation. The advent of web-based services and Big Data technologies are key product differentiators, and required technology competencies found in this technology cluster include *Data Processing, Management and Analysis*. While not included in past technology industry studies for Maine, it is clearly today a major application focus of information technology.

- **The Marine Technology and Aquaculture targeted technology area** continues to have a specialized presence in Maine, though a small one. In this more refined assessment, the Boatbuilding and Related Industries technology cluster remains a distinct technology cluster found in Maine and draws on the state's technology competencies in *Coatings and Composite Materials*. As mentioned earlier, aquaculture in Maine is primarily connected to seafood production and so has been shifted to the Agriculture, Aquaculture, Fisheries and Food Production technology cluster.

- **The Precision Manufacturing targeted technology area** was not identified as a specific, stand-alone technology cluster in Maine, but is better understood as a cross-cutting technology competency and supply chain component for many of the technology clusters in Maine, including Defense, Alternative Energy and Turbines, and Medical Devices. As a technology competency, the patent cluster in *Electromechanical Components and Systems* is closely aligned with Precision Manufacturing.

This refreshed and refined analysis of Maine's technology clusters offers a more focused way for MTI to consider the specific industry drivers of Maine's economy across the broader targeted technology areas found in Maine. The next sections examine the performance and then the line of sight to growth opportunities for the thirteen technology clusters identified.

SECTION II:
PERFORMANCE OF MAINE'S TECHNOLOGY CLUSTERS

Maine's thirteen technology clusters represent key drivers of economic activity and employment in the state. Thirteen of Maine's top fifty businesses, based on employment size, are found within these technology clusters, including Bath Iron Works, New Balance, and Anthem Health. As the core components of Maine's economic base industries, these thirteen technology clusters bring new income into the state and support economic activity across the state's economy. Battelle analyzed the economic impact of the thirteen technology clusters on the overall Maine economy and found that the 84,305 jobs found in the thirteen technology clusters generate almost 100,000 additional total jobs in the state and generate over $15 billion in labor income.[14]

Given the major impact of these technology clusters on Maine's economy, a comprehensive assessment of the performance of these clusters in Maine is critical. While the generation of jobs is an important measure of success, there are many other measures of economic performance to be considered. Battelle analyzed the performance of Maine's technology clusters using eight performance criteria, including:

- Concentration of the technology cluster relative to the nation;
- Job generation for the technology cluster;
- Growth of the technology cluster relative to the nation;
- Productivity;
- Average wages;
- Economic multiplier;
- Projected national growth;
- Position in the New England regional economy.

Before each of these economic indicators is examined by cluster, it is important to place the performance of Maine's technology clusters in the context of the overall Maine and national economies. The Maine economy was not as severely impacted as the nation in terms of employment losses in the Great Recession, with both total Maine employment and employment in the thirteen technology clusters falling less severely than national employment in 2009 and 2010. However, Maine's economic recovery in 2011 and 2012 has lagged the national recovery, and both Maine and the nation have not yet attained pre-recession employment levels. Maine's 2012 total employment is 3.2 percent below 2007 levels, slightly worse than the national decline of 3.1 percent.

[14] Battelle analyzed the economic impact of the 84,305 jobs in Maine's thirteen technology clusters using the IMPLAN model. Multiplier effects include the "induced" effects created by the in-state purchases of the industries analyzed and the "induced" effects of the resident incomes supported by these industries themselves and impacted industries.

Defining the Key Measures of Technology Cluster Performance for Maine

Relative concentration of the technology cluster – a measure of how specialized a technology cluster is in Maine relative to the nation, and so gauges "competitive advantage" for the technology cluster in Maine relative to the nation. The specific measurement of relative concentration is known as a location quotient. A location quotient is the share of Maine's employment found in a particular technology cluster divided by the share of total industry employment in that technology cluster for the nation. A location quotient greater than 1.0 indicates a higher relative concentration, whereas a location quotient of less than 1.0 signifies a relative underrepresentation. A location quotient greater than 1.20 denotes employment concentration significantly above the national average, and is considered "specialized".

Job generation for the technology cluster – a more straightforward measure of whether a technology cluster has been gaining or losing jobs in Maine.

Relative growth of the technology cluster – a measure of whether a local technology cluster is gaining or losing competitive share compared to the nation. It is measured as the difference between the percentage change in employment in a technology cluster in Maine minus the percentage change in employment in that same technology cluster for the nation.

Productivity – a measure of the economic output generated by each job. Comparing the level of productivity of Maine's technology cluster to its national level provides insights into whether the state's technology cluster is more or less productive, and therefore more or less competitive. Higher levels of productivity in Maine compared to national levels mean that, for each job, more economic output is generated; this suggests that the Maine technology cluster is better able to make use of advances in technology to produce goods and services and is able to produce more complex, higher value products.

Average wages of the technology cluster – a reflection of the overall quality of jobs found within a technology cluster. It is a measure that relates the contribution of the cluster to Maine's per capita income and ultimately to the economic well-being of the state. By comparing average wage levels across technology clusters, it is possible to learn which industries offer high-quality jobs. Average wage levels are measured by taking the total payroll reported by employers and dividing by the number of jobs. These data are reported by employers to federal and state agencies.

Economic multiplier of the technology cluster – a way to consider the broader economic impact of the cluster's economic activity on a local economy. Of particular importance for economic development is how inter-connected a technology cluster is to the broader regional (in this case New England) economy. These broader economic linkages consist of two types. The first type of local impacts consists of the presence of a local supply chain for that industry, often referred to as "indirect" impacts. Also important is the local income generated by an economic activity. Businesses pay wages and salaries to their workers, which are translated into local purchases of products ranging from housing, to medical care to groceries. These local income effects are termed "induced" impacts. Both the indirect and induced multipliers for each cluster were estimated using the IMPLAN input-output model of the inter-industry purchasing and income effects that occur on the national level. The model then considers the Maine industry structure in considering the opportunity for such inter-industry and personal consumption related purchases to happen in Maine. IMPLAN is one of the most widely used input-output models in the nation, and provides for each county in the nation its own customized input-output model based on national inter-industry purchases and the structure of the local industry base.

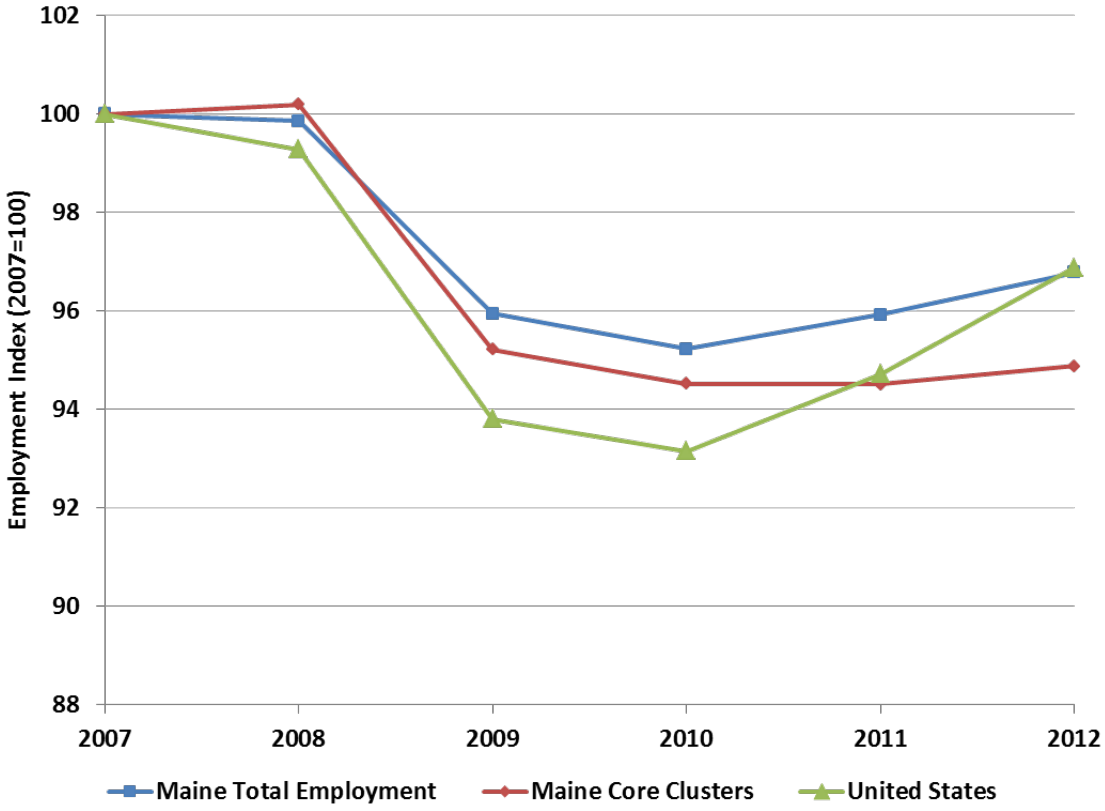
Projected national growth of the technology cluster – although past performance of technology clusters matters, it is critical also to have a view towards the expected future development of technology clusters. Of particular importance is whether technology clusters are expected to grow or decline in the next five to ten years. The long-term industry employment projection of national average annual employment growth developed by the U.S. Bureau of Labor Statistics (BLS) was used as the measure of national performance. The ten-year, long-term industry employment forecast generated by BLS has been a widely utilized tool for career guidance, educational and training program planning, and studying long-range employment trends. It is prepared every two years by BLS. The most recent period for which projections are available is for 2012 to 2022.

Position in the New England Regional Economy – since Maine is part of New England's dynamic regional economy, there are considerable economic linkages across these states. Understanding how Maine is positioned relative to other states in New England offers an important insight into the growth and development of its technology clusters. This measure considers Maine's position concerning the size of the cluster, level of cluster specialization, and the cluster's job generation, compared to the other New England states, for each of the thirteen technology clusters.

As presented in Figure 2, the overall recovery of employment levels in Maine's thirteen technology clusters has been slow, and has hindered Maine's overall recovery. Thus, it is clear that the performance of these technology clusters has an important impact on Maine's overall economic well-being.

A closer examination of the performance of these thirteen technology clusters suggests a more mixed picture of development across the seven measures of technology cluster performance.

Figure 2. Maine Employment Index, 2007-2012



Relative Concentration

In regional economic analysis, it is recognized that each local area has a distinguishing set of industries in which it has competitive advantages that have translated into greater past economic success, as indicated by a higher level of concentration in its local economy than in the overall national economy. Those industries that have a substantially higher level of concentration in the local economy than in the national economy are considered specializations for the local economy.

The specific measurement of industry specialization or relative concentration is known as a location quotient**.** A location quotient is the share of a local area's employment found in a particular technology cluster divided by the share of total industry employment in that technology cluster for the nation. A location quotient greater than 1.0 indicates a higher relative concentration, whereas a location quotient

of less than 1.0 signifies a relative underrepresentation. A location quotient greater than 1.20 denotes employment concentration significantly above the national average, and is considered specialized.

Maine has a mixed performance in relative concentration, which measures how specialized a technology cluster is in the state. Only six of the thirteen clusters have a very high degree of specialization, as measured by having more than a 20% higher level of industry concentration than the nation. Three of these technology clusters that are specialized in Maine are found in traditional industry strengths represented by the Boatbuilding and Related Industries, Forestry-related Products, and Materials for Textiles, Apparel, Leather and Footwear technology clusters. However, these traditional, high specialization industries face significant pressures in terms of recession-driven decreases in demand and international competition.

The other technology clusters with a high relative concentration or industry specialization in Maine include Alternative Energy and Turbines, Biopharmaceuticals, and Defense. What is particularly interesting is that a traditional Defense technology strength in Maine has been in turbine engines and that is now helping to position the state in alternative energy, particularly in the use of turbines for wind power generation. The fact that Maine is not specialized in seven of its technology clusters reflects the still-emerging nature of Maine's technology base and the need to build a critical mass of development.

Table 1. Relative Concentration to National Average for Maine's Thirteen Technology Clusters

Technology Cluster	Degree of Specialization 2012 (LQ)
Maine Technology Clusters	**1.10**
Agriculture, Aquaculture, Fisheries and Food Production	0.85
Alternative Energy and Turbines	5.07
Biopharmaceuticals	1.21
Boatbuilding and Related Industries *	1.88
Defense*	2.18
Electronics and Semiconductors	0.65
Engineering and Other Scientific/Technical Services	0.65
Environmental Services	0.74
Finance and Business Support Services	1.05
Forestry-related Products	3.02
Information Technology Services	0.40
Materials for Textiles, Apparel, Leather and Footwear	2.32
Medical Devices	0.64

Source: IMPLAN QCEW.

Job Generation

"Jobs, jobs, jobs" is a frequent refrain in stating what is important about economic development. Job generation is one of the primary measures of whether an industry is growing or declining, and for the economy as a whole is a key measure of economic growth. For this assessment, the 2007 to 2012 period is considered, since it measures the change in jobs from the Great Recession through the most recent year of available data for the economic recovery.

In job generation, despite the decline in employment across the thirteen technology clusters in total, seven of the thirteen clusters have fully recovered and have increased employment above 2007 levels. Two of these clusters, Alternative Energy and Turbines and Engineering and Scientific/Technical Services, both experienced a more than 10 percent increase in employment since 2007, and the Finance and Business Support Services cluster grew in Maine, despite a national decline. More importantly, six of these seven growing clusters grew more rapidly in Maine than in the nation, with the seventh, Medical Devices, performing at close to the national rate.

Table 2. Job Generation from 2007-2012, Percentage Change for Maine's Thirteen Technology Clusters

Technology Cluster	Change in Employment, 2007–2012	
	Maine	U.S.
Total, all industries	(3.2%)	(3.1%)
Technology Clusters	(5.1%)	(4.2%)
Agriculture, Aquaculture, Fisheries and Food Production	1.8%	0.7%
Alternative Energy and Turbines	11.9%	(38.6%)
Biopharmaceuticals	5.6%	2.4%
Boatbuilding and Related Industries *	(22.0%)	(26.5%)
Defense*	(4.6%)	0.9%
Electronics and Semiconductors	(23.7%)	(13.9%)
Engineering and Other Scientific/Technical Services	10.4%	4.7%
Environmental Services	3.4%	1.7%
Finance and Business Support Services	2.3%	(6.1%)
Forestry-related Products	(18.6%)	(27.9%)
Information Technology Services	(11.1%)	16.4%
Materials for Textiles, Apparel, Leather and Footwear	(18.2%)	(28.7%)
Medical Devices	1.5%	1.5%

*The base year of 2006 was used for this cluster to account for data discrepancies in 2007 and 2008

Source: IMPLAN QCEW.

Still, major declines in traditional technology clusters are holding back overall job growth in Maine. Five of Maine's technology clusters that are still more than 10 percent lower in employment than before the recession. Among these are Maine's large traditional technology clusters, such as Boatbuilding and Related Industries, Forestry-related Products, and Materials for Textiles, Apparel, Leather Products and Footwear. The other two technology clusters recording declines of over 10% are Electronics and Semiconductors and Information Technology Services.

Relative Employment Growth

In considering how a technology cluster is performing, it is also important to consider whether it is gaining or losing market share of the national technology cluster. It may be that a technology cluster is gaining jobs, but still not keeping pace with the national growth and so losing market share. Alternatively, a technology cluster falling in jobs locally may actually be performing better than the nation and so gaining in competitive share, suggesting more resilience than across the nation.

The relative employment growth considers the differences between the percentage change in employment in a technology cluster for Maine minus the percentage in employment in that same technology cluster for the nation. The period 2007 to 2012 is used to view how the industry has recovered since the Great Recession. Relative to the average national job growth from 2007 to 2012, Maine's technology clusters have mostly performed well in employment growth. . Nine of the thirteen technology clusters in Maine outpaced national employment trends and so demonstrated that Maine's economy remains competitive compared to the U.S.

Table 3. Relative Growth of Employment in Maine's Thirteen Technology Clusters, 2007–2012

Technology Cluster	Relative Growth, Percent of National Average
Maine Total, all industries	(0.1)
Maine Technology Clusters	(0.9)
Agriculture, Aquaculture, Fisheries and Food Production	1.1
Alternative Energy and Turbines	50.5
Biopharmaceuticals	3.3
Boatbuilding and Related Industries *	4.5
Defense*	(5.5)
Electronics and Semiconductors	(9.8)
Engineering and Scientific/Technical Services	5.7
Environmental Services	1.7
Finance and Business Support Services	8.4
Forestry-related Products	9.3
Information Technology Services	(27.5)
Materials for Textiles, Apparel, Leather and Footwear	10.5
Medical Devices	(0.0)

*The base year of 2006 was used for this cluster to account for data discrepancies in 2007 and 2008

Source: IMPLAN QCEW.

Still, two nationally growing technology clusters from 2007 to 2012 are declining in Maine. It has been noted that Maine did not benefit from the national recovery in Information Technology Services cluster employment, which grew substantially across the nation, but declined in Maine. Another technology cluster that grew nationally but declined in Maine was the Defense technology cluster, but the national growth was weak and Maine's decline was less than 5 percent from 2007 to 2012.

Productivity of Maine's Thirteen Technology Clusters

Technology-based economic development is more than just promoting the growth of innovative companies and industries. Just as critical, if not as widely heralded, is the ability of industry to "put technology to work." To assess Maine's competitive position in technology deployment an analysis of output per worker was undertaken to compare Maine's overall economy and clusters to national levels of productivity. Output per worker measures total revenues generated by each worker. Higher output per worker suggests more effective deployment of technologies in production as well as an ability to produce more complex, higher-value products. Battelle calculated value-added per employee from data on employment and output reported for industries in Maine and the U.S. by IMPLAN.

Table 4. Productivity – Output per Worker for Maine's Thirteen Technology Clusters

Technology Cluster	2012 Productivity Data		
	Maine	U.S.	Maine's Relative Productivity, %
Total Private Sector	**$124,816**	**$161,195**	**77%**
Agriculture, Aquaculture, Fisheries and Food Production	$209,715	$238,301	88%
Alternative Energy and Turbines	$820,487	$869,295	94%
Biopharmaceuticals	$177,922	$207,601	86%
Boatbuilding and Related Industries (1)	$273,283	$266,475	103%
Defense	$319,705	$476,436	67%
Electronics and Semiconductors	$632,061	$816,623	77%
Engineering and Other Scientific/Technical Services	$111,576	$140,138	80%
Environmental Services	$117,085	$134,765	87%
Finance and Business Support Services	$180,627	$226,196	80%
Forestry-Related Products	$324,170	$207,498	156%
Information Technology Services	$124,286	$191,200	65%
Materials for Textiles, Apparel, Leather and Footwear	$208,613	$202,324	103%
Medical Devices	$239,086	$361,389	66%

(1) Productivity figures are for the Boatbuilding sector only - because this industry accounts for nearly all employment in the cluster.

Source: IMPLAN.

Overall, Maine lags the nation in overall output per worker, but there are a few technology clusters in which Maine's productivity exceeds the U.S. average. Interestingly, it is in Maine's core traditional technology clusters, Boatbuilding and Related Industries, Forestry-related Products, and Materials for Textiles, Apparel, Leather Products and Footwear, where productivity matches or exceeds national levels. As described above, these industries have been hard hit by the recent economic downturn. The state's strong productivity in these clusters relative to the nation is indicative of the potential of Maine to support and experience a recovery in these sectors as the national economy recovers. By and large, however, the lower levels of overall and cluster productivity in Maine suggests the importance of efforts to facilitate the deployment of new technologies and support for the development of new, higher value-added products to raise the overall level of productivity of the state's business base.

Average Wages of Maine's Thirteen Technology Clusters

In economic development, there is a focus not just on jobs, but the quality of those jobs. The average wages paid by each cluster are an important measure of the quality of the jobs created. As presented in Table 5, the average wage across Maine's thirteen technology clusters is well above the overall average wage for the state. Indeed eleven of the thirteen clusters have an average wage above the state average. This demonstrates the importance of these clusters to efforts to grow and diversify the Maine economy.

Table 5. Average Wages for Maine's Thirteen Technology Intensive Technology Clusters Compared to New England and U.S.

Technology Cluster	Maine	New England	U.S.
Total Private Sector	**$38,090**	**$56,855**	**$49,194**
Maine Technology Clusters	**$54,126**	**$101,554**	**$77,290**
Agriculture, Aquaculture, Fisheries and Food Production	$36,755	$42,122	$36,946
Alternative Energy and Turbines	$74,091	$92,629	$90,126
Biopharmaceuticals	$68,313	$118,155	$97,624
Boatbuilding and Related Industries	$42,492	$67,964	$70,931
Defense	$63,959	$95,517	$86,627
Electronics and Semiconductors	$59,513	$102,386	$104,437
Engineering and Other Scientific/Technical Services	$71,348	$101,588	$91,275
Environmental Services	$48,994	$65,474	$62,819
Finance and Business Support Services	$55,405	$119,181	$84,200
Forestry-Related Products	$51,012	$51,646	$46,137
Information Technology Services	$73,168	$116,024	$106,625
Materials for Textiles, Apparel, Leather and Footwear	$33,970	$43,679	$37,171
Medical Devices	$44,602	$85,842	$75,356

Still, average wage levels in Maine are considerably lower than the average for New England states and the national average except in Forestry-Related Products. This finding is consistent with the generally lower levels of productivity found Maine. While it may partially reflect the lower cost of living in Maine compared to other states, it also may reflect a lower skill mix among Maine's technology clusters compared to other states.

Economic Multiplier of Maine's Thirteen Technology Clusters

It is important to consider the broader impact of each industry on the state's economy. One way to look at the impact of and linkages between an industry and the larger economy is to analyze output multipliers. This was accomplished using data on the *indirect multiplier* and the *induced multiplier* for each of the clusters, based on data from the IMPLAN model for Maine. Indirect multipliers estimate the local economic activity generated from the purchase of goods and services all up and down the supply chain to support the production of the industry being analyzed. This is a measure of the local supply chain impact of the industry. Some of the revenue generated by a technology cluster is paid out in wages and , which in turn re-circulate through the regional economy as the wage earners make their own purchases, and so forth. Induced multipliers measure the impacts of the incomes created by the direct and indirect impacts associated with the production by the industry being analyzed. Together, these represent the increase in local economic activity attributable to the activities of the industry being analyzed.

These are expressed in Table 7 in terms of the local economic activity generated by $1 million in industry revenues. The strength of indirect impacts is influenced by the strength and capacity of local suppliers to meet the input needs of a business. The larger and more diverse the local economy and the stronger the local supply chain, the higher the indirect impacts will be. Induced impacts are influenced by the level of wages and salaries being paid, the labor share of industry production, and the strength of the local workforce. The larger the multiplier effects, the bigger the impact of the industry being studied.

Maine's traditional industries, notably Agriculture, Aquaculture, Fisheries and Food Production and Forestry-related Products, exhibit strong indirect impacts. This is indicative of the integrated nature of production in these industries where local raw materials are transformed into final products. Industries, such as Engineering and Scientific/Technical Services, Environmental Services, and Information Technology Services, where labor is the main factor of production and wages tend to be high, have the strongest induced impacts. Industries like Biopharmaceuticals combine strong indirect and induced impacts, indicating both a strong local supplier network and local income component.

The strength of local supply chains in Maine's traditional Agriculture, Aquaculture, Fisheries and Food Production, Boatbuilding and Related Industries, Forestry and related products, and Materials for Textiles, Apparel, Leather and Footwear technology clusters are indicative of both the strength and importance of these clusters. Maine's already strong position in these clusters, as measured by the high degree of specialization in most of them, has supported the development of strong supplier networks that reinforce both the potential and importance of these clusters to support economic and

employment growth in the state. The combination of a strong local supply chain and large induced effects similarly supports both the potential and importance of continued growth in these clusters.

Table 6. Output Multipliers for Maine's Thirteen Technology Intensive Technology Clusters, Impact per $1 Million in Industry Revenues

Technology Cluster	Indirect Impact	Induced Impact	Total Indirect and Induced Impact
Agriculture, Aquaculture, Fisheries and Food Production	$343,922	$192,747	$536,669
Alternative Energy and Turbines	$159,226	$150,499	$309,725
Biopharmaceuticals	$373,816	$372,730	$746,546
Boatbuilding and Related Industries	$279,777	$207,980	$487,757
Defense	$179,494	$263,768	$443,262
Electronics and Semiconductors	$273,095	$173,905	$447,000
Engineering and Scientific/Technical Services	$325,862	$504,207	$830,069
Environmental Services	$321,037	$467,413	$788,450
Finance and Business Support Services	$311,833	$325,240	$637,073
Forestry-related Products	$388,114	$236,388	$624,502
Information Technology Services	$284,898	$491,728	$776,626
Materials for Textiles, Apparel, Leather and Footwear	$222,723	$215,991	$438,714
Medical Devices	$258,763	$227,552	$486,315

Source: IMPLAN.

Future Growth Prospects of Maine's Thirteen Technology Clusters

Much of the technology cluster data presented is based on latest available trends ending in 2012. It is also important to take into account projections of how each cluster is forecast to grow at the national level in the coming years. Past performance may not be a good predictor of future growth potential, while forecasts provide a means to gauge the growth potential of an industry.

In order to analyze the long-term growth potential of each cluster, Battelle analyzed data from the U.S. Bureau of Labor Statistics (BLS) on industry employment and output projections. The long-term industry employment projections of national average annual employment growth developed by the BLS provide insights into which of the technology clusters are best positioned for job growth through 2022. To prepare these long-term employment projections, BLS has developed a very detailed methodology which has been studied for its reliability. In brief, BLS uses the Macroeconomic Advisers econometric model of the U.S. economy to derive estimates of the components of Gross Domestic Product (GDP). These estimates are then disaggregated into commodity-level demand, which is then applied to an input-output model to derive output by industry. Next, industry-level employment is determined on the basis of projected industry output and expectations of productivity growth, which incorporates expected

technological changes.[15] The BLS projected growth rates for employment and output were used to forecast cluster level employment and output growth through 2022 in Maine. In the case of alternative energy, an important component of the Alternative Energy and Turbines technology cluster, there was no separate projection for alternative energy employment and output growth in the BLS data, with alternative energy treated as a component of the overall utility and energy sector. In order to analyze the potential growth of this sector, and therefore for the cluster, third party projections from IBIS World were used for solar, wind, and hydroelectric power output and employment.[16]

While the overall mix of Maine industries is projected to grow at the national level of 1 percent annual growth in employment and 2.9 percent annual growth in output, the national outlook for many of Maine's specific thirteen technology clusters is less positive.

Table 7. Projected Employment and Output Growth for Maine's Thirteen Technology Clusters, Average Annual Growth, 2012-2022

Technology Cluster	Projected Employment	Projected Output
Total Private Sector	**1.0%**	**2.9%**
Total Maine – all industries	**1.0%**	**2.9%**
Agriculture, Aquaculture, Fisheries and Food Production	(0.6%)	1.5%
Alternative Energy and Turbines	4.7%	8.4%
Biopharmaceuticals	1.8%	3.9%
Boatbuilding and Related Industries	(1.0%)	1.5%
Defense	(0.7%)	1.5%
Electronics and Semiconductors	(1.3%)	4.6%
Engineering and Other Scientific/Technical Services	2.2%	4.3%
Environmental Services	2.6%	2.6%
Finance and Business Support Services	0.9%	3.4%
Forestry-related Products	(0.6%)	1.9%
Information Technology Services	3.3%	6.1%
Materials for Textiles, Apparel, Leather and Footwear	(3.3%)	(0.8%)
Medical Devices	(0.3%)	4.2%

Source: BLS, IBIS World and Battelle.

Seven of the thirteen technology clusters are expected to decline in employment nationally and generate weak overall gains in economic activity from 2012 to 2020. This includes Maine's traditional,

[15] See http://www.bls.gov/emp/ep_data_industry_out_and_emp.htm for a description of the projections data and methodology.

[16] Each of the clusters was analyzed using the data from the closest aggregated industry grouping.

high-specialization Boatbuilding and Related Industries, Forestry-related Products, and Materials for Textiles, Apparel, Leather and Footwear clusters, as well as the Defense cluster.

Of the six technology clusters expected to grow nationally, four are expected to be fast growing, with an average annual employment gain nationally of close to or over 2 percent each year from 2012 to 2020. This includes the existing well-performing technology clusters of Alternative Energy and Turbines, Biopharmaceuticals, Engineering and Scientific/Technical Services, and Environmental Services.

One other expected high-growth national technology cluster is Information Technology Services, where Maine has fallen short in recent years with a significant decline in employment, while the nation grew strongly. This suggests a more aggressive approach to growing this cluster might be of value, especially given the technology competencies found in Maine.

Position within the New England Region

Maine is part of New England's dynamic regional economy, and there are considerable economic linkages across these states, with people, companies, and products all moving across state lines in an integrated regional economy. Examining how Maine is positioned relative to other states in New England offers an important insight into the growth and development of its technology clusters. Particularly from the perspective of MTI, some of the technology clusters may be better positioned from a regional perspective rather than viewed simply within the borders of Maine – and so pursuing broader regional collaborations may make sense.

This final performance measure explores the position of Maine's technology clusters compared to the other states in New England. As might be expected, there are wide differences in terms of the size and performance of the thirteen clusters analyzed among the six states that make up New England. A good way to visualize the performance of Maine relative to its neighboring New England states is through the use of bubble charts that present, in one graphic, higher or lower concentration levels along the vertical axis, job growth or decline along the horizontal axis, and size of employment in 2012 by the size of the bubble for each of the states. These bubble charts and the full explanation on a cluster-by-cluster basis is presented in Appendix C.

The analysis examining the level of industry specialization, industry size, and industry growth across New England states reveals that Maine's regional position across the technology clusters varies considerably:

- In three technology clusters, Maine stands out as ***regional leader*** among New England states due to its high standing in size, specialization and/or growth
    - Alternative Energy and Turbines
    - Forestry-related Products
    - Materials for Textiles, Apparel, Leather and Footwear.
- In five technology clusters, Maine is among the ***regional players*** in New England, so not the leading state, but with a good standing in size, industry specialization, and/or growth:

- Agriculture, Aquaculture, Fisheries and Food Production
- Biopharmaceuticals
- Boatbuilding and Related Industries
- Defense
- Financial and Business Support Services.

- In five technology clusters, Maine is more of a ***regional follower*** and lags significantly behind other New England states in size, industry specialization, and/or growth, including
  - Electronics and Semiconductors
  - Engineering and Scientific/Technical Services
  - Environmental Services
  - Information Technology Services
  - Medical Devices.

This varied position of Maine within New England has important implications for how to approach technology cluster activities within a regional context. Where Maine is a regional follower, it may make more sense to look to connect Maine's technology cluster to the broader drivers found within New England through collaborative activities and partnerships, such as supply chain development, talent development, and technology services. This more regional collaborative and partnership approach might also benefit those technology clusters where Maine is a regional player, though it would need to be in focused areas that address gaps found in Maine or in pursuing federal initiatives. Where Maine is a regional leader, it is likely to stand out on its own in advancing the technology cluster.

Summary and Conclusion on the Performance of Maine's Thirteen Technology Clusters

Across the performance measures, there is a mixed picture of development across the refined set of thirteen technology clusters found in Maine:

- **Job generation has been mixed among the thirteen technology clusters.** Despite the overall decline in employment across the thirteen technology clusters from 2007 to 2012, seven of the technology clusters did grow and so stand higher in employment than before the recent severe recession. Still, the employment losses among declining technology clusters have been quite large – typically declining more than 10 percent from before the past recession, suggesting a major economic shake-out has occurred in Maine's economy from the recession and weak recovery.
- **Less than half of the technology clusters are considered to be specialized.** Only six of the thirteen technology clusters in Maine have more than a 20 percent higher concentration than the nation and so represent industry specializations. While many of the technology clusters represent traditional strengths of Maine and as a result have particularly high industry specializations, such as Forestry-related Products, Materials for Textiles, Apparel, Leather and Footwear, and Boatbuilding and Related Industries , most of the technology clusters are emerging but not yet specialized.

- **Most of the technology clusters are outpacing national employment growth rates.** Nine of the thirteen technology clusters in Maine outpaced national employment trends, demonstrating that Maine's economy remains competitive compared to the U.S. Still there are notable technology clusters in Maine which declined substantially in Maine from 2007 to 2012, while growing strongly across the U.S., including the Information Technology Services and the Defense technology clusters.
- **Maine's technology clusters are not keeping pace with the nation in terms of their level of productivity.** Maine's level of productivity – a key measure of technology deployment and activities in higher value-added products – stands generally well below the U.S. average. Only three of the thirteen technology clusters outpace the U.S. average in productivity, not surprisingly the same ones in which Maine has significant specialization. Most notably Forestry-related Products, has a productivity level which is 56 percent higher in Maine than the U.S. average.
- **The average wage for all but one technology cluster is below the national average.** Maine's average wages are below the U.S. average for twelve of the thirteen technology clusters, and only exceed the U.S. average for Forestry-related Products. This partially reflects the lower cost of living in Maine, but also reflects the generally lower productivity of Maine's technology industries. Still, lower wages does mean that Maine has a competitive labor cost position that would be attractive to companies looking to set up shop and that is indicative of the potential for Maine to attract these activities from surrounding jurisdictions.
- **The overall economic impact of the clusters varies significantly.** There is a significant variation across the thirteen technology clusters in what an extra $1 million in revenue in Maine generates in broader economic growth. The highest overall economic multipliers are found among higher wage industries, such as Engineering and Scientific/Technical Services, Environmental Services, Information Technology Services, and Biopharmaceuticals. The strongest local supply chains are found in more traditional technology clusters such as Forestry-related Products, Boatbuilding and Related Industries, Agriculture, Aquaculture, Fisheries and Food Production, and Materials for Textiles, Apparel, Leather and Footwear.
- **Projected national growth rates for the technology clusters vary significantly.** Looking forward, there is significant variation across Maine's technology industries on expected national growth. Seven of the thirteen technology clusters are expected to decline in employment nationally and to generate weak overall gains in economic activity from 2012 to 2020. Of the six technology clusters expected to grow nationally, four are expected to be fast growing, with an average annual employment gain nationally of over 2 percent each year from 2012 to 2020. These are Alternative Energy and Turbines, Engineering and Scientific/Technical Services, Environmental Services, and Information Technology Services.

Taking into account all of the performance measures together suggests that each of Maine's thirteen technology clusters offers a different set of strengths and opportunities in terms of their performance criteria. How one views the relative importance of different performance measures would influence which of the technology clusters stands out.

If all eight of the performance measures were equally weighted then there are a number of technology clusters that stand out:

- **Two of the technology clusters have no weak ratings across the eight performance measures**

- Biopharmaceuticals
- Finance and Business Support Services

- **Two of the technology clusters have just one weak rating across the eight performance measures**
  - Agriculture, Aquaculture, Fisheries and Food Production
  - Alternative Energy and Turbines
- **Four of the technology clusters have just two weak ratings across the eight performance measures:**
  - Boatbuilding and Related Industries
  - Engineering and Scientific/Technical Services
  - Environmental Services
  - Forestry-related Products.

However, given the breadth of the performance measures in reflecting each technology cluster's strengths and weaknesses in the state, even those technology clusters doing well have a mixed economic performance profile within the cluster itself. The performance profile for each technology cluster – even those that generally are lagging across most of the performance measures – suggests how Maine might consider advancing the development of that cluster in the years ahead.

Battelle's insights into the development implications based on the technology cluster performance is set out below grouped into those well-performing technology clusters and those mixed-performing technology clusters:

Performance Profiles for Well-Performing Technology Clusters in Maine:

Agriculture, Aquaculture, Fisheries and Food Production. This is a highly integrated technology cluster in Maine with strong supply chain linkages and a sizable employment base of 10,352 jobs. This industry has shown promise in Maine with moderate job growth of 1.8% from 2007 to 2012, which slightly exceeds the average of 1.1% for the cluster nationally. Still, as an integrated technology cluster which runs from harvesting/fishing to processing, Maine is still not yet at national levels of employment concentration. By comparison, Maine still lags well behind the high specialization and strong growth found in Vermont, the leader in New England in this technology cluster. One particular sign of concern for Maine is its lower levels of productivity in this cluster relative to the nation, suggesting the need for more deployment of process technologies and for raising the value-added of its processing activities.

Alternative Energy and Turbines. Although this is the smallest technology cluster in Maine, with just 948 jobs in 2012, it is one of the fastest growing with job gains of 11.9% from 2007 to 2012, and it is the most specialized with an impressive five times the national level of employment concentration. It also is one of the highest paying technology clusters in the state, with average annual wages of $74,091. The national growth prospects for this industry are strong and Maine appears to be well-positioned for

growth. Both national and state policies and incentives are critical for the growth of this industry in Maine.

Biopharmaceuticals. This technology cluster is performing particularly well in its recent employment growth compared to both the nation and the New England region, and also stands out in its future growth prospects. This future growth is particularly important for Maine given the cluster's high economic multiplier impacts in the state, reflecting both its high wages and good supply chain linkages. Still, it is only a moderately sized technology cluster in Maine, with just 3,950 workers, and lacks resources such as a strong academic medical center to help advance more translational and clinical research. Therefore, it is important to pursue efforts to connect Maine's biopharmaceuticals industry to the broader complex of academic resources found across New England.

Boatbuilding and Related Industries. This is a specialized cluster in Maine, though it is one of the smaller clusters in the state, with1,003 jobs in 2012, and has undergone significant employment declines both in Maine and nationally from 2007 to 2012. Still, Maine's technology cluster appears to be competitive, with both lower declines in employment and higher productivity levels than those seen nationally. Looking to the future, national employment projections suggest only modest declines of 1% annually in the years ahead. This suggests this technology cluster, with its more competitive positioning, can perhaps hold its own and remain a niche industry for Maine, though it is not expected to be a strong economic driver for the state.

Engineering Scientific/Technical Services. This is one of the moderately sized clusters in the state, with 3,928 jobs in 2012. Maine is gaining jobs in this technology cluster at a fast pace, with gains of 10.4% from 2007 to 2012 that more than doubled this cluster's national gains of 4.7%. This is most promising since future national projections suggest this will continue to be a high-growth industry, with expected annual average growth of 2.2% through 2022. Still, Maine is a follower in this technology cluster to Massachusetts, a national leader that appears to be driving the growth of this technology cluster for all of New England. This suggests that Maine needs to maintain close connections to this technology cluster at the regional level and find ways to competitively position itself to benefit from growth opportunities being driven by Massachusetts.

Environmental Services. This is a smaller technology cluster, with 1,660 jobs in 2012, that is not yet specialized in Maine, but recording strong growth of 3.4% from 2007 to 2012 that outpaced the national growth of 1.7%. It is forecasted to continue to grow strongly at the national level with expected average annual growth of 2.6% through 2022. At the regional level, there appears to be a shift in this industry within New England, with Rhode Island and New Hampshire having gained employment, along with Maine, while the larger and more specialized states of Massachusetts and Connecticut lost employment from 2007 to 2012. This suggests that Maine needs to maintain close connections to this technology cluster at the regional level and find ways to competitively position itself to benefit from growth opportunities being driven by Massachusetts. One important competitive issue will be both national and state policies and incentives, according to industry stakeholders.

Finance and Business Support Services. This is one of the largest technology clusters in Maine, with employment nearing 30,000. Maine also has significant momentum in this technology cluster, growing through the recession and economic recovery years of 2007 to 2012 even while the technology cluster's employment at the national and New England regional level declined and still remain below its 2007 levels. To continue to gain market share, Maine needs to be focused on growing talent, particularly for the more technical Information Technology jobs associated with this technology cluster.

Forestry-Related Products. This sizable technology cluster remains an anchor within Maine's economy, with 15,157 jobs in 2012, an industrial specialization that is three times the national level, and a high economic multiplier reflecting the most well-developed supply chain linkages among Maine's technology clusters. While employment declined from 2007 to 2012 in Maine and the U.S., the state appears highly competitive. Most outstanding is that Maine's productivity level for this technology cluster is 56% higher than the national average, suggesting that this industry is deploying technology and finding higher value-added at a level far greater than the industry across the nation. In addition, Maine's employment declines stood below that of the national average, and looking to the future national projections suggest small employment declines of less than 1% annually. So, while not a direct employment driver for the future, this competitive technology cluster remains important for Maine, and the continued output growth from the high productivity in this cluster adds significant value to Maine's economy through its supply chain linkages.

Performance Profiles for Mixed-Performing Technology Clusters in Maine:

Defense. This is a sizable and specialized technology cluster in Maine, with 7,397 jobs in 2012, but a declining one. Even as employment in this industry grew from 2007 to 2012 nationally, it declined in Maine. Future prospects at the national level are not strong, with expected small annual employment declines of less than one percent through 2022. More importantly for Maine, this industry is driven by just a few major employers – including Pratt & Whitney and Electric Boat (General Dynamics) – and so the attention needs to be on ensuring their continued successful operations in the state.

Despite the limited near-term growth prospects for this technology cluster, it is a viable target for state technology development efforts, because it is comprised of several of Maine's leading employers, it operates with strong linkages to the rest of the state's economy, and it generally pays high wages. As a result, efforts to stabilize the performance of this technology cluster even in the context of national declines represents an opportunity to protect and retain high wage employment opportunities both in this technology cluster itself and in its local supplier community.

Electronics and Semiconductors. This is a smaller technology cluster, with 2,055 jobs in 2012, that is not specialized in the state and lost jobs faster in Maine than nationally from 2007 to 2012. Future employment prospects at the national level are weakly negative with expected annual average declines of 1.3% through 2022.

Still, this technology cluster is led by major companies with operations in Maine, particularly Fairchild Semiconductor Corporation and Texas Instruments. Similar to the Defense technology cluster, the

attention needs to be on ensuring that these major employers have continued successful operations in the state.

Information Technology Services. This is a moderately sized technology cluster in Maine, with 4,065 jobs in 2012, but is surprisingly a declining one, with job losses of 11.1% from 2007 to 2012, despite strong national growth of 16.4% and growing employment levels for all of the other New England states during that same period.

Still, this industry's national growth projections are outstanding at over 3% average annual growth through 2022 and it is a high wage technology cluster in Maine, with average annual wages of $73,168 in 2012. So this technology cluster is hard to ignore, but clearly struggling in Maine. Perhaps this cluster is best viewed for Maine as a critical enabler to the state's Finance and Business Support Services technology cluster. They share a need for specialized talent and many of the growth opportunities are in related markets.

Materials for Textiles, Apparel, Leather and Footwear. This is a moderately sized technology cluster in Maine, with 4,194 jobs in 2012, and is highly specialized with over two times the national average concentration in the state.

While a declining technology cluster in Maine and nationally, it is a competitive cluster in Maine with productivity standing 3% higher in the state than in the nation, and job losses at a much lower level from 2007 to 2012 than nationally. Still, the national projections are for continued major employment declines of more than 3% annually through 2022. So, while a clear niche for Maine, this technology cluster will not be a strong economic driver.

Medical Devices. This is a small technology cluster, with total employment of 1,036 in 2012, and a much lower level of industry concentration found in Maine than in the nation (unlike the Biopharmaceuticals cluster, which is specialized in Maine).

While Maine has enjoyed job gains mirroring the national average of 1.5% from 2007 to 2022, this cluster in Maine has a low level of productivity and low average salary of $44,602. Future national employment projections are forecasted to be relatively flat with average annual declines of less than 0.5% through 2022. So this technology cluster is not expected to be a major economic driver for the state. Still, across New England Medical Devices are an industry specialization, led by large and highly specialized technology clusters in Massachusetts and Connecticut. From an economic development perspective, it appears that Maine needs to maintain close connections to this technology cluster at the regional level – especially to fill in a lack of translational and clinical research drivers in the state – and continue to look for ways to competitively position itself within the region.

Table 8. Summary of Performance Criteria for Technology Clusters in Maine

Performance Level Scale	Symbol	Relative Concentration	Job Generation	Relative Growth	Productivity	Output Multiplier	Average Wages	Projected Growth	Regional Position
Strong	↑	LQ >1.2	>5%	>5%	> National	>$600K	>150%	>1%	Leader
Average	■	LQ 0.8–1.2	0%–5%	0%–5%	80%–100% of National	$400K–$600K	<125%	0%–1%	Player
Weak	↓	LQ <0.8	Negative	Negative	<80% of National	<$400K	<Maine Average	Negative	Follower

Technology Cluster	Relative Concentration	Job Generation	Relative Growth	Productivity	Output Multiplier	Average Wages	Projected Growth	Regional Position
Agriculture, Aquaculture, Fisheries and Food Production	■	■	■	■	■	■	↓	■
Alternative Energy and Turbines	↑	↑	↑	■	↓	↑	↑	↑
Biopharmaceutical	↑	↑	■	■	↑	↑	↑	■
Boatbuilding and Related Industries	↑	↓	■	↑	■	■	↓	■
Defense	↑	↓	↓	↓	■	↑	↓	■
Electronics and Semiconductors	↓	↓	↓	↓	■	↑	↓	↓
Engineering and Scientific/Technical Services	↓	↑	↑	■	↑	↑	↑	↓
Environmental Services	↓	■	■	■	↑	■	↑	↓
Finance and Business Support Services	■	■	↑	■	↑	■	■	■
Forestry-Related Products	↑	↓	↑	↑	↑	■	↓	↑
Information Technology Services	↓	↓	↓	↓	↑	↑	↑	↓
Materials for Textiles, Apparel, Leather and Footwear	↑	↓	↑	↑	■	↓	↓	↑
Medical Devices	↓	■	■	↓	■	■	↓	↓

SECTION III:
LINE OF SIGHT TO GROWTH OPPORTUNITIES ACROSS MAINE'S TECHNOLOGY CLUSTERS

In today's globally-based economy, the key to success for states is to identify those growth opportunities within its core industry clusters in which it is best positioned to differentiate itself and become a world leader. While the thirteen technology clusters in Maine are economic drivers for the state, they vary considerably in how they are positioned for economic and employment growth. More importantly, even in technology clusters that were hard hit by the recession, key component industries or sub-sectors may offer important growth opportunities, even when the overall technology cluster has limited overall growth potential based on national or international economic trends. As a result, it is important to analyze Maine's technology clusters in more depth to examine how they are positioned.

To identify likely areas for growth opportunities over the next three to five years across Maine's technology clusters, Battelle applied a "line of sight" analysis to market opportunities. This line of sight analysis examines the focus areas of strength in Maine today based on the most recent detailed industry performance together with a forward-looking assessment of core technology competencies based on the patent cluster analysis developed for this study (see Figure 3).

Figure 3. Identification of Growth Opportunities based on Target Product/Service Markets and Presence of Core Technology Competencies

Battelle reviewed each of the thirteen technology clusters using three key steps to identify likely growth opportunities:

- **Step One:** Identified, for each of the 13 technology clusters, those detailed product/service markets in which Maine has a strong or growing presence and are economic drivers. In this context, a detailed product/service market is defined very narrowly in order to be able to specifically identify the high-performing detailed industries within a cluster. Examining the most detailed level of industry classification available for each technology cluster offers insights into those specific industry product and service focus areas in which Maine is best positioned for economic growth based on its level of industry specialization (relative concentration) and job generation performance over the 2007 to 2012 period. Well-established product/service markets are those that are both specialized and growing in Maine, while emerging product/service markets are those that are growing, but not yet an industry specialization.
- **Step Two:** Assessed how these detailed product/service market drivers align with technology competencies or specific assets found in Maine. The focus here is whether there is an opportunity to leverage specific industry know-how to position Maine for future growth in one or more of the detailed product/service markets that are either well-established or growing.
- **Step Three:** Surveyed market research studies at the detailed industry and project level to identify, for the most attractive product/service market opportunities, the market growth potential and critical technology and market advances required. Battelle generally relied on the market research intelligence from IBISWorld or BCC Research to identify faster growing market opportunities and specific market and technology challenges. The advantage of IBISWorld is that its industry research reports align well with the industry classification system and so focus on detailed industry product markets.

From this three-step process, Battelle identified a promising set of growth opportunities that take advantage of Maine's position over a range of detailed product/service markets over the next several years. These growth opportunities range from those that draw upon technology competencies in Maine, such as turbine-powered energy and molecular-based diagnostics, to those that build upon assets found in Maine that have fueled traditional industries, such as aquaculture and functional foods.

These identified **detailed product/service market growth opportunities** across Maine's thirteen technology clusters include:

- Aquaculture
- Electronic Components
- Engineering Services
- Enterprise and Data Hosting Services
- Financial Transaction Processing and Telemarketing
- Functional Foods
- Molecular-Based Diagnostics and Genomics
- Remediation and Environmental Consulting

- Turbines For Energy Production
- Wireless Sensor Networks.

The detailed analysis of these market opportunities is presented below:

Aquaculture

How It Stands as a Product/Service Market for Maine

Aquaculture and fisheries stands out as a well-established product market for Maine and is part of a detailed industry of Fishing and Seafood Production that has 1,209 jobs in Maine in 2012, a location quotient of 6.01 and job growth of 80 jobs from 2007 to 2012. Aquaculture falls within the Agriculture, Aquaculture, Fisheries and Food Production technology cluster.

Alignment with Maine's Technology Competencies and Broader Assets

The strongest alignment with Maine's technology competencies are found in the many innovative small businesses found in the state involved in aquaculture research and development funded by the federal Small Business Innovation Research program, including Bagaduce River Oyster, Harmon Brook Farms, Pemaquid Mussel Farms, Pemaquid Oyster Farm, Ocean Approved, Acadia Harvest, Sea & Reef Aquaculture and Jesse Leach. In addition, there are a number of companies who are applying *Networking, Signal Processing and Communications* technologies for sensing of fish, including AXAT and Mainely Sensors. This product/service market can also take advantage of the *Fluid Handling and Filtering* technology competencies found in the state.

More broadly, Maine's natural resource of fisheries and access to the sea has a long tradition as an economic driver for the state.

What Are Its Market Prospects?

Aquaculture is the fastest growing food production system in the world, with global 2012 revenue of $135 billion and a projected average annual growth of 5.1% from 2013-2019.[17] The U.S. currently has only a small presence, at $1.2 billion in 2013 revenue, and the U.S. market is projected to grow at an average annual rate of 3.5 percent over the next five years, reaching $1.4 billion by 2018.[18] A major opportunity for the Maine aquaculture industry is that today 56% of the U.S. demand for aquaculture products is met through imports, as the U.S. does not have the capacity to meet domestic demand. Pending legislation, in the form of the National Sustainable Offshore Aquaculture Act, has the potential to vastly open up U.S. coastal waters for industrial aquaculture farming and, if passed, would have a significant impact on the growth of employment and revenue, allowing domestic capacity to start to

[17] Transparency Market Research "Aquaculture Market for Carp, Molluscs, Crustaceans, Salmon, Trout and Other Fishes - Global Industry Analysis, Size, Share, Growth, Trends and Forecast, 2013–2019

[18] IBISWorld Fish & Seafood Aquaculture in the U.S., May 2013

catch up to domestic demand. Overall demand for U.S. aquaculture products will continue to grow, driven by growing per capita consumption in the U.S., increased demand from emerging economies internationally, and a steady decline in wild fish stocks. Conventional wisdom holds that traditional fisheries are producing near their maximum capacity and that future increases in seafood production must come largely from aquaculture.

Among the technology challenges and opportunities to address are:

- Sustainability – early aquaculture efforts were hindered, and the reputation of the discipline damaged, by water degradation caused by fish waste and other byproducts of aquaculture. New methods of seafood farming have been developed to address this issue. In particular, scientists and practitioners are looking at developing entire ecosystems around fish farms, where, for example, the waste generated by salmon gets taken up by mussels, another valuable seafood commodity. The excess nutrients that might have become pollutants instead get productively recycled.
- Breeding – selective breeding and the use of biotechnology are increasingly being used worldwide to increase resistance to disease, speed up the reproductive process, and increase meat yield in aquaculture products.
- Feed – many food fish are predators and rely on protein in their feed. Thus a huge amount of feed fish is needed to sustain fish farms, with the average being 5kg of feed fish needed to produce 1kg of food fish, causing a rapid depletion in the supply of wild fish stocks. Scientific efforts are underway to develop plant-based proteins to replace feed fish, the challenge being to do so without degrading the attractive qualities (e.g., flavor, health benefits)

Electronic Components

How It Stands as a Targeted Industry Product Market for Maine

Semiconductors and Related Device Manufacturing is the largest detailed industry in the Electronics and Semiconductors technology cluster and an emerging product market, with 902 workers in 2012 and a growth rate of 15.3% from 2007 to 2012.

Alignment to Maine's Technology Competencies

The technology competency of *Semiconductors* is the largest grouping in the patent analysis. It involves various integrated circuit design and manufacturing processes, as well as various transistors, flash memories, connectors, and electronic packaging technologies.

What Are Its Market Prospects?

Passive and interconnecting electronic components are devices and products that run the electronics we use daily. The industry is comprised of firms creating, designing, and manufacturing products that go into a range of electronic components. These products are either passive components – which give circuits their electrical characteristics without requiring a separate source of power to run (capacitors,

resistors, inductors, and transformers) – or they are interconnecting components which direct the operation of electronic products (bare and loaded printed circuit boards, fuses, relays, switches, and other electronic connectors).

Globally, the market for passive and interconnecting electronic components is expected to reach $136 billion in 2012 and continue to grow at a CAGR of 9.4 percent till 2017 for a market value of $213.5 billion.[19] In the U.S. the market for circuit boards and electronic components – a subset of the passive and interconnecting electronic component industry – is expected to grow at a modest annualized growth rate of 0.9 percent, going from a market value of $43.9 billion in 2014 to a value of $45.9 billion in 2019.[20]

The emerging trends and technologies in the electronic components industry are:

- Emerging markets – aside from the Asia-Pacific market, emerging markets are expected to be the fastest growing market for with a CAGR of 8.8 percent between 2012 and 2017 for passive electronic components.
- Micro-miniaturization – electronic components are expected to continue to shrink in size and become increasingly more sensitive using manufacturing methods that include micro-fabrication, ion implementation, and thin-film deposition.
- Composite integration – as the miniaturization trend continues more and more composites are expected to be used to increase product reliability and sensitivity. In some product lines, such as high-end speaker components, the use of aerospace titanium and laminated high-density composite cones are already being used to improve quality. Other composites (grapheme, lead zirconium titanate (PZT), etc.) are expected to be used starting with products at the high-end of the spectrum (smart sensors, speaker components, and sensor arrays) and slowly migrating down throughout the product range.

Engineering Services

How It Stands as a Product/Service Market for Maine

The emergence of Engineering Services as a product/service market in Maine is taking hold and represents a growing and now sizable detailed industry focus within the broader technology cluster of Engineering and Other Scientific/Technical Services.

In 2012, the detailed industry of Engineering Services stood at 3,077 jobs and recorded growth of 11% from 2007-2012. Maine's relative concentration as measured by location quotient stands at 0.78, so approximately 20% below the U.S. average concentration.

[19] BCC Research Passive and Interconnecting Electronic Components, Jan 2012

[20] IBIS World Circuit Board & Electronic Component Manufacturing, Feb 2014

Alignment to Maine's Technology Competencies

Engineering cuts across many of the non-life sciences core competencies found in Maine. As a broad discipline that focuses on the application of scientific knowledge in order to design, build, maintain, and improve structures, machines, devices, systems, materials, and processes, it is an important dimension in many of the core technology competencies found in Maine, such as: *Semiconductors*; *Coatings and Composites; Electronic Signal Conversion and Power Switches; Fluid Handling and Filtering; Networking, Signal Processing and Communications; Engines and Turbines; Electromechanical Components and Systems*; and *Image Processing*.

What Are Its Market Prospects?

According to IBIS World, this detailed industry is due to see an increase in demand from private investments in infrastructure – largely spurred on by low interest rates – and is expected to grow at an annualized rate of 4.4 percent to $247.1 billion over the next five years into 2018. A key growth market for outsourced engineering services to support companies, which is estimated to have reached $100 billion in 2012 – about 10 percent of the total engineering services market –is expected to grow 3-4 times the rate of total spending on engineering into 2020.[21]

Maine has a significant opportunity to benefit from the broader New England strength in Engineering Services, by focusing on offering a competitive location with access to talent and other key resources.

Enterprise and Data Hosting Services

How It Stands as a Product/Service Market for Maine

While Maine's performance across the overall Information Technology Services technology cluster has been disappointing, with job losses even as the cluster has grown nationally since 2007, a closer examination finds a detailed grouping of related computer industries that are advancing in the state.

A well-established Information Technology Services product/service market in Maine is computer facilities management services, which includes Data Hosting, Processing and Network Management, a detailed industry within the technology cluster with employment of 319 workers in 2012, an industry specialization above the national average with a 1.40 location quotient, and growth of 71% from 2007 to 2012.

Complementing this strength in computer facilities management services are two sizable and growing areas of software development:

- Custom Computer Programming Services, a detailed industry with 1,881 jobs in Maine in 2012 and growing by 39% from 2001 to 2007, though not yet an industry specialization for the state.

[21] Information Services Group Robust Growth for Engineering Services Outsourcing, Dec. 2013

- Computer Systems Design Services, a detailed industry with 1,082 jobs in Maine in 2012 and growing by 24% from 2001 to 2007, but quite small in relative concentration at 1/3 the level found nationally.

Alignment to Maine's Technology Competencies

Data Processing, Management and Analysis is one of the largest core competency groupings from the patent analysis. The patent activities involve a wide range of companies involved in electronic commerce, database design, knowledge management systems, health IT and computer security, among other applications. There are also a 10 emerging innovation companies identified who received SBIR funding or venture capital funding from 2008 to 2013 in Maine in this technology area of *Data Processing, Management and Analysis*.

What Are Its Market Prospects?

Enterprise computing has become ubiquitous across industries as a means to reduce costs, raise the efficiency of operations, and offer higher valued services to customers. The demand for enterprise computing has led many business customers to seek assistance of outside vendors, not only for the design and programming of software applications for all business functions and processes, but for the computing infrastructure to deliver those applications, process data, and manage and store data.

Across each segment of enterprise computing the market prospects are strong. Datamonitor expects business software in North America to grow at an annual compounded rate of 7.7% through 2015[22]. Not only is there strong demand for specific applications, such as customer relationship management software, but there are new demands for software to analyze the expanding amounts of data available, from digitizing of records and on-line transactions.

The outsourcing of computing for data processing and hosting services industry is also expected to grow at a healthy rate, growing at an annualized rate of 3.9% from 2014 to 2019[23]. More than half of the industry's revenues are generated through three services: business process management and data processing; data management services; and application service provisioning. Other significant services include IT technical support, IT computer and network management, and website hosting. It is a highly fragmented industry with more than 15,000 firms across the U.S., with no company claiming more than 5 percent of the industry's revenues.

An emerging technology is cloud computing, which is expected to establish new business models in data processing and hosting. Cloud computing enables the delivery of computer infrastructure "on demand" over the Internet through a shared pool of configurable computing resources. Cloud computing may be best understood as "computing as a utility"; a technological shift similar to the change from on-site electrical generation to plugging into the electrical grid at the turn of the 20th century.

[22] Datamonitor, Global Market Trends: Business Software Forecasts, 2011

[23] IBISWorld, Data Processing & Hosting Services in the U.S., February 2014

Financial Transaction Processing and Telemarketing

How It Stands as a Product/Service Market for Maine

Maine has a sizable Financial and Business Support Services technology cluster that involves highly strong specializations in traditional financial services activities involving savings institutions and insurance carriers.

A growing strength in Maine is broader activities supporting financial institutions. Two detailed industries that particularly stand out in Maine as well-established financial support product/service markets are:

- Financial Transaction Processing and Clearing with 976 jobs in 2012, a specialization of 1.63 location quotient and growth of 262% from 2007 to 2012.
- Telemarketing with 4,749 jobs in 2012 – making it the largest detailed industry in the Financial and Business Support Services cluster – an industry specialization of 2.22 location quotient and growth of 64% from 2007 to 2012.

Alignment to Maine's Technology Competencies and Assets

Financing transaction processing and electronic commerce is an important application area of Maine's technology competency in *Data Processing, Management and Analysis*. Companies like Bill Me Later, Cashstar, and Sperancza are involved in patent activities and generating venture capital funding.

What Are Its Market Prospects?

The processing of financial transactions, most of which involve credit and debit card services, but also include check processing and automated clearinghouse products, has been a thriving market even through the recession. The key driver is the growth of electronic transactions, which have been increasingly replacing cash-only purchases and thus have accounted for an increasing proportion of total financial transactions each year. In 2013 the revenues from financial transaction processing reached $55.7 billion, and it is expected to increase at a healthy average annual rate of 4.8%, reaching $70.3 billion by 2018.

The growth of financial transaction processing will be driven by increases in consumer spending in general, and in e-commerce, technological advances in mobile apps, and personalization of online services. The ability for customers to be able to perform nearly every type of financial transaction online has helped spur growth. A critical success factor for companies in financial transaction processing is adopting innovative, efficient technology. The increasing use of mobile banking via smartphones will continue to help boost electronic transactions. New apps are changing the face of the industry, such as mobile check deposit, offered by most banks, which allows individuals to deposit checks using a cell phone's camera to take a photo of the check and process it online. Other key technology advancements

are cloud computing and Big Data, which together are allowing for faster, more efficient processing and reducing costs, leading to increased profits.

Another related activity closely connected to e-commerce is telemarketing, which provides a wide range of customer services. The U.S. telemarketing industry has a massive employment base, with 475,275 employees in 2013 generating revenue of $18.2 billion. The industry is expected to realize healthy average annual growth of 3.9% each year through 2018.[24] The increased adoption of broadband technology and a move to cloud-based systems will allow more call center employees to work from home, which should greatly mitigate the cost differential between domestic and foreign labor and allow more growth in U.S. industry employment. Web-enabled call centers – where a customer engaged in an on-line transaction can push or click on a button on their computer to initiate a voice chat – is attractive to on-line retailers who want to keep potential customers on their web site.

Functional Foods

How It Stands as a Product/Service Market for Maine

Maine has a fast growing crop production industry that encompasses primarily wild blueberries and potatoes. In 2012, crop production employed 2,020 workers in Maine in 2012, and grew a robust 25% from 2001 to 2012, though not yet an overall industry specialization for Maine. In addition, Maine has a fast growing and specialized presence in frozen foods that involves its wild blueberry production. Two important detailed industries in this area include:

- Frozen Cakes and Other Pastries, with 350 jobs in Maine in 2012, a location quotient of 5.18 and job growth of 139% from 2007 to 2012
- Frozen Specialty Food Manufacturing, with 344 jobs in Maine in 2012, a location quotient of 1.18 and 394% job growth from 2007 to 2012

Alignment with Maine's Technology Competencies and Broader Assets

There is not a strong technology competency in Maine aligned with Functional Foods, but Maine's wild blueberry production does open opportunities for a high value functional food. These wild blueberries are specific to Maine, Atlantic Canada and Quebec, who offer the glacial soils and northern climate needed to grow them. The Wild Blueberry Association of North America explains how the benefits of wild blueberries stand out from more cultivated berries[25]:

- Antioxidant capacity - Wild blueberries contain more of the powerful antioxidant anthocyanin and demonstrate greater antioxidant capacity per serving than cultivated blueberries.
- Taste - Wild blueberries have a more intense, sweet and tangy taste than cultivated blueberries

[24] IBISWorld, Telemarketing & Call Centers in the U.S., Oct. 2013

[25] See http://www.wildblueberries.com/contact/

- Size - Wild blueberries are naturally smaller and more compact (less water content) than cultivated, which means you get more Wild Blueberries per pound.
- Performance - Wild blueberries hold their shape, texture and color through a variety of baking and manufacturing process. They also freeze very well: IQF Wild Blueberries maintain their quality for more than two years.

What Are Its Market Prospects?

BCC Research projects that by 2016 the global market for Functional Foods should be worth $67 billion and reflect a compounded annual growth rate from 2011 to 2016 of 6.4%.[26] As a separate market segment, Functional Beverages is expected to reach $88 billion by 2016 and record an 8.8% compounded annual growth rate from 2011 to 2016.

Market growth in functional foods and beverages is fueled by increasingly health-conscious consumers. Blueberries are one of the herald "functional" fruits that are a major source of antioxidants, along with pomegranate, acai berries, and cranberries. Health research points to the important role that antioxidants have in protecting against diseases such as cancer, heart disease, diabetes, and Alzheimer's by blocking the activity of damaging cell processes.

One limiting factor in advancing the market for blueberries is how fast they can perish. Incorporating blueberries into frozen foods and drinks can extend the market for these products. A key area for technology advancement is in freezing technologies. Though vastly improved over the past 25 years, frozen foods and beverages are still considered inferior to their freshly made counterparts. Industry researchers are continually searching for ways to retain fresh-baked qualities after freezing, and at the same time to reduce the stabilizers and other perceived unhealthy additives that are in use.

Molecular-Based Diagnostics and Genomics

Detailed Industry Strengths

There is one well-established detailed industry in Maine in the Biopharmaceutical technology cluster that is both specialized and growing: In-vitro Diagnostic Substance Manufacturing, employing 474 workers in 2012, with a 5.61 location quotient and growing by 26.4% from 2007 to 2012.

Alignment to Maine's Technology Competencies

Biologics and Biotechnology is one of the most extensive technology competencies found in Maine, with 8% of all grouped patent records and an extensive base of emerging innovative companies. The applications found within the patents suggests the extensive breadth of this technology competency

[26] BCC Research, Nutraceuticals: Global Markets and Processing Technologies (FOD013D) – see http://www.bccresearch.com/pressroom/fod/global-nutraceutical-market-worth-$207-billion-2016

including such diverse areas as genomic-based analysis techniques, development of monoclonal antibodies, biological detection systems, transgenic mouse development, and stem cell biology.

What are Its Market Prospects?

Molecular-based diagnostics is a new class of diagnostics tests based on identifying nucleic acids or proteins of patients or foreign organisms residing in a patient. They are used to confirm the status of a disease and its progress in order to help physicians in developing a specific treatment plan for a patient or gauging their risks of developing a specific health problem/disease. The applications for molecular-based diagnostics include infectious disease molecular testing, oncology, blood screening, genetic testing, DNA, microbiology, tissue typing, and food pathogen detection.

Globally, the market for molecular-based diagnostics is estimated to reach revenues of $17.3 billion in 2012. It is expected to grow at a compound annual growth rate of 12.6 percent for a market value of $36.5 billion by 2018.[27]

Molecular diagnostics are integrally linked with the emerging era of personalized medicine. Bioscience advances based on genomics are shaping and advancing medicine in the 21st century from being an inexact science of detection and treatment to one of prediction, prevention, and strategic intervention or what is more popularly referred to as "personalized" medicine. As Janet Woodcock, Deputy Administrator of the Food and Drug Administration explains: "We're telling everyone that we can tell that diagnostics are excruciatingly important—they're actually the foundation of medicine, because you have to know what the person has. And personalized medicine—sub-setting patients and everything—it's going to be the future of medicine. We can't do that without good diagnostics."[28] The application of diagnostics in health care promises a means of controlling costs through more informed decision-making and this may help in advancing the market for diagnostics in the years to come.

Molecular diagnostics also are being advanced in line with new scientific discoveries and technology advancements. Among the emerging technologies in molecular-based diagnostics are:

- Single cell sequencing – identity testing of human DNA from a single cell is a growing field that relies on short tandem repeats (STR). New plate-based systems both amplify and sequence the single cell, greatly reducing contamination risk thus improving results.
- Epigenetic tests – these tests rely on studying the epigenetic changes in the genome instead of relying solely on genetic changes. The epigenetic changes in genomes are influenced by non-genetic inheritable changes in gene regulation.

[27] BCC Research Molecular Diagnostics: Technologies and Global Markets, Mar 2013

[28] Interview with Janet Woodcock, Pharmacogenomics Perspectives, Vol I, pages 14-15

Remediation and Environmental Consulting

How It Stands as a Product/Service Market for Maine

Two emerging growth areas, which are detailed industries within the Environmental Services technology cluster, are now reaching a critical size in Maine:

- Environmental Consulting Services with employment of 380 workers in 2012 and growth of 24% from 2007 to 2012. This detailed industry is now close to the national average in concentration with a location quotient of 0.91.
- Remediation Services with employment of 335 workers in 2012 and growth of 50% from 2007 to 2012. Similarly, just slightly behind the national average in concentration with a location quotient of 0.86.

Alignment to Maine's Technology Competencies

Environmental and remediation services are found in a number of technology competencies in Maine including *Fluid Handling and Filtering* involving applications in storm water and environmental management and in *Chemistry and Organic Compounds* involving applications such as carbon dioxide removal and scrubbing processes. Among emerging innovation companies are Cerahelix, involved in nanofilteration membranes for water re-use and recycling, which received both SBIR and venture capital funding, and Fluid Imaging Technologies that develops particle analysis instrumentation.

What Are Its Market Prospects?

The Remediation and Environmental Consulting industry provides advice to businesses and governments on environmental issues and risks, as well as providing services to assist in the cleanup of contaminated buildings, mine sites, soil, and ground water. The industry has three main services that comprise a majority of their business: Site remediation planning and services leads the way with 29.5 percent of the market, followed by building remediation services (19.4 percent), and environmental assessments (10.7 percent).

In the United States the market for environmental consulting and remediation is estimated to reach a value of $41 billion, with remediation services expected to make up 60 percent of the market. The industry in the U.S. is expected to continue growing into 2018 with revenues estimated to reach $48.4 billion for a compound annual growth rate (CAGR) of 3.4 percent.[29] Globally, the market for these products and services is estimated to have generated revenues of $63 billion in 2012 with most of the demand coming from the North American and Western European markets.[30]/[31]

[29] IBISWorld Environmental Consulting in the U.S., Dec 2013

[30] McIlvaine Company $36 Billion World Site Remediation Market in 2012, Apr 2012

[31] First Research, Inc. Environmental Consulting Services, Feb 2014

A key driver overall for this market remains how environment regulations are advanced and enforced. Technology advances also are shaping activities. The remediation industry is starting to address environmental problems with biological approaches, such as bacteria to clean up contaminates in groundwater or fungi to return soil to a less contaminated state. The use of genetically modified organisms (GMOs) is leading the way for bioremediation with many of the most promising enzymes now being rolled out into limited field experiments.

Turbines for Energy Production

Detailed Industry Strengths

Maine has a well-established industry position in the detailed industry of Turbine and Turbine Generator manufacturing that employed 400 workers in 2012, had a location quotient of 3.12 and recorded a 158% employment increase from 2007 to 2012. This industry manufacturers wind and solar powered turbine generators, windmills for generating electric powe,r and more traditional turbines for steam, gas and hydraulics.

Hydroelectric power and other electric power generation involving solar, wind or tidal power are also specialized in Maine, but are not growing in employment.

Alignment with Maine's Technology Competencies

There is a direct alignment to the *Engines and Turbines* technology competency found in Maine to support the future growth of the well-established Turbine and Turbine Generator industry product/service market. This strength has a good presence among innovative small businesses in Maine attracting federal Small Business Innovation Research funding and/or venture capital financing, such as Ocean Renewable Power, Sergie Breus, and Pika Energy.

What Are the Market Prospects?

The market for turbine and turbine generators is getting a boost from the shift towards more natural gas-fired electricity plants, as unconventional sources of natural gas soar in the U.S. These gas-fired plants are more environmentally friendly than coal plants, and have a smaller minimum efficient size than coal-fired plants. The U.S. Energy Information Administration reports that natural gas-fired generation of electricity is replacing coal and nuclear plants, and is now a considerably higher level of expected energy generation by 2020 than previously projected[32].

At the same time, the market for wind turbine manufacturing is expected to be very volatile as federal incentive policies unfold. The impact of uncertain federal incentive policies has already been felt in recent years. IBISWorld reports that revenues for wind turbine manufacturing reached over $14 billion in 2009 then fell to $7.6 billion in 2010 and then soared back to nearly $15 billion in 2012, but were

[32] See http://www.eia.gov/forecasts/aeo/er/early_elecgen.cfm

expected to seriously decline in 2013 to just over $5 billion[33]. This volatility reflects the uncertainties surrounding the Federal Production Tax Credit for wind power that was scheduled to expire in 2012 and then was extended to 2013 and recently has expired. But even this expiration has been modified by Congress by allowing for wind farms under construction by the end of 2013 to still qualify for the 2.3 cent per kilowatt hour tax credit. Power Magazine reports that utilities have been signing a record number of power purchase agreements for wind energy in late 2013 and early 2014 that involve the Federal Production Tax Credit, suggesting that the demand for wind turbine manufacturing is expected to be strong through 2014.[34] Longer-term there is also interest in Congress to streamline energy tax credits and to make them technology neutral, which may bring back incentives for wind power in the near future.

Still there are important market opportunities for wind turbine manufacturing going forward. One growth opportunity is in export activities. IBISWorld reports that exports will rise at an annualized rate of 4.3% from 2013 to 2018, with key opportunities in Canada, Mexico, and South America. Another growth opportunity longer-term may be in offshore wind power, which has been slow to take off in the U.S., but is being strongly advanced by the Obama Administration. The experience of Europe suggests that offshore wind can become an important source of renewable electricity. According to the Energy Information Administration, offshore wind energy is expected to reach a capacity of 8,300 megawatts[35].

Wireless Sensor Networks

How It Stands as a Product/Service Market for Maine

A well-established product/service market in Electronics and Semiconductors is non-traditional communications equipment manufacturing, involving control and detection systems that integrate advances in wireless communications and sensing technology , with employment of 311 workers in 2012, a high industry specialization of 2.74 location quotient and growth of 532% from 2007 to 2012.

Alignment to Maine's Technology Competencies

One of the larger technology competencies found in Maine is in *Networking, Signal Processing and Communications* technologies involving communication service architecture, teleconferencing systems, and processing for digital video systems, optical networks, and sensor systems. Eight emerging innovative companies were identified from SBIR and venture capital funding over 2008 to 2013 which are involved in this technology competency area.

[33] IBISWorld, Wind Turbine Manufacturing in the U.S., October 2013

[34] See Sonal Patel, Wind Production Tax Credit Expires with Uncertain Impact, January 2, 2014, Power Magazine

[35] See http://www.eia.gov/forecasts/ieo/electricity.cfm

What Are Its Market Prospects?

Advances in sensor technologies and wireless communications are converging into wireless sensor networks that offer significant opportunities to gather and process real-time data to inform control and detection systems. IDTechEx research projects that the Wireless Sensor Networks market will grow to $1.8 billion by 2024, by enabling the automatic monitoring of building systems, energy systems, weather and natural environments, traffic, and many other applications.[36]

As Thomas Davenport, writing in the MIT Sloan Management Review this past July 30, 2012, explained: "companies … will use real-time information from sensors, radio frequency identification and other identifying devices to understand their business environments at a more granular level, to create new products and services, and to respond to changes in usage patterns as they occur."[37]

Key to the growth of Wireless Sensors Networks are advances in energy devices to make sensor networks viable. This includes super-capacitors, thin-film batteries and other energy harvesting devices.

[36] Dr. Peter Harrop and Raghu Das, Wireless Sensor Networks (WSN) 2014-2024: Forecasts, Technologies, Players, IDTechEx, Q1 2014

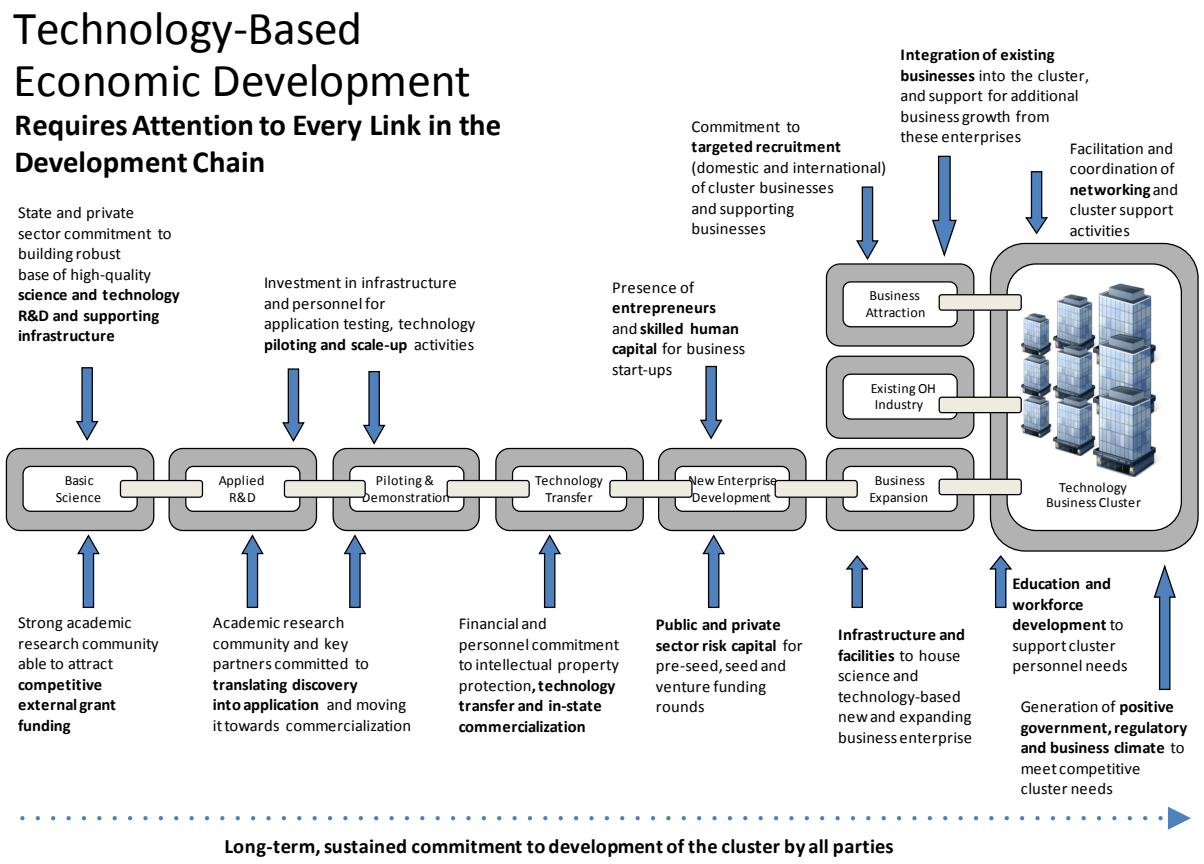
[37] Thomas Davenport, Paul Barth and Randy Bean, "How 'Big Data' Is Different," MIT Sloan Management Review, July 30, 2012.

SECTION IV:
MAINE'S DEVELOPMENT ASSETS AND INNOVATION ECOSYSTEM

Economic development is not easy to achieve in general, while technology-based economic development is an even greater challenge. For economic development to occur an entire interconnected sequence of positive factors has to be in place. For development of technology-based industries the chain of factors is particularly complex and challenging to develop and manage. If any link in the chain in missing, a sustainable technology cluster is unlikely to develop.

Through its years of experience in designing, advancing, implementing, and improving technology-based economic development initiatives, the Battelle Technology Partnership Practice has conceived a model that attempts to encapsulate this complex, inter-related series of elements that drive sustained, long-term economic growth. Figure 4 presents our illustration of the vital linkages found in a robust technology-based economic development innovation ecosystem.

Figure 4. Technology-Based Economic Development Innovation Ecosystem



The states and regions in the U.S. which have achieved success in growing robust technology clusters (places such as the San Francisco Bay region and Boston) have well-developed technology development chains in place. These technology-based economic development chains may form naturally over time (as occurred in Silicon Valley), or they may result from dedicated activities of states, regions and key stakeholders to connect and build links in the chain to assure such development happens. The figure above illustrates a basic technology-based economic development chain and the specific links that need to be in place to form and grow a technology cluster.

For this assessment of Maine, Battelle considered three broad areas that encompass the key functional areas involved in technology development, including:

- Research and Development – including basic and applied research through the process of technology transfer;
- Commercialization/Market Entry – focusing on product development, new business formation, and access to capital; and
- Growth/Scalability – involving the range of issues for growing, retaining, and attracting technology companies to Maine and advancing overall technology clusters.

This assessment relied on several sources:

- Analysis of available databases on Maine's activities in R&D, venture funding, SBIR awards, STEM (science, technology, engineering and math) occupations, entrepreneurial activities, business tax climate, and broadband technology infrastructure.
- Detailed interviews conducted with over 20 Maine stakeholder groups and individuals representing a cross-section of the broad targeted technology areas. It is important to note that when these interviews were conducted, early in the process of developing this analysis, Maine's broad targeted technology areas were still the primary basis for discussion, rather than the refined technology clusters. The insights from these interviews are therefore grouped by the broad targeted technology areas, with technology cluster-specific findings highlighted when possible.
- Results from a Maine Department of Economic and Community Development survey of companies receiving assistance from MTI.

Research and Development Infrastructure

Why It's Important

One of the most critical elements in pursuing a technology-based economy is the ability of the research and development (R&D) base to drive new products, services, and production processes that in turn provide companies with opportunities to enter new markets and to gain greater market share. In other words, R&D drives technological progress and therefore economic growth. A strong R&D base is critical to supporting modern economies and increasing the economic vitality of a region, state, or nation. A state with a robust base of R&D activities can capitalize on the resulting innovations and technologies through the creation of new products, companies and industries, and high-wage jobs.

Research has shown that over the long-term the majority of newly created jobs are the direct or indirect result of advances in science and technology. For example, it was the emergence of Information Technology in the early to mid-1990's that led to broad-based economic development as a result not only of jobs created in the IT sector but the additional jobs created in supporting industries. In the 21st century, advances in the biosciences are driving growth of numerous industries including biopharmaceuticals, medical devices, energy and other bio-based products.

An examination of states and regions that are home to robust innovation-driven economies reveals that they have a strong R&D enterprise. They have both research institutions – including universities, academic medical centers, national laboratories and nonprofit research institutions – and industry that are conducting world-class R&D and moving discoveries into new products and processes.

The presence and productivity of research institutions with recognized areas of research excellence is critical for states seeking to grow technology-based knowledge economies. First, the research conducted at these institutions generates new knowledge and technology, forming the basis for creating new firms and introducing new products and services into the marketplace. Second, these organizations both attract and produce highly-trained personnel who provide the skilled workforce needed by technologically advanced companies. Third, the presence of such a workforce, in turn, attracts technology companies to locate in proximity to these centers of excellence.

The universities that have been most effective in launching and supporting knowledge economies display the following characteristics:

- They are performing world class research in areas that correspond to the science and technology drivers of the regional and national knowledge sectors;
- They have a cadre of nationally prominent faculty. Numerous studies have found that "the presence of star scientists and engineers affect university spin-off activity as they have leading-edge knowledge and the ability to create radical innovations suitable for commercial exploitation;"[38]
- They have leadership who view the university as a key partner with industry and government in creating and growing a knowledge economy;
- They have the physical infrastructure needed to support research and technology development; and
- They have mechanisms in place, including financing programs, to facilitate the translation of research findings into commercial products and processes.

Characteristics of Universities and Other Research Institutions that Contribute to Growing Innovation Economies

- World-class research
- Nationally prominent faculty
- Leadership committed to working with industry
- State-of-the-art labs and facilities
- Aggressive technology transfer and commercialization

[38] Rory P. O'Shea, Thomas J. Allen, Arnaud Chevalier, and Frank Roche. "Entrepreneurial orientation, technology transfer, and spin-off performance of U.S. universities." Research Paper 34 (2005) 994-1009. www.elsevier.com/locate/econbase, July 11, 2005.

Successful states and regions depend on institutional excellence in pertinent areas of science and engineering research to drive the economy. They also recognize that to achieve the requisite level of quality and critical mass within their research base requires public investment. However, academic stature is not sufficient by itself to drive a technology-based economy. Strong technology communities continue to feature top institutional leadership fully committed to engaging with industry and institutional cultures comfortable with participating in the conversion of intellectual capital into economic activity. It is important to note, however, that programmatic incentives are often required to assure these goals of public purpose lead to institutional action.

R&D Infrastructure: Maine's Overall Situation

In the U.S., academic institutions drive a significant portion of basic research conducted, and as such are important indicators for understanding the R&D base in Maine. Academic R&D also affects economic development through job growth as technologies developed at universities are commercialized and brought to market.

Maine's academic R&D expenditures reached almost $130 million in 2011, an increase of 90 percent since 2001. This outpaced the national growth rate of 73 percent during the same time period. However, even with this significant growth, the level of R&D on a per capita basis in Maine is still roughly half that of the nation (see Table 9).

Table 9. Growth Trends in Academic R&D Expenditures on a Per Capita Basis, 2001–2011

Year	Maine University R&D Total	Maine Population	Award Amount per 1,000 Population	
			Maine	U.S.
2001	$68,058,000	1,285,692	$52,935	$114,830
2002	$69,224,000	1,295,960	$53,415	$126,319
2003	$75,092,000	1,306,513	$57,475	$138,372
2004	$87,353,000	1,313,688	$66,494	$146,668
2005	$81,624,000	1,318,787	$61,893	$154,815
2006	$120,038,000	1,323,619	$90,689	$160,066
2007	$137,425,000	1,327,040	$103,558	$164,096
2008	$128,090,000	1,330,509	$96,271	$170,700
2009	$128,434,000	1,329,590	$96,597	$179,076
2010	$118,832,000	1,327,585	$89,510	$188,597
2011	$129,231,000	1,328,544	$97,273	$198,630

Source: Battelle analysis of NSF Survey of R&D Expenditures at Universities and Colleges

It is also important to understand the level of industrial research and development taking place within a state. Maine's industry R&D expenditures reached almost $300 million in 2011, more than twice the level of the state's academic R&D, and an increase of 31 percent since 2001. This mirrored the national growth rate of 33 percent. However, when normalized on a per capita basis, the level of industry R&D expenditure is less than a quarter of that of the nation (see Table 10).

Table 10. Growth Trends in Industry R&D Expenditures on a Per Capita Basis, 2001–2011

Year	Maine Industrial R&D Total	Maine Population	Award Amount per 1,000 Population	
			Maine	U.S.
2001	$202,017,000	1,285,692	$157,127	$708,909
2002	$250,000,000	1,295,960	$192,907	$674,030
2003	$200,724,000	1,306,513	$153,633	$691,894
2004	$208,301,000	1,313,688	$158,562	$711,398
2005	$226,159,000	1,318,787	$171,490	$765,300
2006	$247,669,000	1,323,619	$187,115	$830,046
2007	$269,267,000	1,327,040	$202,908	$893,888
2008	$290,681,000	1,330,509	$218,474	$955,892
2009	$282,393,000	1,329,590	$212,391	$920,532
2010	$278,977,000	1,327,585	$210,139	$901,886
2011	$294,093,000	1,328,544	$221,365	$943,853

Source: Battelle analysis of NSF Business Research and Development and Innovation Survey.

Overall, there is a perception in Maine among some that there is a lack of connection between industry and research, particularly exacerbated by the distance between Orono, the academic center, and Portland, the business center. However, others feel that university research is accessible with specialized industry-specific facilities for prototype development, design manufacturing, and test samples.

R&D Infrastructure: Maine's Cluster-Specific Situation

To better understand the challenges facing the specific technology clusters, Battelle examined more closely the dynamics behind each cluster as it relates to the infrastructure to support research and development. This involved focused outreach and interviews with key cluster leaders, as well as with economic development leadership. The findings, by broad targeted technology areas and associated technology clusters, are highlighted in the summary that follows.

Biotechnology (Technology clusters: Biopharmaceuticals and Medical Devices)

- Research led by non-profit institutions – roughly $70-$75 million in NIH funding
- Lack of an academic medical center is a major weakness – particularly for clinical research.
  - Rise of University of New England might offer an opportunity.
- Still, pre-clinical R&D aided by availability of animal facilities.
  - Considerably less expensive than in Boston.
- Funding for faculty start-up packages is an issue – state funding focuses on capital projects.
- Specifically related to biotechnology, NIH funding is stagnant – Maine recording slight declines.
  - Key strengths in genetics and diagnostics. Emerging efforts in regenerative biology.

- Major NIH INBRE grant focused on comparative functional genomics – brings together 13 Maine institutions.
  - Also enhancing training and networking.
  - Plan to start next year a series of workshops on entrepreneurism and commercialization.

Composites and Advanced Materials (Technology clusters: Boatbuilding and Related Industries; and Materials for Textiles, Apparel, Leather and Footwear)

- Growing research base in materials and metals at UMaine – reaching above $14 million in 2011 up from ~$1 m in 2001. Well over 100 peer-reviewed publications since 2009 to date.
- Active connections with UMass Lowell.
- Composites Engineering Research Laboratory undertaking applied research directly linked to industrial needs.

Environmental Technologies (Technology clusters: Environmental Services; and Alternative Energy and Turbines)

- R&D assets within university system are closely linked with industry.
- Active university research efforts in environmental sciences (beyond just oceanography)
  - $7-8 million in funding and 496 publications in environment/ecology field from 2009 to date.

Forest Products and Agriculture (Technology clusters: Agriculture, Aquaculture, Fisheries and Food Production; and Forestry-related Products)

- Agricultural research is major focus of university research with range of $17 to $26 million in recent years (lots of year to year fluctuations).
- Active publications with 237 in Plant Sciences and 136 in Animal Sciences from 2009 to date.
- Strong Extension program at UMaine with tasting lab and prototyping labs.
- Strong expertise, but limited capacity within processing and food production resources.

Information Technology (Technology clusters: Electronics and Semiconductors; and Finance and Business Support Services)

- There is no significant level of IT research being conducted in Maine within the university system – approximately $3 million annually and 17 peer-reviewed publications (0.1% of U.S. total).
- In addition, the computer engineering programs that do exist are in Orono, which in turn are not particularly connected to the technology cluster which is located primarily in Portland.

Marine Technology and Aquaculture (Technology cluster: Agriculture, Aquaculture, Fisheries and Food Production)

- Maine represents one of the most advanced marine science analytical capabilities in the world.
  - Nearly $15 million in university research and 470 publications in Aquatic Sciences (3% of U.S. total).
  - Strong consortia among research entities to capture federal grant funding – but still need to better share physical assets.
- Still, university focus shifting more to environmental issues and away from industry-related needs.
  - Lack of an ocean engineering program limits impact on advancing fisheries and aquaculture industry.
  - Limited interest in aquaculture – though new Aquaculture Research Institute formed in response to industry needs.

Precision Manufacturing (Technology clusters: Defense; and Electronics and Semiconductors)

- Low levels of R&D and publications for university mechanical engineering and aerospace engineering.
- Specific to defense-related industries, minimal levels of university aerospace engineering research.
  - Industry drives applied research activities.
- Specific to the electronics and semiconductors industry, limited levels of university electrical engineering and electronics research - $3 to $5 million in recent years.
  - Industry drives applied research activities.

Commercialization/Market Entry Infrastructure

Why It's Important

Key to Maine realizing the growth of its innovative clusters will be the entrepreneurs who can turn innovation into successful businesses. Innovation, in and of itself, will not necessarily translate into economic activity. Rather, it is the application of a technology and its introduction into the marketplace that results in economic growth. A number of studies point to the importance of entrepreneurship in changing regional economies. Starting with David Birch's work, validated by the Office of Advocacy of the U.S. Small Business Administration (SBA) and further refined by studies commissioned in recent years by the Kauffman Foundation and others, it is clear that technology, innovation, and entrepreneurship drive economic growth. "The large portion of entrepreneurial firms and the significant number of jobs created by newer, small firms in the U.S. are a strong indication that the entrepreneurial

sector with its flexibility and capacity to adapt quickly is poised to become an even more important protagonist in the future economic growth of the country."[39]

Indeed, research demonstrates that entrepreneurial activity is closely tied to a state or region's level of economic growth. The Global Entrepreneurship Monitor (GEM), a leading research consortium that seeks to improve understanding of the link between entrepreneurship and national economic growth, suggests that levels of entrepreneurship may account for as much as one-third of the variation in economic growth among regions, states, and nations.[40]

With a few notable exceptions – such as Austin, Texas and San Diego, California – the entrepreneurial climate necessary to spawn high-growth enterprises does not develop fully and sustainably through market forces alone. The ability to build a critical mass of entrepreneurial management talent in a locality is first dependent on providing the resources that must be amassed to successfully build a company. Those resources may include technology, capital, professional expertise, and a host of other services such as assistance in determining economic feasibility and identifying markets and distribution channels. While such a climate is important to the retention and attraction of seasoned entrepreneurs, it is essential for the development and support of new generations of entrepreneurs as well.

However, catalyzing entrepreneurial activity is a challenge for many states. It is often stated that entrepreneurship is a "contact sport", and the barriers and obstacles to being able to scale up a firm are significant, particularly for a technology firm. The two areas that entrepreneurs indicate are their greatest obstacles are talent and capital.

Of these, the most significant obstacle to creating and growing entrepreneurial companies is the lack of experienced management talent. For many states, there simply is no cadre of experienced, serial entrepreneurs who know how to turn an idea or a product into a successful venture. Such serial entrepreneurs are needed not only to lead new ventures but also to serve as mentors to help fledgling entrepreneurs develop their skills and increase their chances of success. They have contacts in the investor community, can recognize quality deals, and help to generate deal flow that helps firms access capital markets.

The second challenge facing entrepreneurs is access to capital. Entrepreneurs require access to capital at each stage of their development, from early-stage, proof-of-concept and prototype development to venture financing. States that have limited risk capital to invest end up leaving their entrepreneurial companies on the "runway", unable to take off and reach their growth potential.

Most people realize that the discovery of new knowledge resulting in the development of new technologies is a very expensive process running, in some cases, into millions of dollars. What many people do not realize is that even after discovery, the costs associated with developing and taking a

[39] Global Entrepreneurship Monitor: National Entrepreneurial Assessment U.S.A 2003 Executive Report,p. 7. See www.kauffman.org/items/cfm/536, 11/11/04.

[40] Global Entrepreneurship Monitor 1999 Executive Report, p. 10.

technology product or service to market are also very substantial. Major costs incurred after the research has been completed include the cost of: assessing the market to determine the competition, the likely market, and the price points for competitive advantage; developing a prototype; preparing a marketing and sales plan; and scaling up for manufacturing. Finally, actual product distribution, sales, and marketing must be undertaken. Sufficient capital must be available to fund these activities in order for business growth and economic development to occur.

It is has long been recognized that risk capital is the lifeblood of technology-based ventures.[41] Despite the critical importance of experienced, early-stage, risk capital, the national trend that has occurred as a result of the global financial crisis has been for risk capital to move increasingly toward later-stage deals or to dry-up altogether. The broad spectrum of the risk capital continuum comes into play at different periods in a company's development. Ideally, a region would like to see a large pool of startup companies entering the commercialization and risk capital pipeline and subsequently being supported through the pipeline by a variety of financial mechanisms. If the number of startups is severely constricted at any stage along the continuum then it is unlikely that a region will see companies emerge at the end of the pipeline, where much of the economic development impact is seen.

Yet, few sources of funding bridge the gap between the point at which a discovery has been identified and demonstrated and the point at which a business case has been validated and venture capital or debt capital can be obtained. Research conducted by Lewis Branscomb and Philip Auerswald for the U.S. Department of Commerce's National Institute of Standards and Technology found that "efficient markets do not exist for allocating risk capital to early-stage technology ventures."[42] The sources typically tapped to address this gap include angel investors, venture funds that invest at the seed and early stage, and publicly and privately supported university and non-university programs specifically created for this purpose.

In the past, angel investors played an important role in bridging the gap between funding from friends and family and funding from formal venture capital funds. In fact, data developed by the Center for Venture Research (CVR) at the University of New Hampshire revealed that angels are the largest source of seed and start-up capital. After experiencing a significant contraction in angel investments in 2008 and 2009, the angel investment market began to rebound in 2010. Total investment in 2010 was $20.1 million, an increase of 14 percent over 2009 according to CVR. Over time there has been an increase, however, in angel investment in post-seed and later-stage investments. In 2005, 55 percent of angel investment was at the seed and start-up stage, by 2010 only 31 percent was invested at the seed and early-stage. [43][44] CVR attributes this trend to changes in market conditions, attributable to the fact

[41] See Hellmann, T.F. & M. Puri (2000). "Venture Capital and the Professionalization of Start-up Firms: Empirical Evidence," Research Papers 1661, Stanford University, Graduate School of Business, and Engel, Dirk (2002), The Impact of Venture Capital on Firm Growth: An Empirical Investigation, ZEW Discussion Paper No. 02-02, Mannheim.

[42] Branscomb, L. and P. Auerswald. *Between Inventions and Innovation: An Analysis of Funding for Early-Stage Technology Development.* National Institute of Standards and Technology, U.S. Department of Commerce, 2002.

[43] Sohl, J. "The Angel Investor Market in 2005: The Angel Market Exhibits Modest Growth." Durham, NH: University of New Hampshire, Center for Venture Research, 2006.

[44] Jeffrey Sohl, The Angel Investor Market in 2010 "A Market on the Rebound", Center for Venture Research, April 12, 2011.

that formal venture capital funds are making later-stage investments, thus creating a gap at the post-seed stage, and the preferences of larger, more formal angel alliances.

Another factor making it difficult to obtain seed and early-stage financing is the fact that as formal venture capital funds have become larger—in 2010 the average fund size was $149 million—the amount invested per deal has increased to a minimum of several million dollars initially. This means that the stage of investment has tended to move downstream to larger, later-stage deals. As a result, it has become increasingly difficult to obtain small amounts of seed capital in the $1 million to $2 million range or less.

Figure 5 illustrates the amounts and types of capital needed by technology companies at various stages of their development.

Figure 5. Commercialization Financing Needs by Phase

	R&D	Translational Research and Commercialization	Pre-seed/Seed	Start-up	Expansion
ACTIVITIES	Conduct R&D Identify discoveries with possible commercial potential	Assess potential of technology Identify market Demonstrate proof of concept at lab scale Protect IP Engineering optimization Licensing or business formation	Develop prototype Testing and validation Prepare business strategy Establish business function Secure initial financing	Put management team in place Secure follow-on financing Staff up for sales and marketing Initial sales and marketing	Full scale production
FINANCING SOURCES	Conventional peer reviewed federal grant support	• Within university: Grants funded with university, state or industry dollars • Non-University: Grants funded by public and philanthropic support • SBIR I	• Friends and Family • Pre-Seed/Seed funds • Angel investors • SBIR Ph II	• Early-seed stage venture capital • Publicly supported investment funds	• Venture funds • Equity • Commercial debt • Industry (strategic alliances, mergers and acquisitions)
LEVEL OF INVESTMENT	Varies	$25,000 to $250,000	$250,000 -$1 million	$1 – $2 million	> $2million

Commercialization/Market Entry Infrastructure: Maine's Overall Situation

Overall, there is a growing level of entrepreneurial support services available in the population centers of the state. Still, the level of entrepreneurial activity in Maine is mixed, generally lagging overall national rates, but being competitive within the New England region. This is based on the U.S. Census of Business Dynamics, which uses the longitudinal business database developed by Census to track firm dynamics of births, deaths, contractions, and expansions over time. Over the 2007 to 2011 period (the latest years available), the rate of annual new establishment formation in Maine was 9.4 percent, lower than the national rate of 10.4% but the highest in the New England region. The job creation rate

associated with these new establishments averaged 4.4 percent over that time period, again lower than national rates but competitive within New England.

Another measure of entrepreneurial activity examined is the Inc. 5000 Fastest Growing Companies list, which identifies the private companies experiencing the most rapid growth. The presence of these high-growth firms can serve as a measure of a state's success in starting, attracting, and growing high-growth, entrepreneurial businesses. Maine had fewer of the fast growth firms identified in the Inc. 5000 list than any other New England states except Vermont. Interestingly, nine of Maine's thirteen high-growth firms on the Inc. 5000 list are in one of Maine's technology clusters, indicating the importance of these clusters to the overall economy.

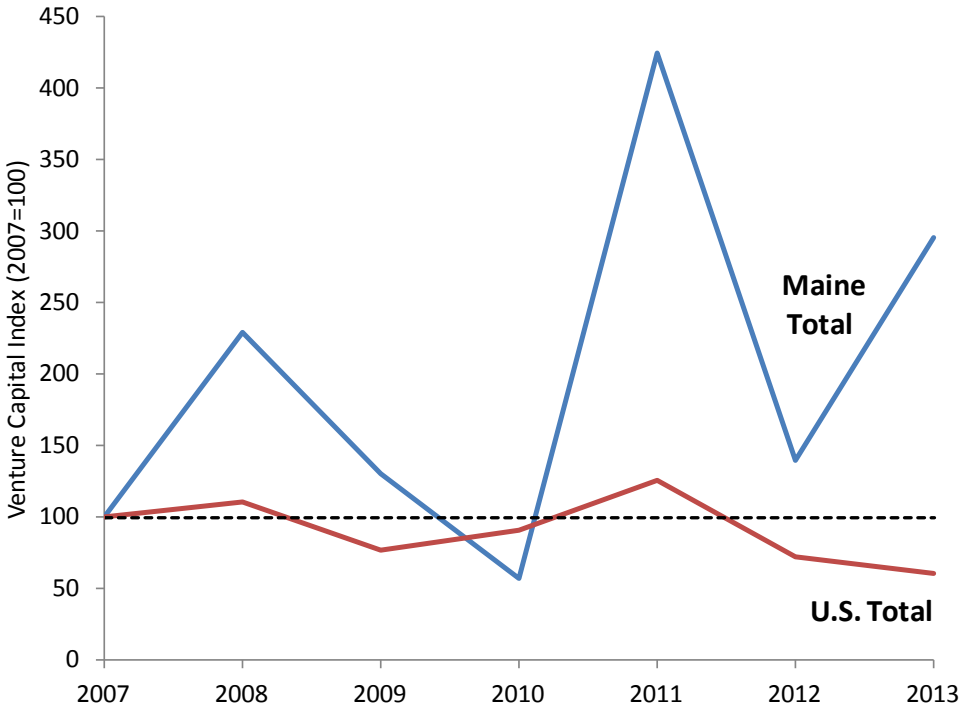
Table 11. Key Indicators: Entrepreneurial Activity

Region	Avg. Annual Growth in New Business Establishments 2007–2011	Job Creation Rate from New Business Establishments 2007–2011	Inc. 5000 Firms 2013
United States	**10.4%**	**5.0%**	**n.m.**
Maine	9.4%	4.4%	13
Connecticut	8.7%	4.4%	50
Massachusetts	9.0%	3.9%	183
New Hampshire	9.1%	4.1%	24
Rhode Island	9.2%	4.5%	16
Vermont	8.8%	4.4%	6

Venture capital funds invested approximately $126 million in Maine-based companies between since 2007. Maine's level of venture capital investment generally stood above the U.S. average for this time period (see Figure 6).

But although higher than the national average, upon closer examination, the data shows that Maine experienced a lower level of investment when compared to other New England states. As Figure 7 illustrates, Maine had not only the lowest level of investment when compared to regional peers, but also experienced the fewest number of deals, with just 49 during the 2007 to 3Q, 2013 time period.

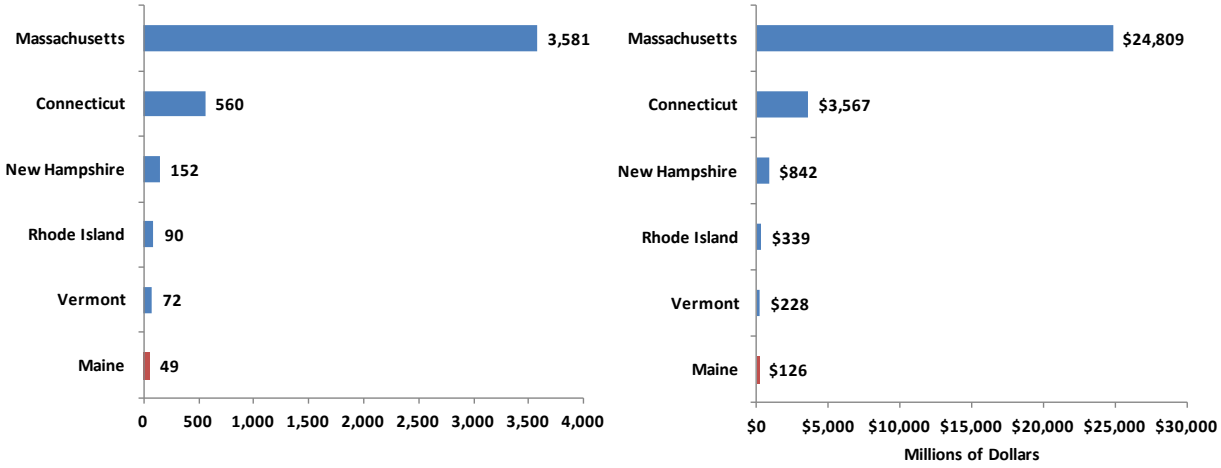
Figure 6. Trends in Venture Capital Investments, Maine and U.S., 2007–3Q 2013



Note: Venture capital data through mid-November 2013

Source: Battelle analysis of Thomson Reuters, ThomsonOne database.

Figure 7. Venture Capital Deals and Investments across the New England Region, 2007–3Q 2013

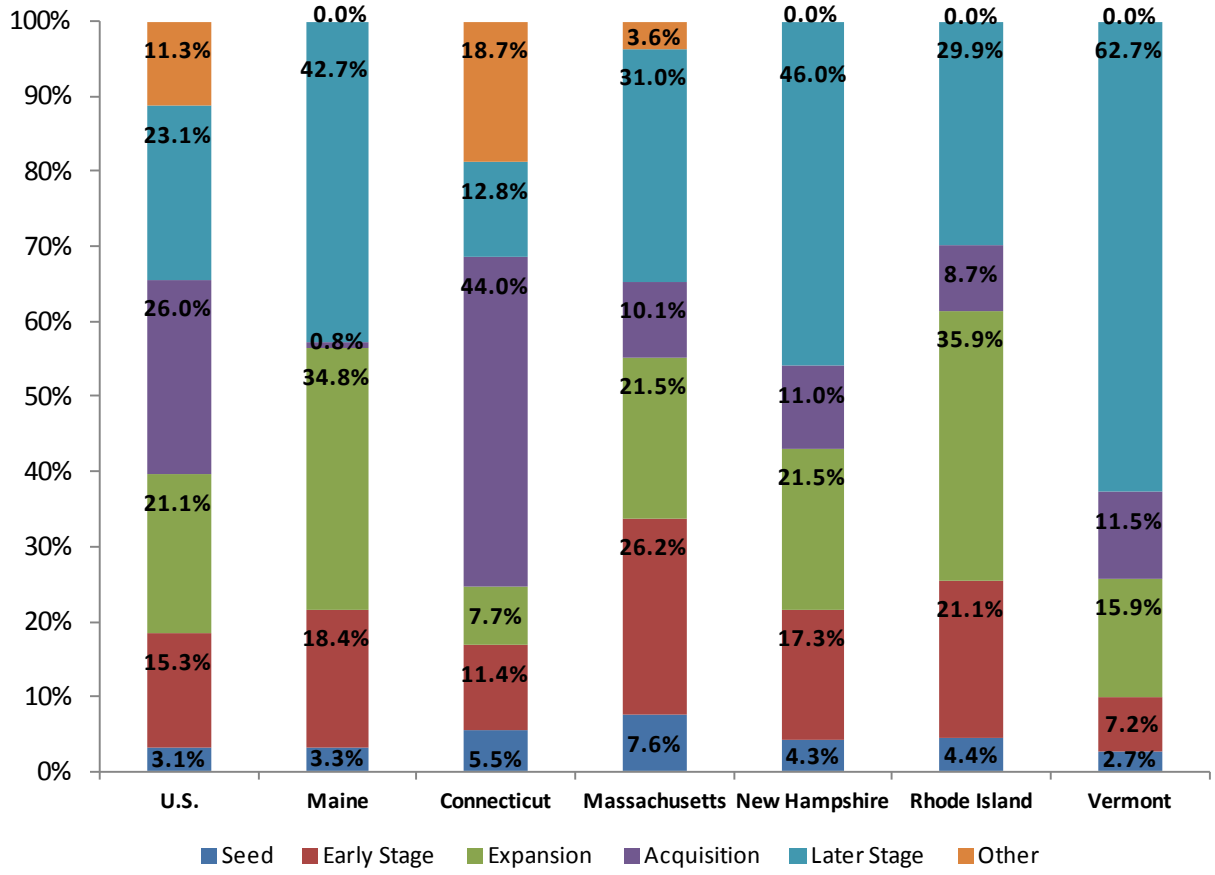


Note: Venture capital data through mid-November 2013

Source: Battelle analysis of Thomson Reuters, ThomsonOne database.

In terms of stage of investment, almost half of the venture capital invested in Maine companies during the 2007–2013 time period were later-stage investments. Investment at the critical seed and early stage are similar to the levels seen nationally (see Figure 8). However, Maine lags significantly behind the nation and the other New England states in the level of acquisition financing available, so that fewer Maine companies were involved in undertaking acquisitions.

Figure 8. Maine Venture Capital Investments by Stage of Investment, 2007–3Q 2013

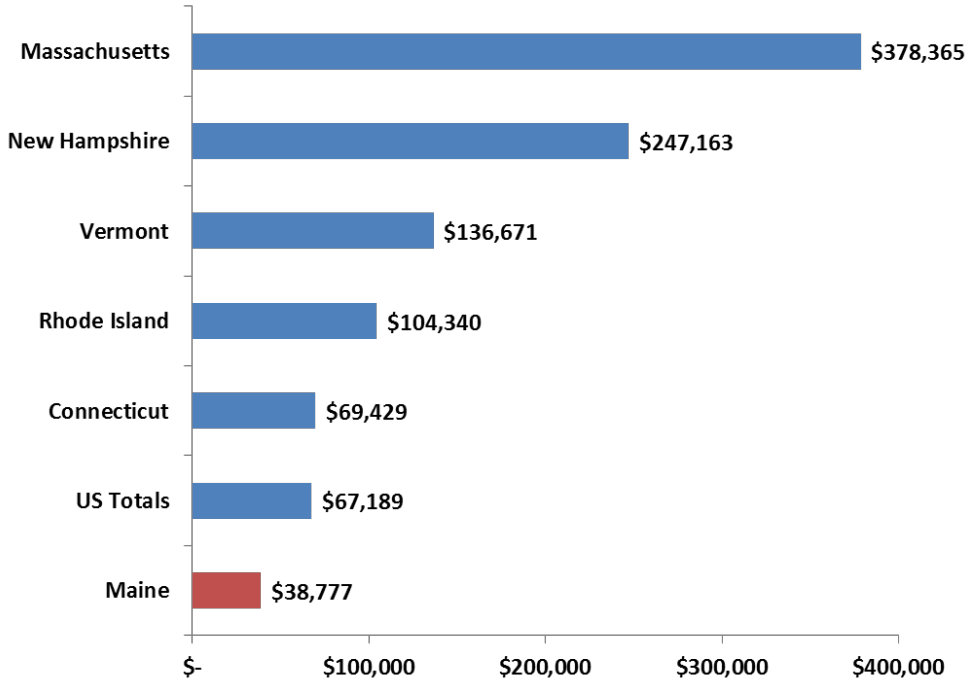


Note: Venture capital data through mid-November 2013

Source: Battelle analysis of Thomson Reuters, Thomson One database

SBIR award funding is an important source of risk capital for many firms within Maine's targeted technology clusters. However, when the level of SBIR funding was examined a similar trend to venture capital funding was discovered. As illustrated in Figure 9, even when normalized to take into account the population size of each state, Massachusetts and New Hampshire led the New England states in the amount of SBIR funding received on a per capita basis in 2012. Maine was the only state to receive less than $50k per capita in SBIR funding with $38,777/person awarded (see Figure 9).

Figure 9. SBIR Per Capita Award Amounts by New England State, 2012



Source: U.S. Small Business Administration

Maine companies assisted by MTI and surveyed by DECD responded that the availability of pre-seed and seed-stage risk capital has grown significantly, and many pointed to the success of MTI programs as a major catalyst for this improved financial climate. While many noted that the statutory ceiling cap on the angel investment tax credit has slowed investment, they are hopeful that with the ceiling raised not much ground will be lost. In another effort to catalyze investment, the Maine legislature recently approved a crowdfunding measure. Maine businesses may now raise up to $1 million in capital by selling small amounts of equity to individual investors. Using a model similar to popular crowdfunding websites, participating businesses are able to register with the Maine Office of Securities, setting both a fundraising goal and deadline. Individual investors are able to then purchase up to $5,000 in equity from a single business.

Commercialization/Market Entry Infrastructure: Maine's Cluster-Specific Situation

To better understand the challenges facing the specific technology clusters, Battelle analyzed results from the MTI survey of its clients and conducted additionaol interviews with cluster industry and organization leadership. The views of these industry and economic development leaders are set out by broad targeted technology area and associated technology clusters are highlighted in the summary that follows.

Biotechnology (Technology clusters: Biopharmaceuticals and Medical Devices)

- IP policies within Maine non-profit institutions as well as general culture is very supportive of industry - this should be further leveraged.
- Survey results found that only 4 out of 8 firms were successful in accessing capital – though industry association indicated that risk capital is available.
- Specifically related to biotechnology, focus on translating research institution discoveries into medical products.
    - Major advantage is ability to work with industry around IP/ commercialization issues.

Composites and Advanced Materials (Technology clusters: Boatbuilding and Related Industries; and Materials for Textiles, Apparel, Leather and Footwear)

- Even with shared-use equipment at Composites Engineering Research Laboratory, obstacles still exist for new materials to meet performance specs and be cost competitive.
- Difficult to find risk capital for materials companies.
- In support of the needs of textile companies for the latest equipment to modernize and to advance new product development, Coastal Enterprises, Inc. has established a $700,000 revolving loan fund funded by the Office of Community Services at the Federal Department of Health and Human Services.

Environmental Technologies (Technology cluster: Environmental Services; and Alternative Energy and Turbines)

- Mixed on IP, but lots of new product development underway from survey responses (5 companies).
- Venture capital has not traditionally invested in cleantech.
- The angels are organized and strong, but the statutory cap was a huge issue for 2013 and 2014 and funding had dried up.
- Maine Venture Fund has not invested its resources.

Forest Products and Agriculture (Technology clusters: Agriculture, Aquaculture, Fisheries and Food Production; and Forestry-related Products)

- 7 firms responding to survey suggest limited IP activity, though active in new product development
- Limited access to patient capital to make investments that are needed to modernize.
- Possible larger role for MTI – survey found that only 2 out of 6 innovation-oriented firms in agriculture and food successful in accessing financing.
- Much of the financing need is for farming and processing equipment – might require rethinking what is technology as well as how to advance matching requirements since average requirements are above $6 million (from survey).

Information Technology (Technology clusters: Electronics and Semiconductors; and Finance and Business Support Services)

- Growing pool of finances and services to support start-ups.
    - Of 12 innovation companies, 10 successful in raising capital and 8 were satisfied with amount.
- Typically the IT companies can bootstrap and aren't large capital intensive firms.
- Maine Cyber Security Center will be focused on working with the "users" of cybersecurity, focusing on demonstrations, developing best practices documents, and methodologies.
- Financing to allow a company to scale (from $15m to $50m) is hard to find in Maine.
- Most seek financing from Boston, but networks to access financing aren't viewed as strong. Maine IT companies need brokering assistance to access financing.

Marine Technology and Aquaculture (Technology cluster: Agriculture, Aquaculture, Fisheries and Food Production)

- Maine Aquaculture Innovation Center in Orono has resulted in a large number of commercial companies being formed over the years.
- Overall, Maine fisheries are not implementing production innovations due to lack of knowledge transfer, dissemination, and demonstration.
- Maine Sea Grant program is limited despite a large coast line of similar size to Florida and California; however, Maine receives less money than Rhode Island.

Precision Manufacturing (Technology clusters: Defense; and Electronics and Semiconductors)

- Limited responses on commercialization ctivities.

Growth/Scalability Infrastructure

Why It's Important

> Among all the riches a nation may possess, its people—its human resources, its human capital—is the most important. The value of this human resource depends not on size, however, but on the occupational and intellectual skills its members possess.
>
> Gray and Herr

In the 21st century, human capital is the key differentiator between states that are able to grow or "scale" – not only individual companies but entire clusters – to a level of critical mass. Without skilled people, technology innovation cannot occur and advanced technologies cannot be deployed. Without skilled technical and managerial personnel, capital is extremely difficult, if not impossible, to secure. Natural resources have ceased to be important sources of economic advancement. It is the talent of people that drives economic success and is the fuel of the innovation and knowledge economy. It is the nations, regions, communities, and individual firms with the most highly skilled workforce that will be the most productive. They will dominate markets by

delivering the best products and services at the lowest costs and, as a result, will earn the highest profits.

A supply of qualified, technology-trained workers is critical to the ability to grow and scale a technology-based innovation economy. Any knowledge-based industry requires a supply of qualified, trained workers at all levels. Successful states and regions maintain an adequate supply of doctoral-level researchers, technicians with two-year degrees, and managerial talent ranging from entrepreneurs themselves through mid- to senior-level executives who are comfortable in high-technology settings. States that lack a deep, natural pool of talent use a variety of tools, including formal university curricula, marketing programs aimed at worker retention, and peer-support for entrepreneurs, to attract and retain talent.

Furthermore, while the three key factors affecting the success of most technology clusters are technology, capital, and talent, lessons learned from best practices around the nation verify that technology-based economies are more likely to thrive in a stable and supportive business environment. Establishing such a climate means achieving alignment in many areas that serve to support business growth, including

- Business-friendly tax policies;
- Incentives designed to support the needs and opportunities of emerging companies;
- A quality of life conducive to the attraction of top-quality scientific and business talent;
- Appropriate technology infrastructure, particular access to broadband;
- Competitive costs of doing business;
- A supportive cluster of businesses achieving agglomeration economies and benefiting from specialized support resources and services that meet their business needs; and
- A network of sector companies and related interests working to drive policies and support programs to enhance the climate for their types of businesses.

The ability of a state to effectively support the growth of its technology clusters through expansion and attraction opportunities tied to fostering value-added supply chain linkages is fundamental in its ability to achieve a critical mass of activity that can impact the trajectory of a state's economy.

Growth/Scalability Infrastructure: Maine's Overall Situation

Since the recession, Maine has been able to grow employment in a number of key, high-skilled, occupational groups, including engineers, life scientists, scientific technicians, and managers, and as a result has outpaced national growth within these critical occupations (see Table12).

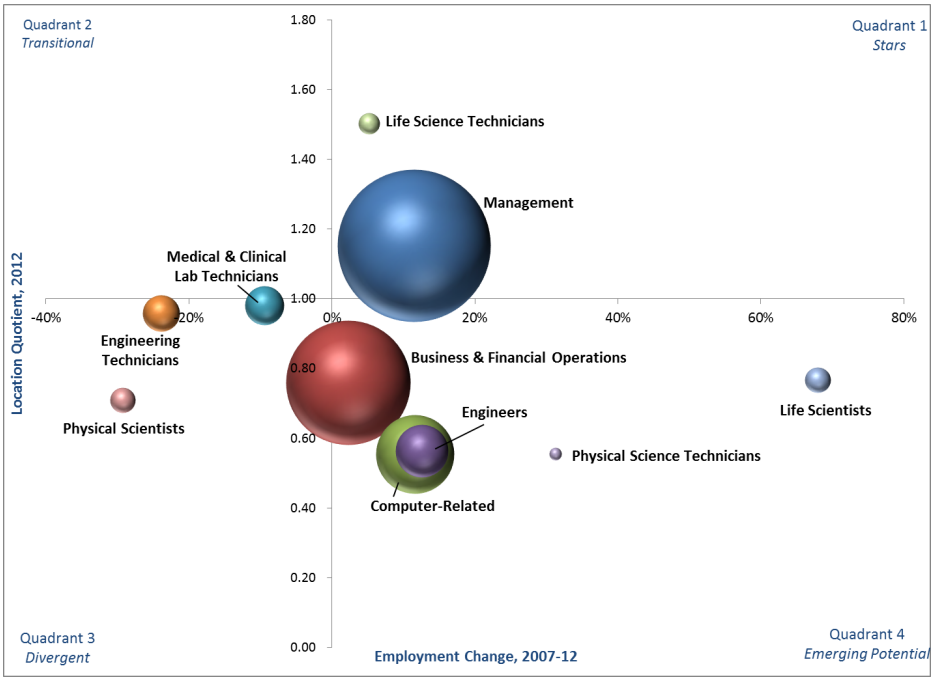
Furthermore, as Figure 10 illustrates, while most high-skilled occupations are not yet concentrated in Maine, they are generally growing. At a time when Maine's total occupational employment declined by 3 percent, seven high-skilled occupational groups saw growth, and only three experienced decline—medical and clinical lab technicians, engineering technicians, and physical scientists.

Table 12. Growth in High-Skilled Occupations, Maine and U.S., 2007-2012

High-Skilled Occupational Groups	Employment Change, 2007–2012	
	Maine	U.S.
All Occupations	-3%	-3%
Life Scientists	68%	11%
Physical Science Technicians	31%	2%
Engineers	13%	3%
Computer-Related	12%	12%
Management	11%	6%
Life Science Technicians	5%	3%
Business and Financial Operations	2%	1%
Medical and Clinical Lab Technicians	-9%	2%
Engineering Technicians	-24%	-11%
Physical Scientists	-29%	7%

Source: Battelle analysis of U.S. Bureau of Labor Statistics, Occupational Employment Statistics data.

Figure 10. Maine High-Skilled Occupations: Employment Size, Change and Relative Concentration, 2012



Source: Battelle analysis of U.S. Bureau of Labor Statistics, Occupational Employment Statistics data.

However, even with growth outpacing the nation in some high-skilled occupations, there are still a number of key innovative occupational drivers where Maine is lagging both the nation and other New England states in terms of a critical mass of employment. As Table 13 indicates, among the New England states, Maine has the lowest share of employment in engineering and IT occupations. This lack of a critical mass of talent stifles Maine's ability to grow and scale value-added technology clusters.

Table 13. Concentration of Key, Occupational Drivers, 2012

State	Talent Share of All Occupations, 2012	
	% Engineers	% IT Workers
U.S. Total	**1.2%**	**2.7%**
Maine	**0.7%**	**1.5%**
Connecticut	1.3%	2.6%
Massachusetts	1.5%	4.2%
New Hampshire	1.2%	2.8%
Rhode Island	1.0%	2.2%
Vermont	0.8%	2.2%

Source: Battelle analysis of U.S. Bureau of Labor Statistics, Occupational Employment Statistics data

In terms of business climate, Maine's business tax climate appears to be competitive compared not just to New England but to all states (see Table 14). The Tax Foundation rates states on their overall tax burden across corporate income tax, individual income tax, sales tax, unemployment insurance tax, and property tax. Maine ranks 29th in the nation and is noted for its low levels of corporate, property, and unemployment insurance taxes. The only states in New England that are ranked lower than Maine are Massachusetts, at a very close 25th ranking, and New Hampshire, which has historically competed as a low tax place to do business.

Table 14. Tax Climate in Maine, 2014

State	Overall Tax Rank, 2014	Lowest Ranked Component(s)*
Maine	**29**	**Corporate; Property; UI**
Connecticut	42	Property; Corporate; Individual; Sales
Massachusetts	25	UI; Property; Corporate
New Hampshire	8	Corporate; UI; Property
Rhode Island	46	All ranked in bottom half
Vermont	45	Property; Individual; Corp

*Lowest ranked components include any that rank among the bottom-half of states. UI = Unemployment Insurance.

Source: Tax Foundation.

Another important business climate factor is the state's broadband technology infrastructure. In today's Internet-driven world, access to broadband is critical for both business and quality of life. The most recent available data (see Table 15), dating back to 2010, suggests that Maine is competitive nationally, but is lagging other states in New England, which can make this a competitive business issue.

Overall, most interviewed noted that the lack of individual companies as well as entire technology clusters ability to scale is the significant issue in Maine. This inability is driven by both a lack of both C-level talent and a skilled workforce in some clusters. Also, companies in rural parts of the state feel very isolated and there are limited connections across existing companies and entrepreneurs.

Table 15. Broadband Adoption and Download Speeds

State	Broadband Adoption (rank)	Median Download Speed in mbps (rank)
U.S. Average	**68%**	**3.0**
Maine	**67% (33)**	**2.8 (43)**
Connecticut	75% (5)	4.8 (14)
Massachusetts	76% (4)	9.3 (2)
New Hampshire	78% (2)	5.5 (8)
Rhode Island	71% (19)	7.0 (6)
Vermont	69% (24)	2.5 (46)

Source: Economics and Statistics Administration and National Telecommunications and Information Administration, Exploring the Digital Nation: Computer and Internet Use at Home, 2011 (2010 survey data).

Communication Workers of America, "Speed Matters: Affordable High Speed Internet for America," 2010.

Growth/Scalability Infrastructure: Maine's Cluster-Specific Situation

To better understand the challenges facing the specific technology clusters, Battelle examined more closely the dynamics behind each cluster as it relates to the infrastructure needed for growth and scalability. This involved focused outreach and interviews with key cluster leaders, as well as with economic development leadership. The findings by broad targeted technology area and associated technology clusters are highlighted in the summary that follows.

Biotechnology (Technology clusters: Biopharmaceuticals and Medical Devices)

- Lack of awareness of markets and customers.
- Lack of industry skills and certifications, including seasoned management, skilled technicians, IRB, Clinical Trials, Regulatory Training, Insurance Reimbursement Codes, etc.
- Inability to find/attract talented workforce.
- Image problem with Maine - rest of world doesn't expect to see biotech companies from this area.

- Lack of affordable/and acceptable wet lab space.
- Opportunity for a Bangor to Boston Corridor for the Biosciences – to provide networking and matchmaking efforts to bring in the resources, supply chain, etc. throughout the region.
- Specific to the biopharma industry:
    - Little to no interaction between research assets and industry.
    - State support not viewed as strong compared to more traditional industries (fishing, farming, forestry) and there is a lack of understanding of the cluster.
    - Need more interaction between economic development organizations (like MTI) and research assets.
- Specific to the medical device industry, the industry in Maine is lower added-value then nationally. Not many OEMs.

Composites and Advanced Materials (Technology clusters: Boatbuilding and Related Industries; and Materials for Textiles, Apparel, Leather and Footwear)

- Maine not well suited for large production composite operations due to geography.
- Focus on specialty materials production.
- Growth hindered by lack of skilled workforce - master level down to the shop floor level.
- Focus is on diversification:
    - All types of composites – clothing/textiles, polymers, ceramics.
    - Wide range of applications – alternative energy, boat building, infrastructure, etc.
- Specific to the boatbuilding industry, majority of suppliers are outside of the state as well as Tier 1 system integrators.
- Specific to the textiles industry, lack of supply chain hindering cluster's ability to scale.

Environmental Technologies (Technology clusters: Environmental Services; and Alternative Energy and Turbines)

- Workforce is highly skilled and available.
- Industry is highly collaborative.
- That being said, the geography still causes a problem in having everyone understand what everyone else is doing and creating supply chains.
- Uncertainty with regards to cleantech policy decisions at a state level causes significant uncertainty to the industry and hinders potential growth.

Forest Products and Agriculture (Technology clusters: Agriculture, Aquaculture, Fisheries and Food Production; and Forestry-related Products)

- Maine is benefitting from the Localvore movement.
- A big issue for growth is that Maine is dominated by smaller, family-owned farms.

- Small to mid-sized food processors/ farming operations not well served by equipment manufacturers – so have need for financing.
- MTI has historically combined forestry with food systems, which is viewed as detrimental to the sustainability of the food production cluster.
- Overall view is that state support is severely lacking.

Information Technology (Technology clusters: Electronics and Semiconductors; and Finance and Business Support Services)

- IT industry dependent upon talent from outside the state.
- In order to sustain the industry, Maine must have the capacity to train the workforce in order to grow the footprint of the cluster.
- Need to have a better focus on this within the University system, particularly around Portland. Cybersecurity Center was created in part to address this.
- Cluster has not been able to find common ground or reasons to coalesce.

Marine Technology and Aquaculture (Technology cluster: Agriculture, Aquaculture, Fisheries and Food Production)

- Very little value-added products are produced in Maine.
- Industry is very fractured – and having lots of trade associations adds to complexity of working with the industry.
- Missed opportunities to advance aquaculture through investments to improve infrastructure, such as dredging.
- Most challenges are not directly linked to technology – but instead to public policy, specifically around leasing public water.

Precision Manufacturing (Technology clusters: Defense; and Electronics and Semiconductors)

- Ability to grow directly tied to access to skilled workers.
    - Active engagement of community college system as well as individual company-led worker training programs in addressing this workforce issue.
    - However, overall lack of interest by students is an issue.
- Value-added precision manufacturing viewed as a strength of Maine – encompasses defense industry and small armaments, jet engines, power systems, etc.
- Key challenge is how to increase footprint of technology cluster across Maine.
- Potential opportunity to foster regional connections to grow cluster.
- Specific to the defense-related industry, while conventional wisdom was to focus efforts on market access, in reality biggest issue is lack of collaboration.
    - Companies turn down work rather than collaborate. Even with Pratt & Whitney serving as "large carrot" couldn't get companies to work together.

- Specific to the electronics and semiconductors industry:
  - Not a strong supply chain in Maine.
  - Companies work in silos and are secretive and very competitive with little interest in collaborating.
  - Workforce is a huge issue because the perception is that all of the jobs are gone – existing companies can't find employees. Fairchild funded the Robotics Institute to try to overcome this problem.

Summary

As it has been duly noted, developing a robust technology-based innovation ecosystem is difficult, which makes the progress that Maine has made, in due part to the investments of MTI, a significant achievement. As future strategic initiatives and efforts are planned and funded, it will be important to make sure that missing links within the innovation development chain are addressed, both at a systemic level when required as well as when there are unique needs within the targeted technology clusters.

The analysis of available databases on Maine's key factors shaping technology development suggests the following:

- The state's university and industry levels of research and development are still well behind the national average per capita, but are growing. In particular, growth in Maine's university research expenditures has significantly outpaced the nation's since 2001, growing by 90 percent, compared to 73 percent nationally.[45]
- New business start-up levels in Maine are higher than those in other New England states but lag the national average. Where Maine appears to fall short compared to other New England states is in high-growth small businesses.
- Formal venture capital funding in Maine has increased since 2007, while it has declined nationally, but its level remains well behind other New England states and the national average.
- Maine is also lagging in federal SBIR awards to innovative small business.
- While high-skilled talent specializations are limited, Maine has been recording strong growth in high-skilled occupations.
- Maine's general business tax climate falls in the middle range of states across the U.S., and within New England it is neither the lowest nor the highest.
- Broadband technology infrastructure, involving the adoption and download speeds of broadband, is at about the national average for Maine, but lags other New England states.

From the more qualitative information garnered through the stakeholder interviews and company survey results, a number of gaps were identified across the innovation ecosystem in Maine and point to possible areas for future program efforts by MTI. Table 16 provides a summary of the current situation across the key innovation system functional activity areas.

[45] Battelle analysis of National Science Foundation data.

Table 16. Summary of Maine's Innovation Ecosystem

Perspective	Research: Basic and Applied	Commercialization/Market Entry	Growth/Scalability
Existing Situation	Perception among some clusters that there is a lack of connection between industry and research, particularly driven by the distance between Orono and Portland. However, others feel that university research is accessible with specialized industry-specific facilities for prototype development, design manufacturing, test samples.	There is a growing level of entrepreneurial support services available, particularly within close proximity to the population centers of the state. However, companies in the rural part of Maine feel quite isolated. The availability of pre-seed and seed-stage risk capital has grown significantly, with MTI programs serving as a major catalyst for this improved financial climate. However, the level of venture capital is still very low relative to the rest of New England The increase of the angel investment statutory cap, along with the legislative approval of crowd-funding measures, should continue to foster a strong early-stage capital. There are limited connections between existing companies and entrepreneurs, limiting the overall supply chain of technology clusters.	Lack of ability to scale is a significant issue across all of the technology clusters in Maine. This inability to scale is driven by the lack of critical mass of capital and talent. Due to both the lack of seed and later stage investment capital (a capital gap from $750k to $5 million) as well as the lack of a skilled workforce. Some of the organization established to support the various targeted technology areas have been ineffective in part due to a lack of resources and critical mass of value-added activities.
Implications for Future Programmatic Initiatives	It will be critical that in the future the targeted technology clusters are closely linked to the industry-driven research base in the state with a clear line of sight to market opportunities. When such research is currently not being conducted or is not linked to industrial needs, investments and refinements in the investment portfolio will be necessary.	It will be critical to address the lack of entrepreneurial/C-level management talent in order to root emerging company operations in Maine. There is also the opportunity to further increase early-stage capital in the state by taking advantage of the Federal SBIR program.	It will be critical that in the future the targeted technology clusters initiatives address: Access to broader regional sources of financial capital; and, Talent generation/attraction efforts. This in turn will require focusing resources on projects to drive development of critical mass.

SECTION V:
LOOKING FORWARD: IMPLICATIONS OF ANALYSIS FOR MTI'S PROGRAMMATIC APPROACHES

For over 20 years, the day-to-day work of MTI has been squarely focused on helping innovators in existing and emerging companies – directly and through more consortium approaches – to accelerate their progress and expand their economic impact in Maine. MTI works at both the individual company level – with direct support for early-stage capital and commercialization assistance in the form of competitive grants, loans and equity – and at the broader technology cluster-level – supporting collaborative initiatives to address industry-wide opportunities and ways to strengthen groups of companies and offering key university research and development capabilities. MTI has earned a strong reputation from its clients for the efficiency of its processes, knowledge of its staff, appropriateness of its reporting requirements, and value of its supporting services—all of which earned high marks from the recent DECD survey of MTI's clients.

While MTI maintains a close connection to the marketplace through its Technology Boards that taps hundreds of experienced business and technology experts to assist in the review of proposals, it still recognizes the need to periodically consider the bigger picture on how Maine is positioned for growth in technology industries and how its innovation ecosystem is functioning. This 2014 assessment builds on the past work done by MTI from 2002 and 2008. It comes at a very appropriate time in being able to consider the shifts and changes in Maine's economy and economic prospects after the recent Great Recession and its uneven economic recovery. As the previous sections have highlighted, this has been a time where there has been significant economic dislocation in some industries due to the recession, while others have flourished in growing markets or improving competitiveness. It is also a period of time in which significant technology advancements have been made that are having a pronounced affect in reshaping specific technology clusters—from the rise of renewable energy technologies to the rapid rise of mobile and wireless devices to the paradigm shift in use of data analytics and real-time data decision-making using Big Data across traditional sectors of the economy.

Implications for the Future

This refined analysis of technology industries, together with the assessment of Maine's innovation ecosystem, points to some important implications for MTI going forward. The analysis points to five major implications for MTI to consider as it moves forward in the years to come relating to either supporting technology cluster development in Maine or to strengthening the broader innovation ecosystem in Maine, as summarized below.

Implications Focused on Supporting Technology Cluster Development in Maine

Implication #1: The use of specific technology clusters offers insights into industries driving Maine's economy and growth opportunities.

Efforts in the past have focused on the seven broad targeted technology areas, but this analysis shows that a more precise examination of technology clusters focused on industries that typically share common supply chains, markets, and technology competencies can offer more helpful insights into how Maine's technology-related economy is performing and a more refined line of sight to growth opportunities. For example, within the Agriculture, Aquaculture, Fisheries and Food Production cluster further engagement on aquaculture is indicated, but MTI may also consider advancing functional foods, linking its wild blueberry production with its traditional frozen food industry. Furthermore, even within struggling technology clusters in Maine, such as Information Technology Services, there are promising opportunities. In this case the continued rapid adoption of IT into the Finance and Business Support Services cluster provides a more effective driver for Maine to take advantage of the high projected national growth in areas such as financial transaction processing.

Implication #2: Raising productivity is a crosscutting challenge for nearly all of Maine's technology clusters and can lead to higher wages, helping to address the lower average wages found in Maine's technology clusters compared to the nation and the New England region.

Maine's level of productivity – a key measure of technology deployment and activities in higher value-added products – stands generally well below the U.S. average. Only three of the thirteen technology clusters outpace the U.S. average in productivity, most notably Forestry-related Products, with productivity which is 56 percent higher in Maine than the U.S. average. Not surprisingly, Maine's average wages are below the U.S. average for twelve of the thirteen technology clusters, and only exceed the U.S. average for the Forestry-related Products. This partially reflects the lower cost of living in Maine, but also reflects the generally lower productivity of Maine's technology clusters. Increased productivity increases the wealth and value of the companies in a cluster, and usually results in increased wages, as some of the increased wealth is passed on to employees. While increased productivity does not guarantee increased wage levels, it is a necessary component.

What will be critical for raising productivity levels is addressing the deployment of technology as well as raising the value-added to the goods and services being produced in Maine across its technology clusters.

Implication #3: Technology cluster development in Maine needs to continue to find the right balance between defined measurable projects to realize growth

opportunities and broader outreach, increased innovation, and networking to create a more closely knit and collaborative business environment.

Often there is a common tension in technology cluster development on whether to support projects involving a group of companies within a technology cluster or to support the industry or trade organizations that help to bring the cluster together through networking and broader outreach. This tension is clearly articulated in a case study of Arizona's cluster activities in the 1990s by Mary Jo Waits, currently Division Director of Economic, Human Services and Workforce at the National Governors Association: "During the early years of strategy implementation, the focus was on keeping the cluster organizations together, connected to each other, and visible to economic development organizations and the broader community … Arizona economic development leaders soon learned, however, that such intelligence might be moot without the ability to modify services accordingly, provide them in a timely holistic manner, and reach enough firms to make an impact. In other words, the full formula to help firms compete in global markets is the identification of their needs *plus* development of an effective system for meeting their needs." [46]

From the stakeholder discussions, it is clear that there is an uneven pattern to the organizational engagement across the broad targeted technology areas in Maine. In some cases, too few resources and too little attention have been paid to particular technology clusters. In other cases, Maine might actually have too many industry groups, none of which has sufficient resources to support the needed networking services for the industry. This uneven infrastructure can inhibit the ability of MTI to advance needed collaborative efforts.

As MTI seeks to be more pro-active in pursuing growth opportunities in the state, rather than expending resources addressing a multitude of different industry groups' requests and needs, some of which may duplicate others, MTI may find it useful to offer a more centralized "shared" service. The mission of this shared service would be to offer a suite of resources – such as web site development, mailing capacity, company directories, and production of materials – that can support multiple industry networking efforts. The users of this service could come and go as MTI probes the opportunities to realize the potential for growth opportunities set out in this report and others that it identifies over time. These industry networking efforts would typically need a facilitator that could be jointly supported through MTI and industry organizations. This can allow MTI to be agile in its industry consortium work, while acknowledging that while industry organizations need to identify the efforts needed to move forward, they cannot always self-organize.

[46] Mary Jo Waits, The Added Value of the Industry Cluster Approach to Economic Analysis, Strategy Development, and Service Delivery, Economic Development Quarterly, February 2000, page 47

Implications Focused on Strengthening Maine's Broader Innovation Ecosystem

Implication #4: Regional context matters.

Many of the refined technology clusters within Maine's broad targeted technology areas are not strong in Maine and need to be connected to regional efforts for development. Where Maine is not a regional leader but is rather either a regional player or regional follower, simply trying to grow these technology clusters outside of the regional context will be difficult. Efforts to advance improved supply chains, talent development, and technology advancements outside of the broader New England states will not be as successful as looking to work on a multi-state basis. This does not necessarily mean having to create government-to-government collaborations. Instead, it is more about how to work across the industrial base found in New England. Regional approaches are also needed to address some of Maine's most difficult ecosystem challenges:

- Financing challenges, particularly for emerging biopharmaceutical and Information Technology services firms, where Maine is a regional player and regional follower, respectively, requires leveraging the private financial institutions that are more prevalent in other New England states. A more regional approach to engaging existing regional financial institutions to support the later stages of financing needs in Maine would greatly compliment MTI's efforts in early stage development and commercialization and is more realistic than Maine establishing its own private financial institutions.
- Entrepreneurial/C-level management talent is another opportunity area for Maine to tap the expertise found across New England. Interestingly, technology organizations in other states that are focused on growing start-up ventures have hit upon a strategy of rooting an emerging company's operations locally but bringing in experienced management talent from outside of the state to see the company through its later stages of development. This is now being done by the Louisiana Fund and the Virtual Incubator Company in Arkansas.
- Talent development may also offer opportunities. Many other New England states that are regional leaders or regional players in specific technology clusters have developed more advanced university programs and research capabilities. There is no reason not to seek ways to collaborate. This is already being done in Maine through its collaborations with the University of Massachusetts, Lowell's advanced materials programs. Universities, even public ones, do not see state boundaries as they advance industry partnerships. Creating collaborations through multi-institutional research institutes might be a way to also establish greater strengths in Maine's universities in areas that are lacking today.

Implication #5: The lack of emerging companies' ability to scale is a critical gap across Maine's innovation ecosystem which must be addressed.

MTI has done an excellent job in its technology development efforts in generating "more shots on goal" through its early-stage investment and commercialization assistance efforts. This is critical to having an effective innovation ecosystem and must diligently be pursued.

Still, MTI may need to consider how to address, on its own or in partnership with other development organizations in the state, the critical factors holding back the ability of companies to scale. Noted from the stakeholder interviews and DECD survey of MTI-assisted companies were the following key factors holding back the ability of emerging technology companies to scale:

- Access to capital, particularly later stage venture capital ($750,000 to $5 million) and expansion capital for equipment;
- Finding the right workers, which combines needs for both specific skills and experience; and
- Reaching markets.

Some of these issues can be addressed through regional New England approaches, but state efforts targeting incentives and programs to grow the talent base and focusing more on opening markets for targeted product markets are crucial. Together these implications can help guide the next generation of activities of MTI by reflecting the new economic realities facing the state, the line of sight to new growth opportunities, and the situation confronting its overall innovation ecosystem.

APPENDIX A: RESULTS OF CORE COMPETENCY ANALYSIS

To understand the core technology competencies of Maine's industry, Battelle analyzed patent applications and awards associated with Maine inventors from 2008 to 2012. Patents represent the intellectual property being generated in Maine, and are a good means of identifying areas of critical mass in technology competencies being advanced specifically by Maine companies, universities, research institutions, and individual inventors. Battelle used a proprietary software tool – OmniViz – to analyze the use of words in sentences for the patent abstracts and to identify how the patents best grouped into innovation themes. This text analysis of the abstracts from publications and patents allows for a high-level understanding of the possible targeted technology areas across industry and other inventors in Maine beyond what standard patent classification categories can offer. Just over 2,000 patent applications and awards from 2008 to 2012 generated by Maine inventors were grouped into innovation themes. Of these, 1,670 were assigned to industry and 69 were assigned to Maine research institutions, primarily to University of Maine, Jackson Labs, and Maine Medical Center.

Battelle also considered the presence of emerging innovation companies found in Maine, receiving Small Business Innovation Research funding and venture capital funding, across the patent innovation themes.

Thirteen "core technology competency" themes were identified by Battelle as set out in the Table below:

Technology Competencies and Alignment with Emerging Innovation Industry in Maine from Patent Analysis

Core Technology Competency Inovation Themes	Patent Records Grouped, Percent	Illustrative Applications	Companies Receiving SBIR or Venture Capital Financing, 2008–2013
Semiconductors	19.8%	Various integrated circuit design and manufacturing processes; Various transistors including field effect, microwave and radio frequency power amplifiers; Flash memories; Electronic packaging technologies; Semiconductor device connectors	None
Data Processing, Management and Analysis	11.6%	Computer security systems involving mobile applications, data encryption, authentication, remotely controlled embedded systems; Computer algorithms for wide range of data assessment systems; Electronic commerce systems and approaches; Medical data storage and analysis systems; Content management systems; Computer systems configuration management systems; Data recovery systems; Data visualization systems; Database design; Knowledge management systems	10 companies: Angel Secure Networks; Anodyne Health Partners; Cashstar; Certify; Collange; Direct Vet Marketing; Emergent Discovery; Medical Device Logistics; Sperancza; and Technology Systems.
Coatings and Composite Materials	9.5%	Thermal barrier coatings, including ceramics; Conductive films; Injection molding; Textured laminates; Nanoscale coating processes; Dry	5 companies: Alba-Technic; Arcast; Fiber Materials; Harbor

Core Technology Competency Inovation Themes	Patent Records Grouped, Percent	Illustrative Applications	Companies Receiving SBIR or Venture Capital Financing, 2008–2013
		adhesives; Powder coatings; Woven composites; Building composites; Metal composites	Technologies; Tex Tech; and Wizbe Innovations
Biologics and Biotechnology	8.0%	Peptides for detection of antibodies; Development of monoclonal antibodies; Immunomodulators; Biological antigen detection systems for hookworm, roundworm, whipworm, herpes viruses; Antibody inhibitors; Genomic based analysis techniques; Transgenic mouse development; Stem cell biology techniques; NMR detection systems	6 companies: AIKO Biotechnology; Bar Harbor Biotech; MariCal; Maine Manufacturing; Mitokine Bioscience; New England Rare Reagants
Electronic Signal Conversion and Power Switches	7.4%	Analog to digital conversion switches; Electronic circuit signal interfaces; Power electric switches in power converters, regulators and amplifiers; Electromedical device signal components; Signal detection in devices	None
Fluid Handling and Filtering	7.4%	Pressurized fluid delivery systems; Fluid filtering systems; Heat exchange and capture systems; Applications in furnaces and ovens, storm water and environmental management, beverage systems and medical applications.	4 companies: Cerahelix; Fluid Imaging Technologies; Nyle Systems; Orono Spectral
Networking, Signal Processing and Communications	6.2%	Communications services architecture; Routing systems; Teleconferencing systems; Network workflow processing systems; Signal processing for digital video systems, digital television, optical networks, multi-media systrems, sensor systems, and smart grid networks.	8 companies: Activias Diagnstics; AXAT; Crossrate Technology; Environetix Technologies; Foneshow; Mainely Sensors; Newfield Design; and Wentworth Technology
Chemistry and Organic Compounds	6.1%	Plant expression of chemical compounds; Carbon dioxide removal and scrubbing processes; Transgenic plants with certain growth characteristics; Chemical processes for wood treatment; Chemical methods for biodiesel production; Chemical catalysts; Chemical dye systems	None
Engines and Turbines	4.9%	Gas turbine seals, turbine blades and other components	3 companies: Ocean Renewable Power Co.; Pika Energy; and Sergie Breus
Electromechanical Components and Systems	3.7%	Devices using magnetic drives; Motors for industrial systems; Wide range of applications from medical devices, snowplows, printing presses, submersibles, guns	Enerco International
Pharmaceutical Formulation and Delivery	3.1%	Wide range of chemical agents for antimicrobial and antibacterial activity, stimulating tissue growth, treatment of heart disease, treatment of ocular disease, inflammatory disorders; Drug	FHC and Putney, Inc.

Core Technology Competency Inovation Themes	Patent Records Grouped, Percent	Illustrative Applications	Companies Receiving SBIR or Venture Capital Financing, 2008–2013
		delivery gels, controlled release of pharmaceutical compounds, pharmaceutical salt formulations	
Image Processing	1.8%	Image map designs for web sites; Computer processing methods of images; 3D object measurement and modeling; Pattern recognition of images; Use of images in navigation systems	None
Aquaculture	N/A	Not a stand-alone patent cluster	8 companies: Bagaduce River Oyster Company; Harmon Brook Farms; Jesse Leach; Pemaquid Mussel Farms; Pemaquid Oyster Farm; Ocean Approved; RAS Corporation; and Sea and Reef Acquaculture.

APPENDIX B: OVERVIEWS OF TECHNOLOGY CLUSTERS BY PERFORMANCE MEASURES

Agriculture, Aquaculture, Fisheries and Food Production

This technology cluster is the third largest of Maine's technology clusters and represents one of the state's traditionally strong natural resource-based technology clusters. The cluster is not specialized in Maine, but is growing at a rate more than twice the national average. The Agriculture, Aquaculture, Fisheries and Food Production technology cluster is classified as an ***emerging strength*** cluster, meaning that it is growing and outperforming the nation in growth but is not yet specialized. The cluster had employment of 10,352 jobs in 2012, up from 10,176 in 2007 and is one of seven out of the thirteen clusters analyzed that have surpassed pre-recession levels in employment.[47] The leading Maine employers in the Agriculture, Aquaculture, Fisheries and Food Production technology cluster include the Perrier Group-Poland Spring (one of Maine 50 top private employers) and McCain Foods USA Inc., but the cluster is dominated by numerous small and mid-sized agricultural and food processing businesses. The cluster represents a vertically integrated system with strong local supply chain linkages that goes from fishing and agricultural production to processing and production. Overall cluster productivity, however, lags national levels. Average wages are $36,755 and the cluster is one of only two of the thirteen clusters where average cluster wages are below the state average.

Key specialized sub-sectors within the Agriculture, Aquaculture, Fisheries and Food Production technology cluster include:

- Bottled water manufacturing – LQ of 12.74 and 750 Jobs
- Aquaculture – LQ of 5.58 and 141 Jobs
- Frozen cakes and other pastries manufacturing – LQ of 6.10 and 305 Jobs
- Distilleries – LQ of 5.56 and 196 Jobs
- Frozen fruit and vegetable manufacturing – LQ of 4.97 and 675 Jobs

Metrics for Technology Cluster Performance for Agriculture, Aquaculture, Fisheries and Food Production

Maine Employment, 2012	Industry Specialization, 2012	Employment Change Since Pre-Recession Peak, 2007–2012		Change in Competitive Share	Forecast Employment Growth 2012–2022	
		Maine	U.S.		Maine	U.S.
10,352	0.85	1.8%	0.7%	1.1%	(0.6%)	(0.4%)
Productivity as a % of U.S.		88.0%		**Average Wage**		$36,755

Source: IMPLAN and BLS Employment and Output Projections, calculations by Battelle. See Section II for more details on each measure.

[47] It is important to note that this employment figure is for businesses with paid employees and does not include all farms or fishing enterprises, many of which are organized as sole proprietorships and not included in the employment data analyzed for this report. According to non-employer data from the U.S. Bureau of the Census there were 5,763 individual proprietorships involved in fishing in Maine in 2011. According to preliminary data from the U.S. Department of Agriculture's 2012 Census of Agriculture there were 8,174 farms in Maine in 2012. Thus, there are a large number of persons who derive all or most of their income from agriculture and fishing that are related to the operation of this cluster.

Alternative Energy and Turbines

The Alternative Energy and Turbines technology cluster is a highly specialized and growing technology cluster in Maine, albeit a small industry with 948 jobs across 31 establishments. The industry is highly specialized in Maine, but what stands out for the cluster is that employment grew by 11.9 percent since 2007 even as the national employment declined for this cluster. While the Alternative Energy and Turbines technology cluster is the smallest of Maine's thirteen clusters, it is the most rapidly growing and one of only seven of these clusters where employment has surpassed pre-recession levels. The combination of high specialization, job creation and relative employment growth classifies the Alternative Energy and Turbines technology cluster as a ***current strength*** and primary target industry for Maine. The cluster has relatively weak linkages to the local economy in terms of local indirect and induced impacts, but has a level of productivity quite close to the national average. It is a high wage industry, with average cluster wages of $74,091, nearly twice the state average wage. Cluster employment is projected to grow 4.7 percent annually in Maine, based on national projections data, the strongest projected rate of growth among of the thirteen clusters.

The Maine Alternative Energy and Turbines technology cluster consists of two very different segments: the manufacturing of turbines and the generation of electricity through alternative (non-fossil fuels or nuclear) sources. The cluster is specialized in all three of its major sub-sectors:

- Hydroelectric power generation – LQ of 8.79 and 230 Jobs
- Other electric power generation[48] – LQ of 9.82 and 318 Jobs
- Turbine and turbine generator set units manufacturing. – LQ of 3.12 and 400 Jobs

Metrics for Technology Cluster Performance for Alternative Energy and Turbines

Maine Employment, 2012	Industry Specialization, 2012	Employment Change Since Pre-Recession Peak, 2007–2012		Change in Competitive Share	Forecast Employment Growth 2012–2022	
		Maine	U.S.		Maine	U.S.
948	5.07	11.9%	(38.6%)	50.5%	4.7%	2.3%
Productivity as a % of U.S.		94.0%		**Average Wage**		$74,091

Source: IMPLAN and BLS Employment and Output Projections, calculations by Battelle. See Section II for more details on each measure.

[48] Other Electric Power Generation is composed of all electric power generation other than hydroelectric, fossil fuel and nuclear power generation and includes biomass, geothermal, solar, tidal, and wind power generation.

Biopharmaceuticals

The Biopharmaceuticals technology cluster is one of the most dynamic of Maine's thirteen technology clusters. With 3,950 employees spread across 98 establishments, the Biopharmaceuticals technology cluster employment has increased by 5.6 percent since 2007, and is one of only seven of Maine's thirteen technology clusters to have surpassed pre-recession employment levels. The industry is specialized in Maine and is growing more rapidly than nationally. This combination of specialization, job creation and relative employment growth classifies the Biopharmaceuticals technology cluster as one of Maine's ***current strength*** clusters. The Biopharmaceuticals cluster is dominated by two firms, Jackson Laboratory and IDEXX Laboratories, Inc., both of which are among Maine's top fifty private employers, but also includes a large number of start-ups, small, and mid-sized firms. Overall cluster productivity is slightly below the national average but the cluster has one of the strongest supply chain and employee income linkage impacts on the state's economy of all of the thirteen clusters. The cluster's average wage of $68,313 is nearly 80 percent higher than the state average annual wage.

The Biopharmaceuticals technology cluster is made up of six sub-sectors, three of which are specialized:

- In-vitro diagnostic substance manufacturing- LQ of 5.61 and 474 Jobs;
- Other biological product manufacturing – LQ of 1.42 and 168 Jobs; and
- Medical laboratories – LQ of 1.24 and 914 Jobs.

Metrics for Technology Cluster Performance for Biopharmaceuticals

Maine Employment, 2012	Industry Specialization, 2012	Employment Change Since Pre-Recession Peak, 2007–2012		Change in Competitive Share	Forecast Employment Growth 2012–2022	
		Maine	U.S.		Maine	U.S.
3,950	1.21	5.6%	2.4%	3.3%	1.8%	1.8%
Productivity as a % of U.S.		86.0%		**Average Wage**		$68,313

Source: IMPLAN and BLS Employment and Output Projections, calculations by Battelle. See Section II for more details on each measure.

Boatbuilding and Related Industries

The Boatbuilding and Related Industries technology cluster is the second smallest of Maine's thirteen technology clusters and represents a traditional Maine and regional industry. The cluster is highly specialized in Maine, with an LQ of 1.88, indicating an employment concentration almost twice the national average. The cluster has been hard hit by the recent economic downturn, and has experienced a decline in employment, though the decline was less than the national average. The Boatbuilding and Related Industries technology cluster is classified as a ***competitive specialization***, meaning that it is highly specialized and outperforming the nation in growth, although in this case this means that Maine's decline in employment was not as steep as the nation's since both saw employment losses since 2007. The cluster had employment of 1,003 jobs in 2012, down from 1,285 in 2007. A single firm, the Talaria Company, is by far the largest employer in the cluster, with a number of smaller companies and suppliers to the cluster accounting for the remaining employment.

The Boatbuilding and Related Industries cluster is dominated by the boatbuilding sector which accounts for 94 percent of all employment, with 941 jobs, and is highly specialized with an LQ of 7.28, indicating a concentration of employment more than seven times the national average. The cluster includes both the boatbuilding sector as well as several key supplier industries. The cluster is one of three of the thirteen clusters where productivity exceeds national rates, and has relatively strong supply chain and income linkages to the larger Maine economy. Average wages of $42,492 exceed the state's average.

Metrics for Technology Cluster Performance for Boatbuilding and Related Industries

Maine Employment, 2012	Industry Specialization, 2012	Employment Change Since Pre-Recession Peak, 2007–2012		Change in Competitive Share	Forecast Employment Growth 2012–2022	
		Maine	U.S.		Maine	U.S.
1,003	1.88	(22.0%)	(26.5%)	4.5%	(1.0%)	(1.0%)
Productivity as a % of U.S.		103.0%			**Average Wage**	$42,492

Source: IMPLAN and BLS Employment and Output Projections, calculations by Battelle. See Section II for more details on each measure.

Defense

The Defense technology cluster is the fourth largest of Maine's technology clusters and has been a leading part of the Maine economy for decades. The industry is specialized in Maine, but experienced a decline in employment in the 2007-2012 period, while the industry grew nationally and declined by 1 percent in New England. Two of Maine's twenty largest private employers, Bath Iron Works, the fourth largest private employer in Maine, and Pratt & Whitney Aircraft Group, the 19th largest, are in the Defense technology cluster which also includes a large and growing base of small and mid-sized firms. The cluster is made up of firms serving three distinct defense-oriented markets: shipbuilding, aerospace, and arms and ammunition. While each of these three industries are quite different, they share a common customer, and face many of the same challenges in what is expected to be a contracting defense market.

Many of the sub-sectors of the Defense technology cluster are specialized in Maine, including:

- Ship building and repairing – LQ of 12.26 and 5,350 Jobs;
- Other ordnance and accessories manufacturing – LQ of 9.79 and 243 Jobs;
- Small arms manufacturing- LQ of 7.28 and 342 Jobs; and
- Aircraft engine and engine parts manufacturing – LQ of 3.81 and 1,341 Jobs.

Metrics for Technology Cluster Performance for Defense*

Maine Employment, 2012	Industry Specialization, 2012	Employment Change Since Pre-Recession Peak, 2007–2012		Change in Competitive Share	Forecast Employment Growth 2012–2022	
		Maine	U.S.		Maine	U.S.
7,397	2.18	(4.6%)	0.9%	(5.5%)	(0.7%	(0.6%)
Productivity as a % of U.S.		67.0%			**Average Wage**	$63,959

*The base year of 2006 was used for this cluster to account for data discrepancies in 2007 and 2008.

Source: IMPLAN and BLS Employment and Output Projections, calculations by Battelle. See Section II for more details on each measure.

Electronics and Semiconductors

Maine has a long history of involvement in the Electronics and Semiconductors technology cluster and is home to operations of Fairchild Semiconductor Corporation and Texas Instruments Incorporated. The cluster has experienced a decline in employment over the past two business cycles, with employment declining almost 60 percent since 2001 and by 24 percent since 2007. The decline in Electronics and Semiconductors technology cluster employment in Maine has been more rapid than the decline experienced nationally and in New England. Maine has a low level of specialization in the cluster. The cluster has an average level of supply chain and employee income linkages to the broader Maine economy, but a lower than national level of productivity. The average cluster wage of $59,513 is well above the state average. Maine's above average concentration in cluster employment coupled with the regional strength of this cluster identifies it as a potential opportunity.

Several components of the Electronics and Semiconductors technology cluster are specialized, including:

- Electronic capacitor manufacturing – LQ of 6.77 and 174 Jobs;
- Other communications equipment manufacturing – LQ of 3.23 and 311 Jobs; and
- The Electronic resistor manufacturing and Electronic coils, transformers, and inductors are both specialized, but each employs fewer than 100 workers.

Metrics for Technology Cluster Performance for Electronics and Semiconductors

Maine Employment, 2012	Industry Specialization, 2012	Employment Change Since Pre-Recession Peak, 2007–2012		Change in Competitive Share	Forecast Employment Growth 2012–2022	
		Maine	U.S.		Maine	U.S.
2,055	0.65	(23.7%)	(13.9%)	(9.8%)	(1.3%)	(1.5%)
Productivity as a % of U.S.		77.0%		**Average Wage**		$59,513

Source: IMPLAN and BLS Employment and Output Projections, calculations by Battelle. See Section II for more details on each measure.

Engineering and Scientific/Technical Services

Maine's Engineering and Scientific/Technical Services technology cluster is non-specialized and relatively small, but the cluster is growing more rapidly in Maine than in the nation. Maine's growth however, lags the New England region's growth in this cluster. Cluster employment has grown from 3,558 jobs in 2007 to 3,928 jobs in 2012. Only one sub-sector of the Engineering and Scientific/Technical Services technology cluster is specialized, drafting services, with an LQ of 1.72, but this industry has fewer than 100 employees. The cluster has an above average level of supply chain and employee income linkages to the broader Maine economy, but a lower than national level of productivity. The average cluster wage of $71,348 is well above the state average and is the third highest among the thirteen clusters.

Metrics for Technology Cluster Performance for Engineering and Scientific/Technical Services

Maine Employment, 2012	Industry Specialization, 2012	Employment Change Since Pre-Recession Peak, 2007–2012		Change in Competitive Share	Forecast Employment Growth 2012–2022	
		Maine	U.S.		Maine	U.S.
3,982	0.65	10.4%	4.7%	5.7%	2.2%	2.2%
Productivity as a % of U.S.		80.0%		**Average Wage**		$71,348

Source: IMPLAN and BLS Employment and Output Projections, calculations by Battelle. See Section II for more details on each measure.

Environmental Services

The Environmental Services technology cluster is a relatively small and non-specialized cluster in Maine; however, this is a strong cluster in the New England region and has been growing more rapidly in Maine than in the nation and region. The industry is not specialized in Maine, but is growing at a rate twice the national average. Cluster employment has increased from 1,605 in 2007 to 1,660 in 2012 and there are 297 establishments in this cluster. Maine's Environmental Services technology cluster is the second smallest and least specialized in the New England region and most New England states are specialized in this cluster, creating regionally-based opportunities to support the growth and further development of this regionally important industry. Moreover, overall state employment is projected to increase by 2.6 percent annually over the coming year, supporting the growth potential of this cluster. The cluster has above average linkages to the local economy, but has a lower level of productivity than nation. The cluster's average wage of $48,994 is well above the statewide average.

Only two sub-sectors of the Environmental Services technology cluster are specialized, but both have fewer than 100 employees:

- Solid waste combustors and incinerators – LQ of 3.39; and
- Materials recovery facilities – LQ of 1.49.

Metrics for Technology Cluster Performance for Environmental Services

Maine Employment, 2012	Industry Specialization, 2012	Employment Change Since Pre-Recession Peak, 2007–2012		Change in Competitive Share	Forecast Employment Growth 2012–2022	
		Maine	U.S.		Maine	U.S.
1,660	0.74	3.4%	1.7%	1.7%	2.6%	2.3%
Productivity as a % of U.S.		87.0%		**Average Wage**		$48,994

Source: IMPLAN and BLS Employment and Output Projections, calculations by Battelle. See Section II for more details on each measure.

Finance and Business Support Services

The Finance and Business Support Services technology cluster is the largest of Maine's technology clusters. The cluster had employment of 29,561 jobs in 2012, up from 28,904 in 2007, and is one of seven out of the thirteen clusters analyzed that have surpassed pre-recession levels in employment. The industry is not specialized in Maine, but still has an above average concentration of employment, and Maine employment increased by 2.3 percent since 2007, while national and regional employment fell. The cluster is classified as an ***emerging strength*** cluster, meaning that it is growing and outperforming the nation in growth but is not yet specialized. Four of Maine's top 50 private employers are in the Finance and Business Support Services technology cluster, including TD Bank, Maine's eighth largest private employer and UNUM Provident, the ninth largest. The cluster has above average linkages to the local economy, but has a lower level of productivity than the nation. The cluster's average wage of $55,405 is well above the statewide average. Cluster employment is projected to grow almost 1 percent annually over the coming decade.

The key components of the Finance and Business Support Services technology cluster are specialized in Maine, including:

- Depository credit intermediation (banking and related financial activities) – LQ of 1.23 and 9,930 Jobs;
- Financial transaction processing and clearing – LQ of 1.92 and 976 Jobs;
- Insurance carriers- LQ of 1.25 and 6,411 Jobs; and
- Telemarketing and other contact centers- LQ of 2.22and 4,749 Jobs.

Metrics for Technology Cluster Performance for Finance and Business Support Services

Maine Employment, 2012	Industry Specialization, 2012	Employment Change Since Pre-Recession Peak, 2007–2012		Change in Competitive Share	Forecast Employment Growth 2012–2022	
		Maine	U.S.		Maine	U.S.
29,561	1.05	2.3%	(6.1%)	8.4%	0.9%	1.0%
Productivity as a % of U.S.		80.0%	**Average Wage**			$55,405

Source: IMPLAN and BLS Employment and Output Projections, calculations by Battelle. See Section II for more details on each measure.

Forestry-Related Products

The Forestry-Related Products technology cluster is the second largest of Maine's technology clusters and represents one of Maine's traditionally strong natural resource-based technology clusters. The industry is highly specialized in Maine, but has been hard hit by the recent great recession and has seen employment fall from 18,623 in jobs in 2007 to 15,157 in 2012. National and regional employment declined more rapidly and the cluster is classified as a ***competitive specialization***, meaning that it is highly specialized and outperforming the nation in growth, although in this case this means that Maine's decline in employment was not as steep as the nation's. Many of the state's leading employers are represented among the 832 business establishments in the cluster, including Verso Paper Corporation, Maine's 13th largest private employer, S D Warren, Maine's 15th largest private employer, and the Rumford Paper Company, Maine's 38th largest employer. The cluster is highly vertically integrated with strong supply chin linkages that include growing, harvesting, processing, and manufacturing end-products from Maine's substantial timber resources. The Forestry-related Products technology cluster is among the three industries where Maine's productivity exceeds the national average for the cluster. Average wages in the cluster are $51,012, well above the state average.

Most of the sub-sectors of the Forestry-related Products technology cluster are specialized in Maine, including:

- Logging – LQ of 10.60 and 2,281 Jobs;
- Sawmills – LQ of 5.82 and 1,742 Jobs;
- Plywood and engineered wood product mfg.- LQ of 1.81 and 500 Jobs;
- Other wood product manufacturing – LQ of 2.30 and 1,934 Jobs; and
- Pulp, paper, and paperboard mills – LQ of 11.69 and 5,563 Jobs.

Metrics for Technology Cluster Performance for Forestry-Related Products

Maine Employment, 2012	Industry Specialization, 2012	Employment Change Since Pre-Recession Peak, 2007–2012		Change in Competitive Share	Forecast Employment Growth 2012–2022	
		Maine	U.S.		Maine	U.S.
15,157	3.02	(18.6%)	(27.9%)	9.3%	(0.6%)	0.1%
Productivity as a % of U.S.		156.0%			**Average Wage**	$51,012

Source: IMPLAN and BLS Employment and Output Projections, calculations by Battelle. See Section II for more details on each measure.

Information Technology Services

Despite the high concentration of employment and strong national position of the New England region in this cluster, especially Massachusetts in information technology, the Information Technology Services cluster is both small and non-specialized in Maine. The Information Technology Services cluster saw employment fall from 4,750 in 2007 to 4,065 in 2012, despite expanding employment significantly both nationally and in New England. Maine's Information Technology Services cluster has strong supply chain and income linkages to the broader state economy, but lags the nation in terms of productivity. With an average wage of $73,168, the cluster offers average wages nearly twice the state average, and has the second highest average wages among the thirteen clusters, after Alternative Energy and Turbines.

Only one of the sub-sectors of Maine's Information Technology Services cluster is specialized: computer facilities management services, with an LQ of 1.40 and 319 jobs.

Despite Maine's low level of specialization and declining employment in this cluster, the industry represents a potential growth opportunity for the state. The industry is projected to grow by 3.1 percent annually nationally and by 3.3 percent annually in Maine, based on national projections data. This is the second strongest projected rate of growth for all of the thirteen clusters. The key to the growth in this cluster will be creating opportunities to capitalize on the New England region's strength and Maine's competitive labor and business costs are a potential advantage in efforts to promote the growth of this cluster.

Metrics for Technology Cluster Performance for Information Technology Services

Maine Employment, 2012	Industry Specialization, 2012	Employment Change Since Pre-Recession Peak, 2007–2012		Change in Competitive Share	Forecast Employment Growth 2012–2022	
		Maine	U.S.		Maine	U.S.
4,065	0.40	(11.1%)	16.4%	(27.5%)	3.3%	3.1%
Productivity as a % of U.S.		65.0%		**Average Wage**		$73,168

Source: IMPLAN and BLS Employment and Output Projections, calculations by Battelle. See Section II for more details on each measure.

Materials for Textiles, Apparel, Leather and Footwear

The Materials for Textiles, Apparel, Leather and Footwear technology cluster is a traditional Maine industry that includes textiles, apparel, and shoe manufacturing. The industry as long played an important role in the state's economy, but has been strongly impacted in the near and long term by increased international competition. The cluster is highly specialized in Maine, with and LQ of 2.32, but employment fell by 18 percent since 2007, from 5,126 jobs to 4,194 jobs. Cluster employment in Maine, however, fell less than nationally. The Materials for Textiles, Apparel, Leather and Footwear technology cluster is classified as a ***competitive specialization***, meaning that it is highly specialized and outperforming the nation in growth, although in this case this means that Maine's decline in employment was not as steep as the nation's. One of Maine's top 50 private employers, New Balance Athletic Shoe, Inc., is in the Materials for Textiles, Apparel, Leather and Footwear technology cluster, which also includes a large number of both small and mid-sized firms among the 148 business establishments in the cluster. The Materials for Textiles, Apparel, Leather and Footwear technology cluster is among the three industries where Maine's productivity exceeds the national average for the cluster. Average wages in the cluster are $33,970, one of only two clusters where average wages are below the state average. This cluster is projected to continue to experience declines in employment over the coming decade.

Key specialized sub-sectors within the Materials for Textiles, Apparel, Leather and Footwear technology cluster include:

- Fabric mills – LQ of 3.58 and 873 Jobs;
- Other textile product mills – LQ of 2.08 and 582 Jobs;
- Leather and hide tanning and finishing – LQ of 11.44 and 201 Jobs; and
- Footwear manufacturing – LQ of 24.57 and 1,474 Jobs.

Metrics for Technology Cluster Performance for Materials for Textiles, Apparel, Leather and Footwear

Maine Employment, 2012	Industry Specialization, 2012	Employment Change Since Pre-Recession Peak, 2007–2012		Change in Competitive Share	Forecast Employment Growth 2012–2022	
		Maine	U.S.		Maine	U.S.
4,194	2.32	(18.2%)	(28.7%)	10.5%	(3.3%)	(3.6%)
Productivity as a % of U.S.		103.0%		**Average Wage**		$33,970

Source: IMPLAN and BLS Employment and Output Projections, calculations by Battelle. See Section II for more details on each measure.

Medical Devices

The Medical Devices technology cluster is the second smallest of Maine's technology clusters. The industry is not specialized in Maine and is growing at about the national rate of growth. While Maine's Medical Device technology cluster is small, this cluster is quite important in the overall New England region, creating opportunities for growth. The cluster had employment of 1,036 jobs in 2012, up slightly from 2007, and is one of seven out of the thirteen clusters analyzed that have surpassed pre-recession levels in employment. Overall productivity for the cluster lags the nation, but the cluster offers an average level of supply chain and income linkages to the larger Maine economy. Average cluster wages of $44,602 are well above the statewide average.

Two of the sub clusters in the Medical Devices technology cluster are specialized:

- Surgical appliance and supplies manufacturing – LQ of 1.55 and 676 Jobs; and
- Analytical laboratory instrument manufacturing – LQ of 1.55 and 220 Jobs.

Metrics for Technology Cluster Performance for Medical Devices

Maine Employment, 2012	Industry Specialization, 2012	Employment Change Since Pre-Recession Peak, 2007–2012		Change in Competitive Share	Forecast Employment Growth 2012–2022	
		Maine	U.S.		Maine	U.S.
1,036	0.64	1.5%	1.5%	(0.0%)	(0.3%)	(0.2%)
Productivity as a % of U.S.		66.0%		**Average Wage**		$44,602

Source: IMPLAN and BLS Employment and Output Projections, calculations by Battelle. See Section II for more details on each measure.

Appendix C: Detailed Industry Composition of Maine's Technology Clusters

Industry Code	NAICS Description	Maine Technology Cluster
111	Crop production	Agriculture, Aquaculture, Fisheries and Food Production
112	Animal production	Agriculture, Aquaculture, Fisheries and Food Production
115	Agriculture and forestry support activities	Agriculture, Aquaculture, Fisheries and Food Production
114111	Finfish fishing	Agriculture, Aquaculture, Fisheries and Food Production
114112	Shellfish fishing	Agriculture, Aquaculture, Fisheries and Food Production
114119	Other marine fishing	Agriculture, Aquaculture, Fisheries and Food Production
114210	Hunting and trapping	Agriculture, Aquaculture, Fisheries and Food Production
311111	Dog and cat food manufacturing	Agriculture, Aquaculture, Fisheries and Food Production
311119	Other animal food manufacturing	Agriculture, Aquaculture, Fisheries and Food Production
311211	Flour milling	Agriculture, Aquaculture, Fisheries and Food Production
311212	Rice milling	Agriculture, Aquaculture, Fisheries and Food Production
311213	Malt manufacturing	Agriculture, Aquaculture, Fisheries and Food Production
311221	Wet corn milling	Agriculture, Aquaculture, Fisheries and Food Production
311222	Soybean processing	Agriculture, Aquaculture, Fisheries and Food Production
311223	Other oilseed processing	Agriculture, Aquaculture, Fisheries and Food Production
311225	Fats and oils refining and blending	Agriculture, Aquaculture, Fisheries and Food Production
311230	Breakfast cereal manufacturing	Agriculture, Aquaculture, Fisheries and Food Production
311311	Sugarcane mills	Agriculture, Aquaculture, Fisheries and Food Production
311312	Cane sugar refining	Agriculture, Aquaculture, Fisheries and Food Production
311313	Beet sugar manufacturing	Agriculture, Aquaculture, Fisheries and Food Production
311320	Confectionery manufacturing from cacao beans	Agriculture, Aquaculture, Fisheries and Food Production
311330	Confectionery mfg. from purchased chocolate	Agriculture, Aquaculture, Fisheries and Food Production
311340	Nonchocolate confectionery manufacturing	Agriculture, Aquaculture, Fisheries and Food Production
311411	Frozen fruit and vegetable manufacturing	Agriculture, Aquaculture, Fisheries and Food Production
311412	Frozen specialty food manufacturing	Agriculture, Aquaculture, Fisheries and Food Production
311421	Fruit and vegetable canning	Agriculture, Aquaculture, Fisheries and Food Production
311422	Specialty canning	Agriculture, Aquaculture, Fisheries and Food Production
311423	Dried and dehydrated food manufacturing	Agriculture, Aquaculture, Fisheries and Food Production
311511	Fluid milk manufacturing	Agriculture, Aquaculture, Fisheries and Food Production
311512	Creamery butter manufacturing	Agriculture, Aquaculture, Fisheries and Food Production
311513	Cheese manufacturing	Agriculture, Aquaculture, Fisheries and Food Production
311514	Dry, condensed, and evaporated dairy products	Agriculture, Aquaculture, Fisheries and Food Production
311520	Ice cream and frozen dessert manufacturing	Agriculture, Aquaculture, Fisheries and Food Production
311611	Animal, except poultry, slaughtering	Agriculture, Aquaculture, Fisheries and Food Production
311612	Meat processed from carcasses	Agriculture, Aquaculture, Fisheries and Food Production
311613	Rendering and meat byproduct processing	Agriculture, Aquaculture, Fisheries and Food Production
311615	Poultry processing	Agriculture, Aquaculture, Fisheries and Food Production

Industry Code	NAICS Description	Maine Technology Cluster
311711	Seafood canning	Agriculture, Aquaculture, Fisheries and Food Production
311712	Fresh and frozen seafood processing	Agriculture, Aquaculture, Fisheries and Food Production
311811	Retail bakeries	Agriculture, Aquaculture, Fisheries and Food Production
311812	Commercial bakeries	Agriculture, Aquaculture, Fisheries and Food Production
311813	Frozen cakes and other pastries manufacturing	Agriculture, Aquaculture, Fisheries and Food Production
311821	Cookie and cracker manufacturing	Agriculture, Aquaculture, Fisheries and Food Production
311822	Mixes and dough made from purchased flour	Agriculture, Aquaculture, Fisheries and Food Production
311823	Dry pasta manufacturing	Agriculture, Aquaculture, Fisheries and Food Production
311830	Tortilla manufacturing	Agriculture, Aquaculture, Fisheries and Food Production
311911	Roasted nuts and peanut butter manufacturing	Agriculture, Aquaculture, Fisheries and Food Production
311919	Other snack food manufacturing	Agriculture, Aquaculture, Fisheries and Food Production
311920	Coffee and tea manufacturing	Agriculture, Aquaculture, Fisheries and Food Production
311930	Flavoring syrup and concentrate manufacturing	Agriculture, Aquaculture, Fisheries and Food Production
311941	Mayonnaise, dressing, and sauce manufacturing	Agriculture, Aquaculture, Fisheries and Food Production
311942	Spice and extract manufacturing	Agriculture, Aquaculture, Fisheries and Food Production
311991	Perishable prepared food manufacturing	Agriculture, Aquaculture, Fisheries and Food Production
311999	All other miscellaneous food manufacturing	Agriculture, Aquaculture, Fisheries and Food Production
312111	Soft drink manufacturing	Agriculture, Aquaculture, Fisheries and Food Production
312112	Bottled water manufacturing	Agriculture, Aquaculture, Fisheries and Food Production
312113	Ice manufacturing	Agriculture, Aquaculture, Fisheries and Food Production
312120	Breweries	Agriculture, Aquaculture, Fisheries and Food Production
312130	Wineries	Agriculture, Aquaculture, Fisheries and Food Production
312140	Distilleries	Agriculture, Aquaculture, Fisheries and Food Production
221111	Hydroelectric power generation	Alternative Energy and Turbines
221119	Other electric power generation	Alternative Energy and Turbines
333611	Turbine and turbine generator set units mfg.	Alternative Energy and Turbines
325411	Medicinal and botanical manufacturing	Biopharmaceuticals
325412	Pharmaceutical preparation manufacturing	Biopharmaceuticals
325413	In-vitro diagnostic substance manufacturing	Biopharmaceuticals
325414	Other biological product manufacturing	Biopharmaceuticals
621511	Medical laboratories	Biopharmaceuticals
541380S	Testing laboratories (Bio Share only)	Biopharmaceuticals
54171S	Physical, engineering and biological research (Bio Share Only)	Biopharmaceuticals
325211	Plastics material and resin manufacturing	Boatbuilding and Related Industries
325212	Synthetic rubber manufacturing	Boatbuilding and Related Industries
325221	Cellulosic organic fiber manufacturing	Boatbuilding and Related Industries
325222	Noncellulosic organic fiber manufacturing	Boatbuilding and Related Industries
336612	Boat building	Boatbuilding and Related Industries

Industry Code	NAICS Description	Maine Technology Cluster
332992	Small arms ammunition manufacturing	Defense
332993	Ammunition, except small arms, manufacturing	Defense
332994	Small arms manufacturing	Defense
332995	Other ordnance and accessories manufacturing	Defense
334511	Search, detection, and navigation instruments	Defense
336411	Aircraft manufacturing	Defense
336412	Aircraft engine and engine parts mfg.	Defense
336413	Other aircraft parts and equipment	Defense
336414	Guided missile and space vehicle mfg.	Defense
336415	Space vehicle propulsion units and parts mfg.	Defense
336419	Other guided missile and space vehicle parts	Defense
336611	Ship building and repairing	Defense
334111	Electronic computer manufacturing	Electronics and Semiconductors
334112	Computer storage device manufacturing	Electronics and Semiconductors
334113	Computer terminal manufacturing	Electronics and Semiconductors
334119	Other computer peripheral equipment mfg.	Electronics and Semiconductors
334210	Telephone apparatus manufacturing	Electronics and Semiconductors
334220	Broadcast and wireless communications equip.	Electronics and Semiconductors
334290	Other communications equipment manufacturing	Electronics and Semiconductors
334310	Audio and video equipment manufacturing	Electronics and Semiconductors
334411	Electron tube manufacturing	Electronics and Semiconductors
334412	Bare printed circuit board manufacturing	Electronics and Semiconductors
334413	Semiconductors and related device mfg.	Electronics and Semiconductors
334414	Electronic capacitor manufacturing	Electronics and Semiconductors
334415	Electronic resistor manufacturing	Electronics and Semiconductors
334416	Electronic coils, transformers, and inductors	Electronics and Semiconductors
334417	Electronic connector manufacturing	Electronics and Semiconductors
334418	Printed circuit assembly manufacturing	Electronics and Semiconductors
334419	Other electronic component manufacturing	Electronics and Semiconductors
334515	Electricity and signal testing instruments	Electronics and Semiconductors
541330	Engineering services	Engineering and Scientific/Technical Services
541340	Drafting services	Engineering and Scientific/Technical Services
541690	Other technical consulting services	Engineering and Scientific/Technical Services
54171R	Scientific research and development services (non-bio)	Engineering and Scientific/Technical Services
221310	Water supply and irrigation systems	Environmental Services
221320	Sewage treatment facilities	Environmental Services
221330	Steam and air-conditioning supply	Environmental Services
334512	Automatic environmental control manufacturing	Environmental Services

Industry Code	NAICS Description	Maine Technology Cluster
541620	Environmental consulting services	Environmental Services
562211	Hazardous waste treatment and disposal	Environmental Services
562212	Solid waste landfill	Environmental Services
562213	Solid waste combustors and incinerators	Environmental Services
562219	Other nonhazardous waste disposal	Environmental Services
562910	Remediation services	Environmental Services
562920	Materials recovery facilities	Environmental Services
562991	Septic tank and related services	Environmental Services
562998	Miscellaneous waste management services	Environmental Services
541380R	Testing laboratories (partial)	Environmental Services
521110	Monetary authorities - central bank	Finance and Business Support Services
522110	Commercial banking	Finance and Business Support Services
522120	Savings institutions	Finance and Business Support Services
522130	Credit unions	Finance and Business Support Services
522190	Other depository credit intermediation	Finance and Business Support Services
522210	Credit card issuing	Finance and Business Support Services
522220	Sales financing	Finance and Business Support Services
522291	Consumer lending	Finance and Business Support Services
522292	Real estate credit	Finance and Business Support Services
522293	International trade financing	Finance and Business Support Services
522294	Secondary market financing	Finance and Business Support Services
522298	All other nondepository credit intermediation	Finance and Business Support Services
522310	Mortgage and nonmortgage loan brokers	Finance and Business Support Services
522320	Financial transaction processing and clearing	Finance and Business Support Services
522390	Other credit intermediation activities	Finance and Business Support Services
523110	Investment banking and securities dealing	Finance and Business Support Services
523120	Securities brokerage	Finance and Business Support Services
523130	Commodity contracts dealing	Finance and Business Support Services
523140	Commodity contracts brokerage	Finance and Business Support Services
523210	Securities and commodity exchanges	Finance and Business Support Services
523910	Miscellaneous intermediation	Finance and Business Support Services
523920	Portfolio management	Finance and Business Support Services
523930	Investment advice	Finance and Business Support Services
523991	Trust, fiduciary, and custody activities	Finance and Business Support Services
523999	Miscellaneous financial investment activities	Finance and Business Support Services
524113	Direct life insurance carriers	Finance and Business Support Services
524114	Direct health and medical insurance carriers	Finance and Business Support Services
524126	Direct property and casualty insurers	Finance and Business Support Services
524127	Direct title insurance carriers	Finance and Business Support Services
524128	Other direct insurance carriers	Finance and Business Support Services

Industry Code	NAICS Description	Maine Technology Cluster
524130	Reinsurance carriers	Finance and Business Support Services
524210	Insurance agencies and brokerages	Finance and Business Support Services
524291	Claims adjusting	Finance and Business Support Services
524292	Third party administration of insurance funds	Finance and Business Support Services
524298	All other insurance related activities	Finance and Business Support Services
525110	Pension funds	Finance and Business Support Services
525120	Health and welfare funds	Finance and Business Support Services
525190	Other insurance funds	Finance and Business Support Services
525910	Open-end investment funds	Finance and Business Support Services
525920	Trusts, estates, and agency accounts	Finance and Business Support Services
525990	Other financial vehicles	Finance and Business Support Services
561410	Document preparation services	Finance and Business Support Services
561421	Telephone answering services	Finance and Business Support Services
561422	Telemarketing and other contact centers	Finance and Business Support Services
561431	Private mail centers	Finance and Business Support Services
561439	Other business service centers	Finance and Business Support Services
561440	Collection agencies	Finance and Business Support Services
561450	Credit bureaus	Finance and Business Support Services
561491	Repossession services	Finance and Business Support Services
561492	Court reporting and stenotype services	Finance and Business Support Services
561499	All other business support services	Finance and Business Support Services
113110	Timber tract operations	Forestry-Related Products
113210	Forest nursery and gathering forest products	Forestry-Related Products
113310	Logging	Forestry-Related Products
115310	Support activities for forestry	Forestry-Related Products
321113	Sawmills	Forestry-Related Products
321114	Wood preservation	Forestry-Related Products
321211	Hardwood veneer and plywood manufacturing	Forestry-Related Products
321212	Softwood veneer and plywood manufacturing	Forestry-Related Products
321213	Engineered wood member manufacturing	Forestry-Related Products
321214	Truss manufacturing	Forestry-Related Products
321219	Reconstituted wood product manufacturing	Forestry-Related Products
321911	Wood window and door manufacturing	Forestry-Related Products
321912	Cut stock, resawing lumber, and planing	Forestry-Related Products
321918	Other millwork, including flooring	Forestry-Related Products
321920	Wood container and pallet manufacturing	Forestry-Related Products
321991	Manufactured home, mobile home, manufacturing	Forestry-Related Products
321992	Prefabricated wood building manufacturing	Forestry-Related Products
321999	Miscellaneous wood product manufacturing	Forestry-Related Products
322110	Pulp mills	Forestry-Related Products

Industry Code	NAICS Description	Maine Technology Cluster
322121	Paper, except newsprint, mills	Forestry-Related Products
322122	Newsprint mills	Forestry-Related Products
322130	Paperboard mills	Forestry-Related Products
322211	Corrugated and solid fiber box manufacturing	Forestry-Related Products
322212	Folding paperboard box manufacturing	Forestry-Related Products
322213	Setup paperboard box manufacturing	Forestry-Related Products
322214	Fiber can, tube, and drum manufacturing	Forestry-Related Products
322215	Nonfolding sanitary food container mfg.	Forestry-Related Products
322221	Coated and laminated packaging paper mfg.	Forestry-Related Products
322222	Coated and laminated paper manufacturing	Forestry-Related Products
322223	Coated paper bag and pouch manufacturing	Forestry-Related Products
322224	Uncoated paper and multiwall bag mfg.	Forestry-Related Products
322225	Flexible packaging foil manufacturing	Forestry-Related Products
322226	Surface-coated paperboard manufacturing	Forestry-Related Products
322231	Die-cut paper office supplies manufacturing	Forestry-Related Products
322232	Envelope manufacturing	Forestry-Related Products
322233	Stationery and related product manufacturing	Forestry-Related Products
322291	Sanitary paper product manufacturing	Forestry-Related Products
322299	All other converted paper product mfg.	Forestry-Related Products
337110	Wood kitchen cabinet and countertop mfg.	Forestry-Related Products
337121	Upholstered household furniture manufacturing	Forestry-Related Products
337122	Nonupholstered wood household furniture mfg.	Forestry-Related Products
337124	Metal household furniture manufacturing	Forestry-Related Products
337125	Household furniture, exc. wood or metal, mfg.	Forestry-Related Products
337127	Institutional furniture manufacturing	Forestry-Related Products
337129	Wood TV, radio, and sewing machine housings	Forestry-Related Products
337211	Wood office furniture manufacturing	Forestry-Related Products
337212	Custom architectural woodwork and millwork	Forestry-Related Products
337214	Office furniture, except wood, manufacturing	Forestry-Related Products
337215	Showcases, partitions, shelving, and lockers	Forestry-Related Products
337910	Mattress manufacturing	Forestry-Related Products
337920	Blind and shade manufacturing	Forestry-Related Products
511210	Software publishers	Information Technology Services
518210	Data processing, hosting and related services	Information Technology Services
519130	Internet publishing and web search portals	Information Technology Services
541511	Custom computer programming services	Information Technology Services
541512	Computer systems design services	Information Technology Services
541513	Computer facilities management services	Information Technology Services
541519	Other computer related services	Information Technology Services
313111	Yarn spinning mills	Materials for Textiles, Apparel, Leather and Footwear

Industry Code	NAICS Description	Maine Technology Cluster
313112	Yarn texturizing and twisting mills	Materials for Textiles, Apparel, Leather and Footwear
313113	Thread mills	Materials for Textiles, Apparel, Leather and Footwear
313210	Broadwoven fabric mills	Materials for Textiles, Apparel, Leather and Footwear
313221	Narrow fabric mills	Materials for Textiles, Apparel, Leather and Footwear
313222	Schiffli machine embroidery	Materials for Textiles, Apparel, Leather and Footwear
313230	Nonwoven fabric mills	Materials for Textiles, Apparel, Leather and Footwear
313241	Weft knit fabric mills	Materials for Textiles, Apparel, Leather and Footwear
313249	Other knit fabric and lace mills	Materials for Textiles, Apparel, Leather and Footwear
313311	Broadwoven fabric finishing mills	Materials for Textiles, Apparel, Leather and Footwear
313312	Other textile and fabric finishing mills	Materials for Textiles, Apparel, Leather and Footwear
313320	Fabric coating mills	Materials for Textiles, Apparel, Leather and Footwear
314110	Carpet and rug mills	Materials for Textiles, Apparel, Leather and Footwear
314121	Curtain and drapery mills	Materials for Textiles, Apparel, Leather and Footwear
314129	Other household textile product mills	Materials for Textiles, Apparel, Leather and Footwear
314911	Textile bag mills	Materials for Textiles, Apparel, Leather and Footwear
314912	Canvas and related product mills	Materials for Textiles, Apparel, Leather and Footwear
314991	Rope, cordage, and twine mills	Materials for Textiles, Apparel, Leather and Footwear
314992	Tire cord and tire fabric mills	Materials for Textiles, Apparel, Leather and Footwear
314999	All other miscellaneous textile product mills	Materials for Textiles, Apparel, Leather and Footwear
315111	Sheer hosiery mills	Materials for Textiles, Apparel, Leather and Footwear
315119	Other hosiery and sock mills	Materials for Textiles, Apparel, Leather and Footwear
315191	Outerwear knitting mills	Materials for Textiles, Apparel, Leather and Footwear
315192	Underwear and nightwear knitting mills	Materials for Textiles, Apparel, Leather and Footwear
315211	Men's and boys apparel contractors	Materials for Textiles, Apparel, Leather and Footwear
315212	Women's, girls, infants apparel contractors	Materials for Textiles, Apparel, Leather and Footwear
315221	Men's and boys underwear and nightwear mfg	Materials for Textiles, Apparel, Leather and Footwear
315222	Men's and boys suit, coat, and overcoat mfg	Materials for Textiles, Apparel, Leather and Footwear
315223	Men's and boys shirt, except work shirt, mfg	Materials for Textiles, Apparel, Leather and Footwear
315224	Men's and boys pants, except work pants, mfg	Materials for Textiles, Apparel, Leather and Footwear
315225	Men's and boys work clothing manufacturing	Materials for Textiles, Apparel, Leather and Footwear
315228	Other men's and boys outerwear manufacturing	Materials for Textiles, Apparel, Leather and Footwear
315231	Women's and girls lingerie and nightwear mfg	Materials for Textiles, Apparel, Leather and Footwear
315232	Women's and girls blouse and shirt mfg	Materials for Textiles, Apparel, Leather and Footwear
315233	Women's and girls dress manufacturing	Materials for Textiles, Apparel, Leather and Footwear
315234	Women's and girls suit, coat, and skirt mfg	Materials for Textiles, Apparel, Leather and Footwear
315239	Other women's and girls outerwear mfg	Materials for Textiles, Apparel, Leather and Footwear
315291	Infants' cut and sew apparel manufacturing	Materials for Textiles, Apparel, Leather and Footwear
315292	Fur and leather apparel manufacturing	Materials for Textiles, Apparel, Leather and Footwear
315299	All other cut and sew apparel manufacturing	Materials for Textiles, Apparel, Leather and Footwear
315991	Hat, cap, and millinery manufacturing	Materials for Textiles, Apparel, Leather and Footwear
315992	Glove and mitten manufacturing	Materials for Textiles, Apparel, Leather and Footwear

Industry Code	NAICS Description	Maine Technology Cluster
315993	Men's and boys' neckwear manufacturing	Materials for Textiles, Apparel, Leather and Footwear
315999	All other accessory and apparel manufacturing	Materials for Textiles, Apparel, Leather and Footwear
316110	Leather and hide tanning and finishing	Materials for Textiles, Apparel, Leather and Footwear
316211	Rubber and plastics footwear manufacturing	Materials for Textiles, Apparel, Leather and Footwear
316212	House slipper manufacturing	Materials for Textiles, Apparel, Leather and Footwear
316213	Men's nonathletic footwear manufacturing	Materials for Textiles, Apparel, Leather and Footwear
316214	Women's nonathletic footwear manufacturing	Materials for Textiles, Apparel, Leather and Footwear
316219	Other footwear manufacturing	Materials for Textiles, Apparel, Leather and Footwear
316991	Luggage manufacturing	Materials for Textiles, Apparel, Leather and Footwear
316992	Women's handbag and purse manufacturing	Materials for Textiles, Apparel, Leather and Footwear
316993	Other personal leather good manufacturing	Materials for Textiles, Apparel, Leather and Footwear
316999	All other leather and allied good mfg.	Materials for Textiles, Apparel, Leather and Footwear
334510	Electromedical apparatus manufacturing	Medical Devices
334516	Analytical laboratory instrument mfg.	Medical Devices
334517	Irradiation apparatus manufacturing	Medical Devices
339112	Surgical and medical instrument manufacturing	Medical Devices
339113	Surgical appliance and supplies manufacturing	Medical Devices
339114	Dental equipment and supplies manufacturing	Medical Devices
339115	Ophthalmic goods manufacturing	Medical Devices

Appendix D: More Details on the Position of Maine's Technology Clusters Within the New England Region

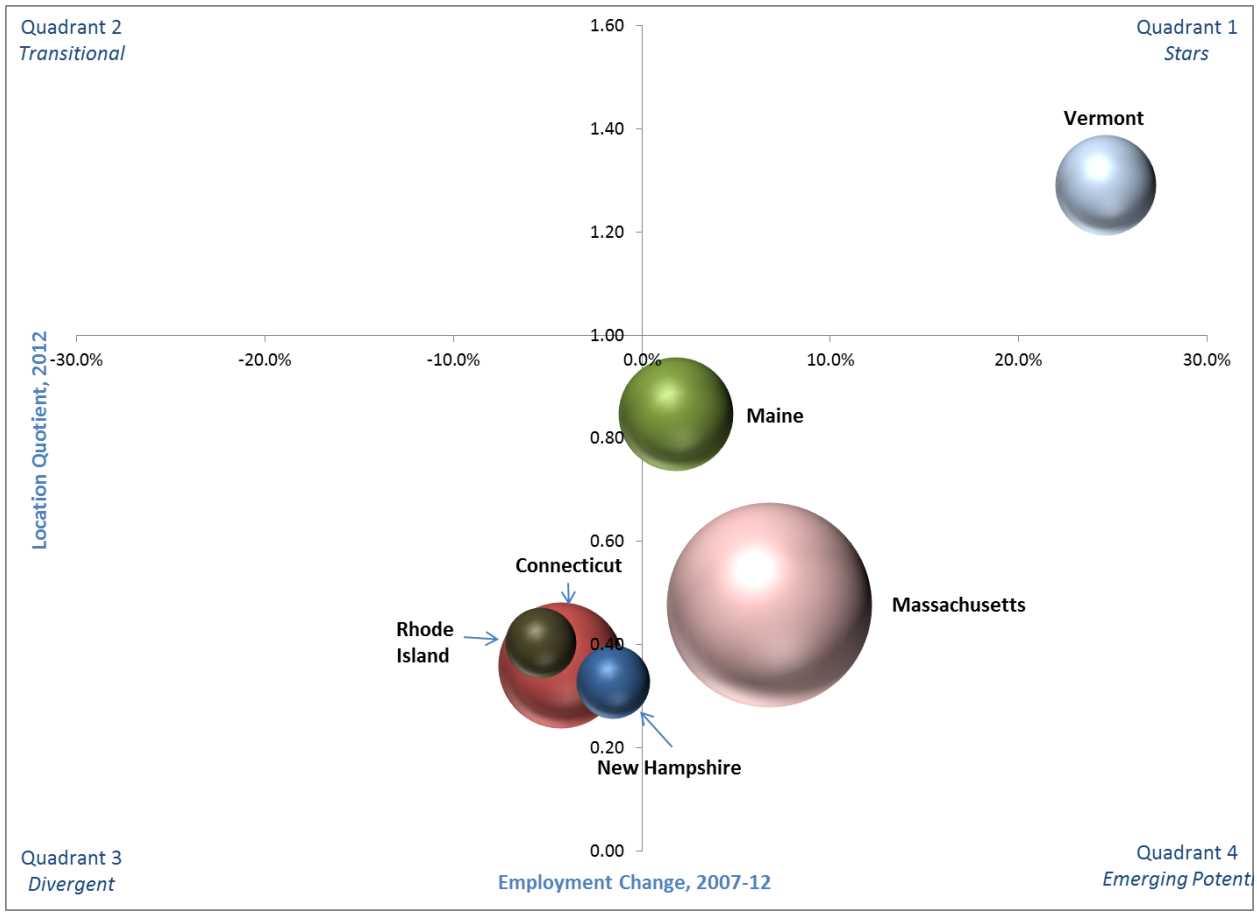
This section explores the position of Maine's technology clusters compared to other states in New England. As might be expected, there are wide differences in terms of the size and performance of the thirteen clusters analyzed among the six states that make up New England. A good way to visualize the performance of Maine relative to its neighboring New England states is through the use of bubble charts that present in one graphic higher or lower concentration levels along the vertical axis, job growth or decline along the horizontal axis, and size of employment in 2012 by the size of the bubble for each of the states. The evaluation of Maine's position in each cluster will result in the state being identified as a regional leader, follower, or player.

Agriculture, Aquaculture, Fisheries and Food Production

Key Finding: Maine is a regional player

- Across New England, only Vermont has an industry specialization in Agriculture, Aquaculture, Fisheries and Food Production.
- Both Vermont and Massachusetts are growing faster than Maine.
- Still, Maine is growing and nearing the national average in industry concentration.

Figure C-1. Maine and New England Performance - Agriculture, Aquaculture, Fisheries and Food Production



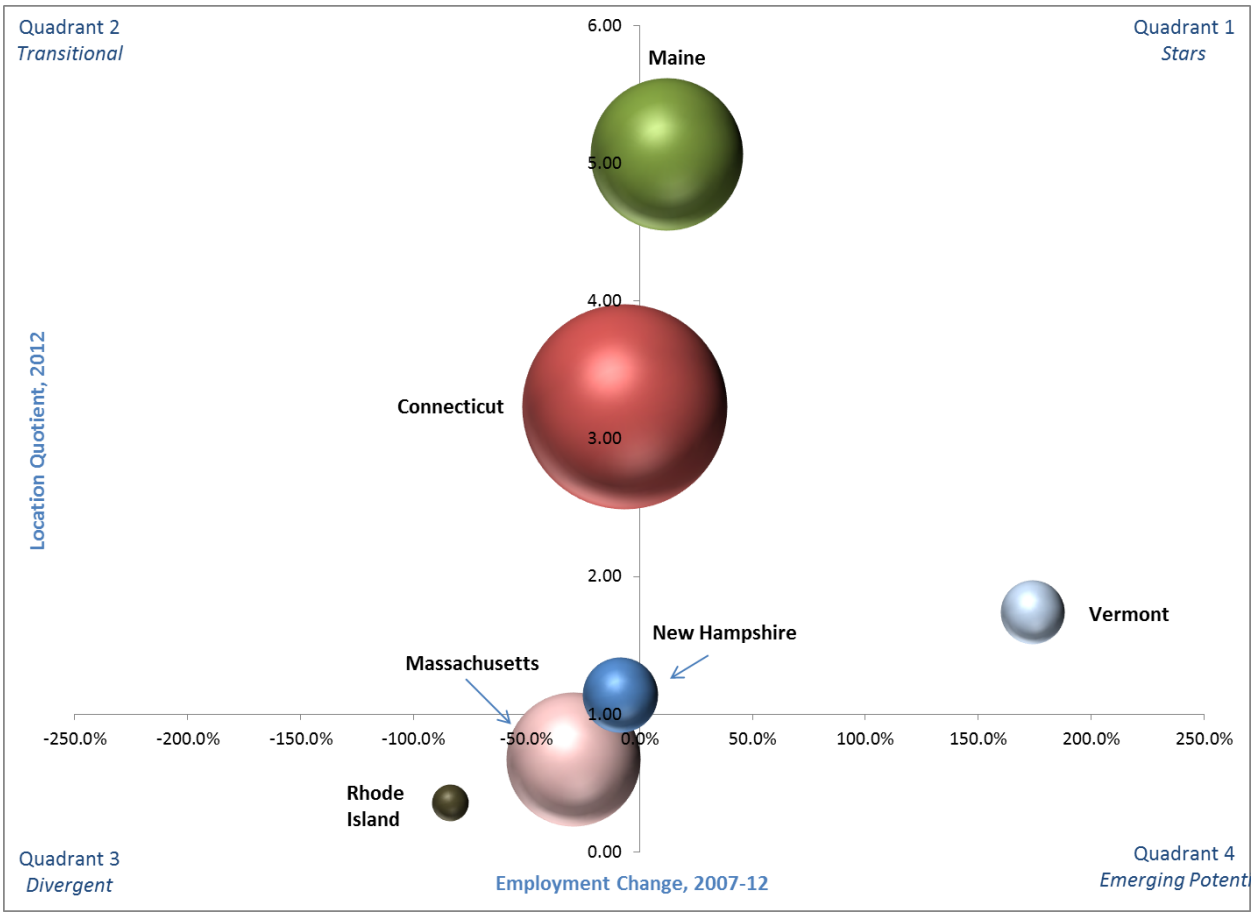
Source: IMPLAN, calculations by Battelle.

Alternative Energy and Turbines

Key Finding: Maine is a regional leader

- Maine's Alternative Energy and Turbines technology cluster is the most specialized in New England.
- Maine is second only to Connecticut in employment.
- Along with Vermont, Maine is the only state to realize employment gains in this industry since 2007.

Figure C-2. Maine and New England Performance - Alternative Energy and Turbines



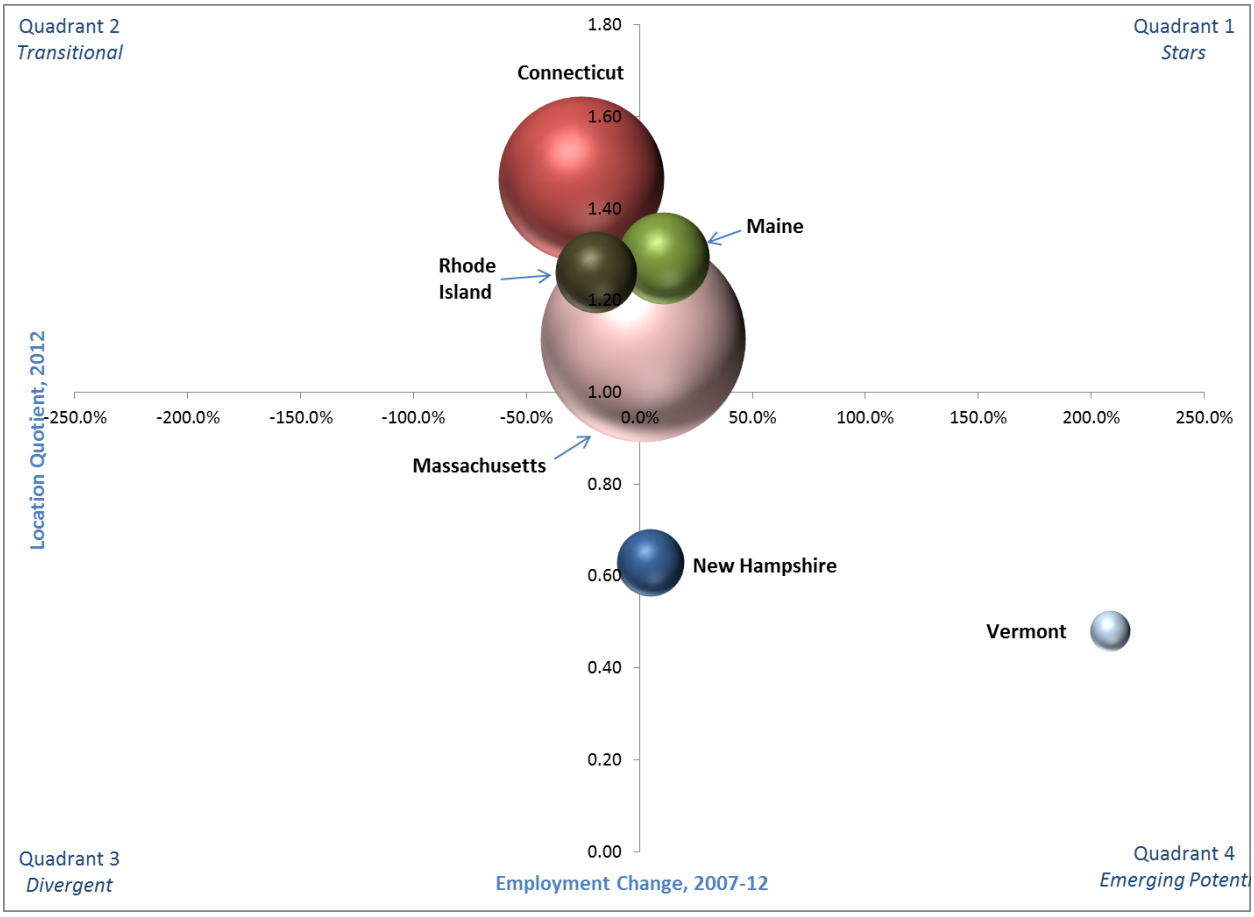
Source: IMPLAN, calculations by Battelle.

Biopharmaceuticals Technology Cluster

Key Finding: Maine is a regional player

- Four of New England's six states, including Maine, are specialized in Biopharmaceuticals.
- Maine's Biopharmaceuticals technology cluster has the second highest level of industry specialization in New England behind Connecticut, and it grew faster than more traditional biopharmaceutical states of Massachusetts and Connecticut.
- Still, the small size of Maine's Biopharmaceutical technology cluster relative to Massachusetts and Connecticut, suggests Maine is a player in a regional industry specialization.

Figure C-3. Maine and New England Performance – Biopharmaceuticals



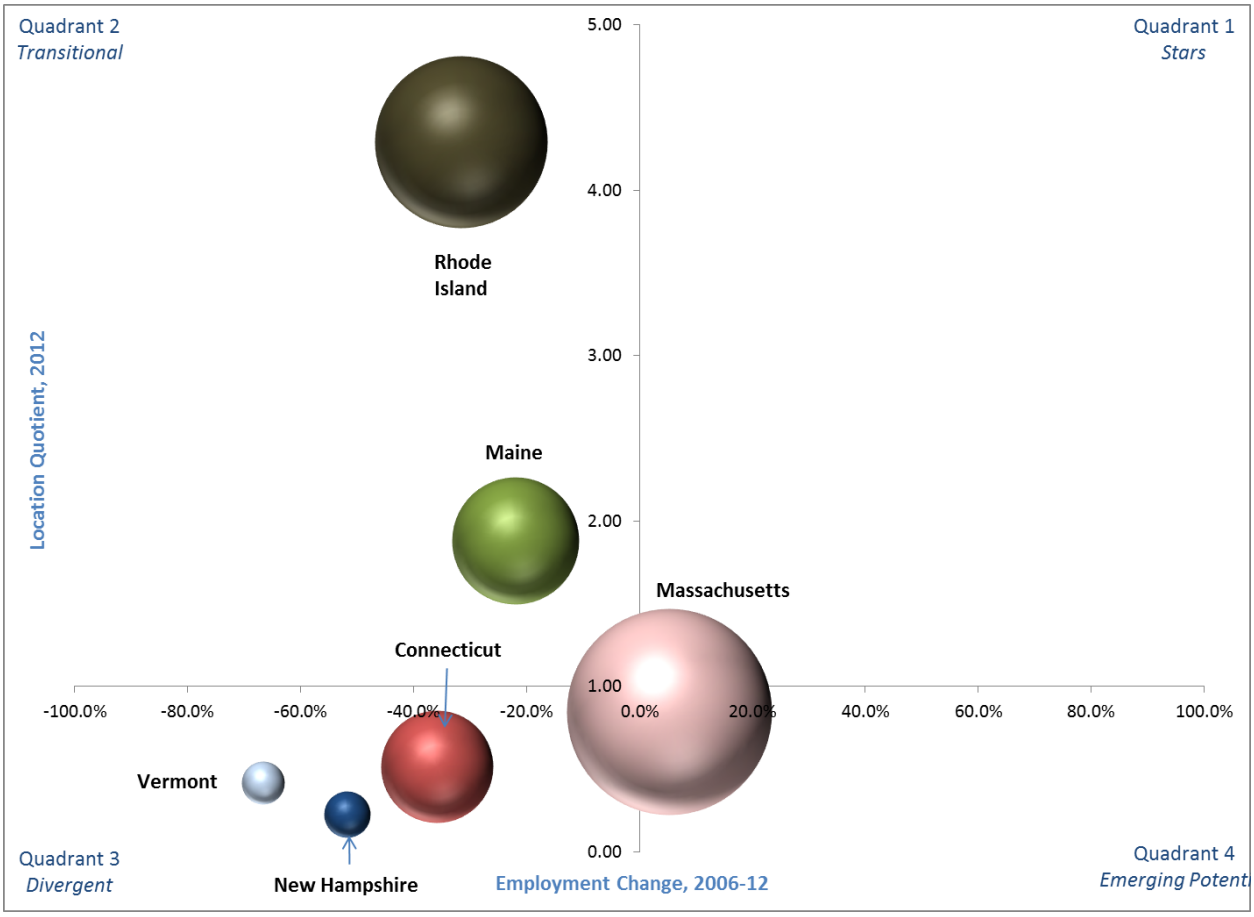
Source: IMPLAN, calculations by Battelle.

Boatbuilding and Related Industries Technology Cluster

Key Finding: Maine is a regional player

- Rhode Island has the highest industry specialization in the Boatbuilding and Related Industries technology cluster among New England states, and Massachusetts has been the one New England state growing in Boatbuilding and Related Industries.
- Still, Maine does have a high industry specialization and is the third largest among New England states.

Figure C-4. Maine and New England Performance – Boatbuilding and Related Industries



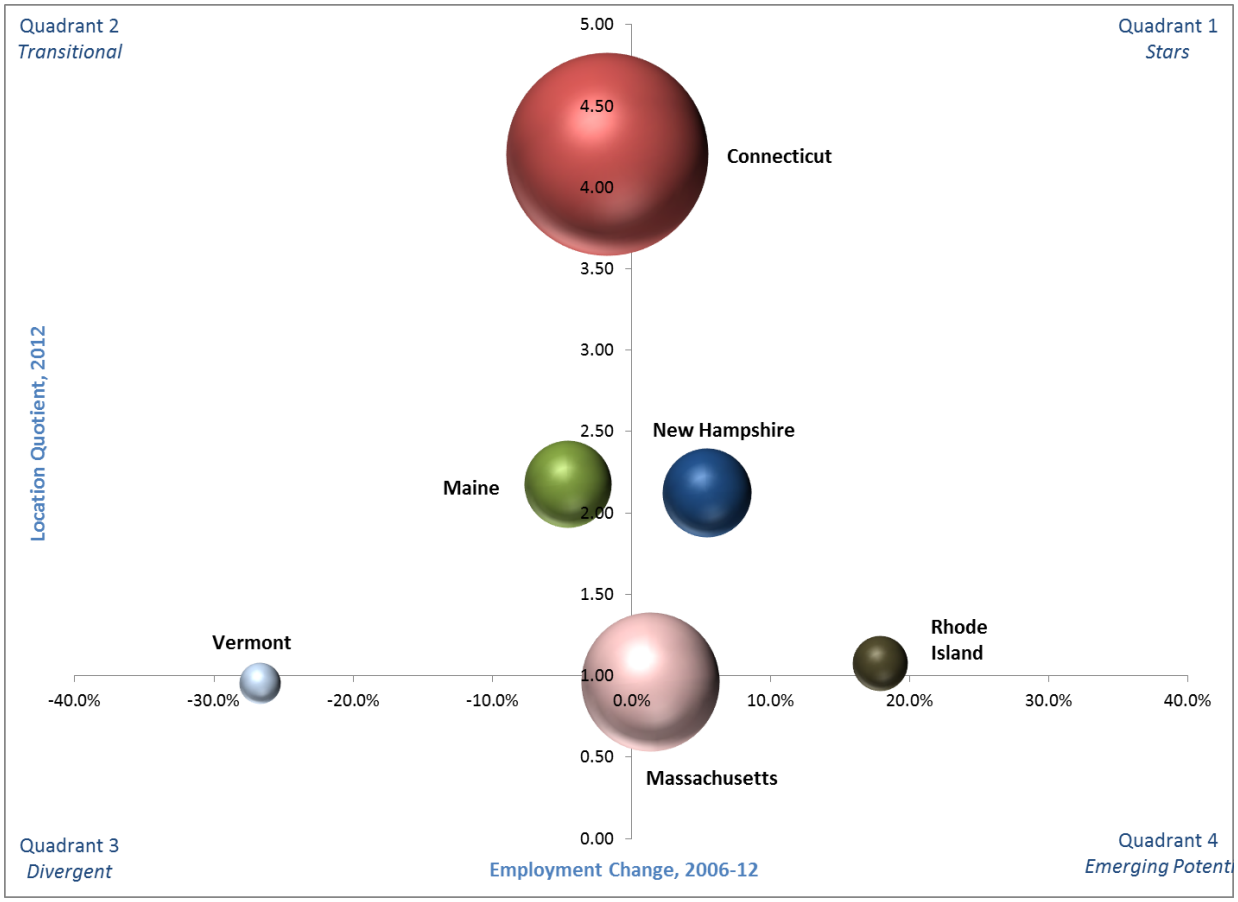
Source: IMPLAN, calculations by Battelle.

Defense Technology Cluster

Key Finding: Maine is a regional player

- Connecticut stands out as the New England leader in the Defense technology cluster, despite having flat employment in recent years.
- Only Rhode Island, New Hampshire and Massachusetts recorded job gains over the 2007-2012 period.
- Still, Maine does have an industry specialization and is home to several leading national companies in the Defense technology cluster.

Figure C-5. Maine and New England Performance – Defense



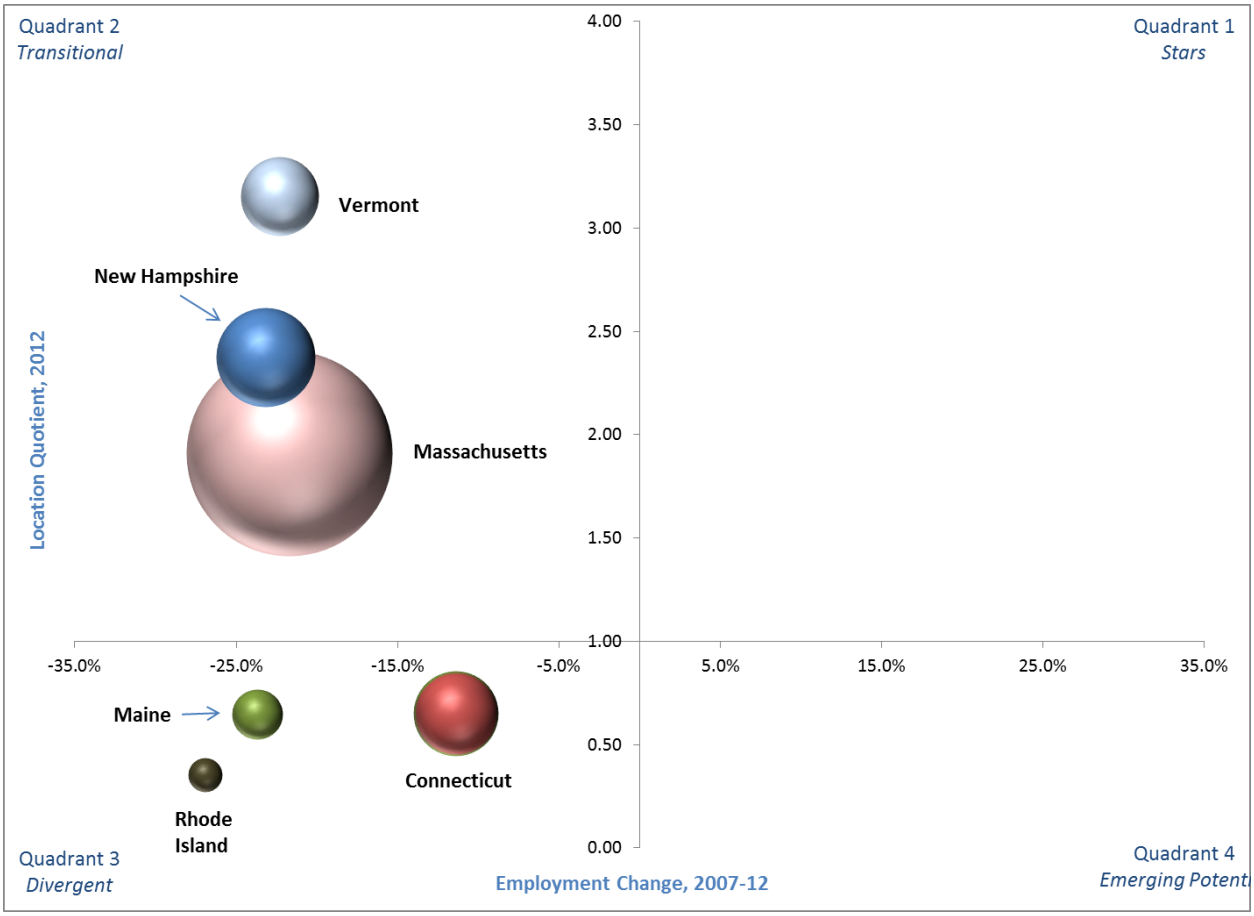
Source: IMPLAN, calculations by Battelle.

Electronics and Semiconductor Technology Cluster

Key Finding: Maine is a regional follower

- Three other states in New England have regional specializations in Electronics and Semiconductor technology cluster, but Maine does not.
- Across all states in New England, employment has been declining over the 2007 to 2012 period.

Figure C-6. Maine and New England Performance – Electronics and Semiconductors



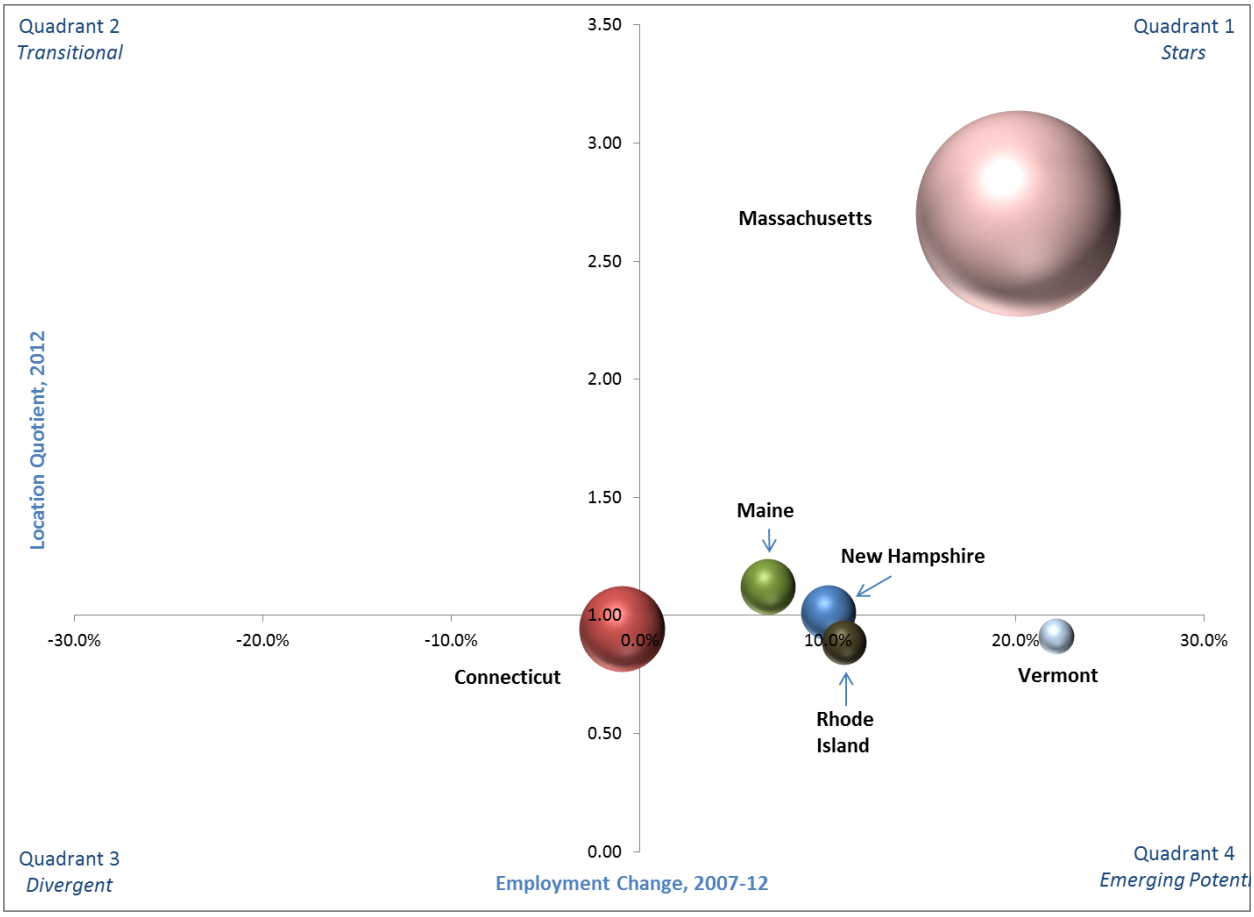
Source: IMPLAN, calculations by Battelle.

Engineering and Scientific/Technical Services

Key Finding: Maine is a regional follower

- Massachusetts is the clear regional leader in Engineering and Scientific/Technical Services, outshining all other New England states in size, industry specialization, and employment growth.
- Maine, similar to other New England states, is growing, but is just at the national average for concentration and pales in size to Massachusetts.

Figure C-7. Maine and New England Performance – Engineering and Scientific/Technical Services



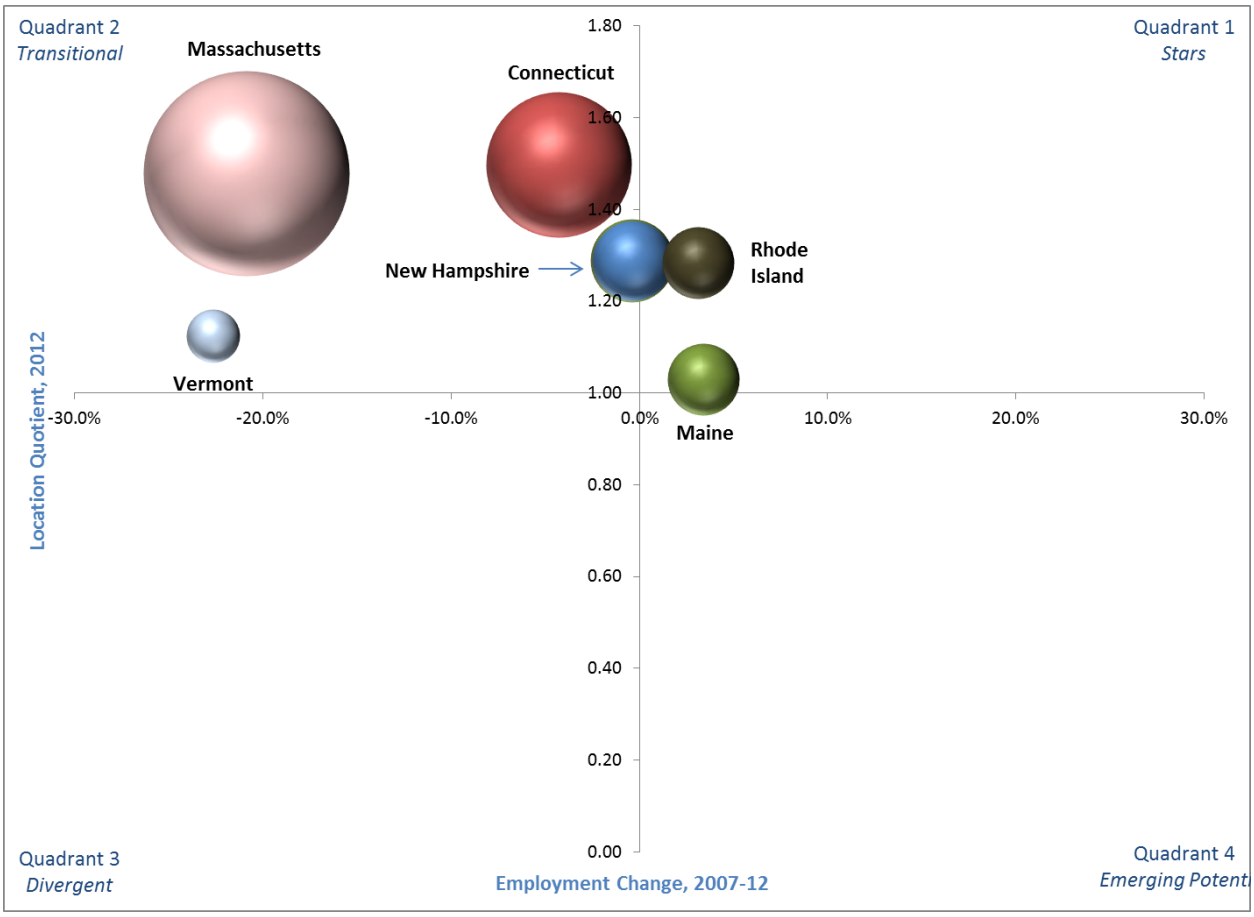
Source: IMPLAN, calculations by Battelle.

Environmental Services Technology Cluster

Key Finding: Maine is a regional follower

- Most New England states, other than Maine, are specialized in this cluster.
- Maine's Environmental Services technology cluster is the second smallest and least specialized in the New England region.
- Still, Maine was one of only two in the region to experience employment growth since 2007.

Figure C-8. Maine and New England Performance – Environmental Services



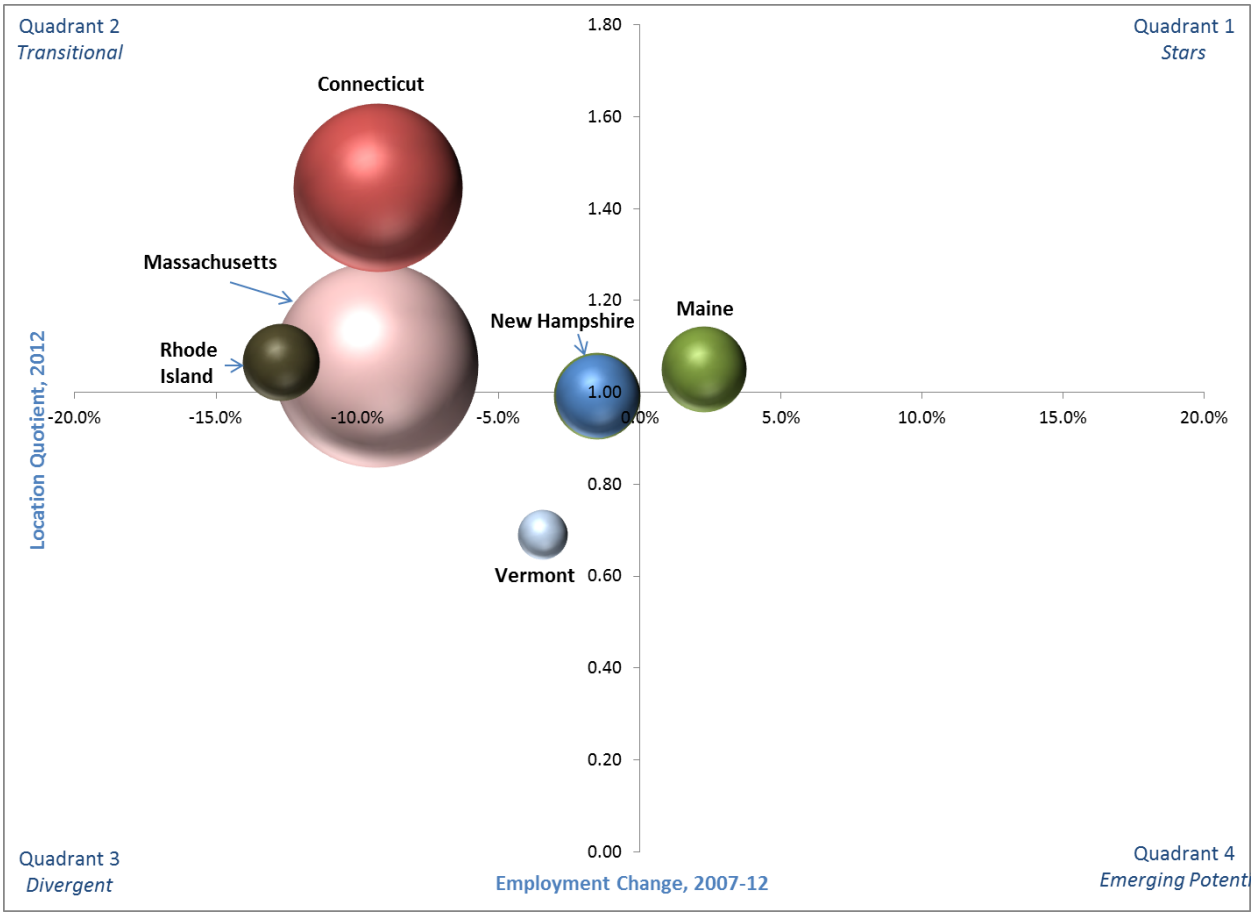
Source: IMPLAN, calculations by Battelle.

Finance and Business Support Services Technology Cluster

Key Finding: Maine is a regional player

- Maine's Finance and Business Support Services technology cluster is the only one that grew in New England, and it stands slightly above the national average in industry concentration.
- Both Connecticut and Massachusetts have higher industry specializations, but not significantly higher than Maine – and both are declining in employment since 2007.

Figure C-9. Maine and New England Performance - Finance and Business Support Services



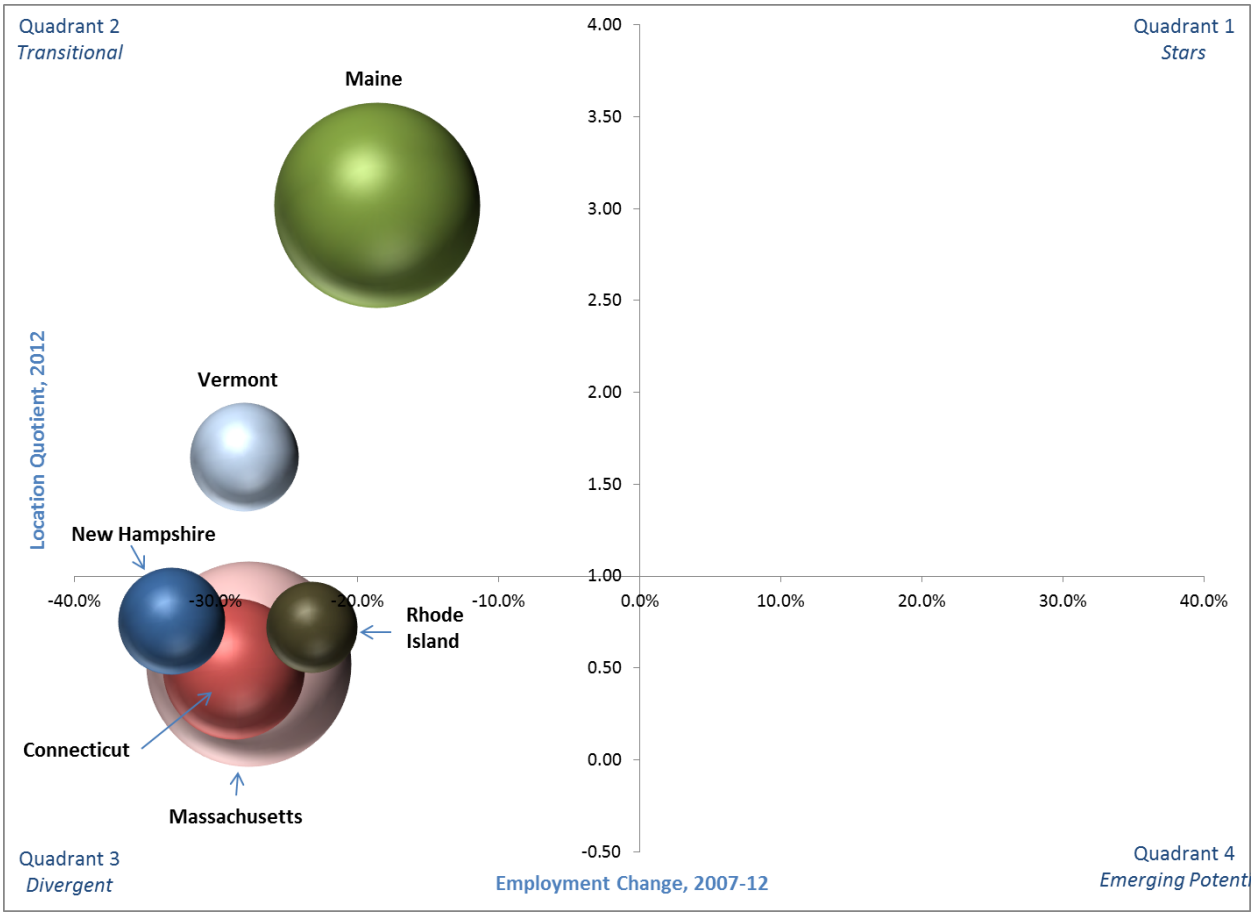
Source: IMPLAN, calculations by Battelle.

Forestry-Related Products Technology Cluster

Key Finding: Maine is a regional leader

- Maine has by far has the highest industry specialization in the Forestry-related Products technology cluster and is nearly as large in total employment as Massachusetts.
- While no state in New England gained employment since 2007, Maine's losses have been the smallest, in percentage terms, in New England.

Figure C-10. Maine and New England Performance – Forestry-Related Products



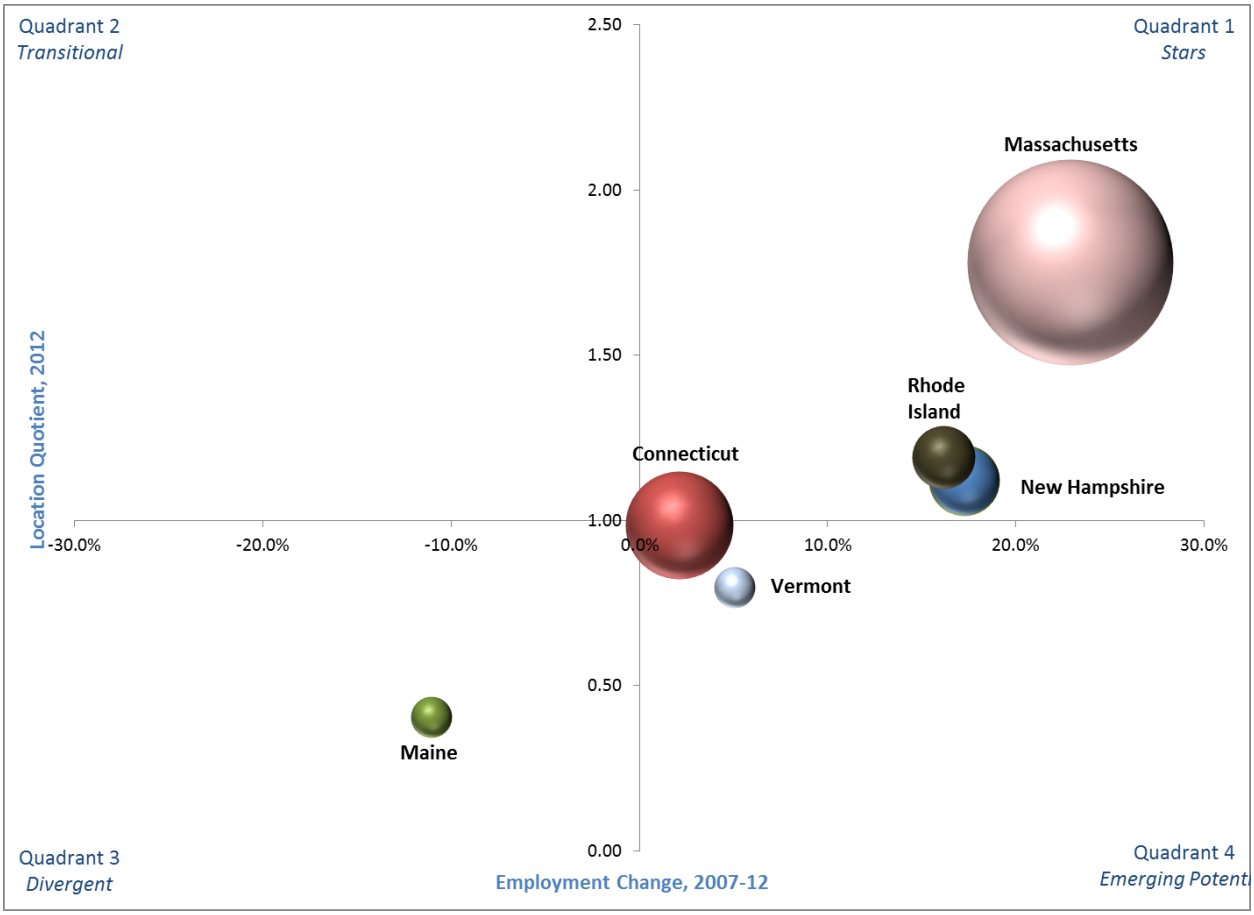
Source: IMPLAN, calculations by Battelle.

Information Technology Services Technology Cluster

Key Finding: Maine is a regional follower

- Maine's Information Technology Services technology cluster is the smallest and least specialized in the New England region, and the state was the only one in the region to experience a decline in employment since 2007.

Figure C-11. Maine and New England Performance – Information Technology Services



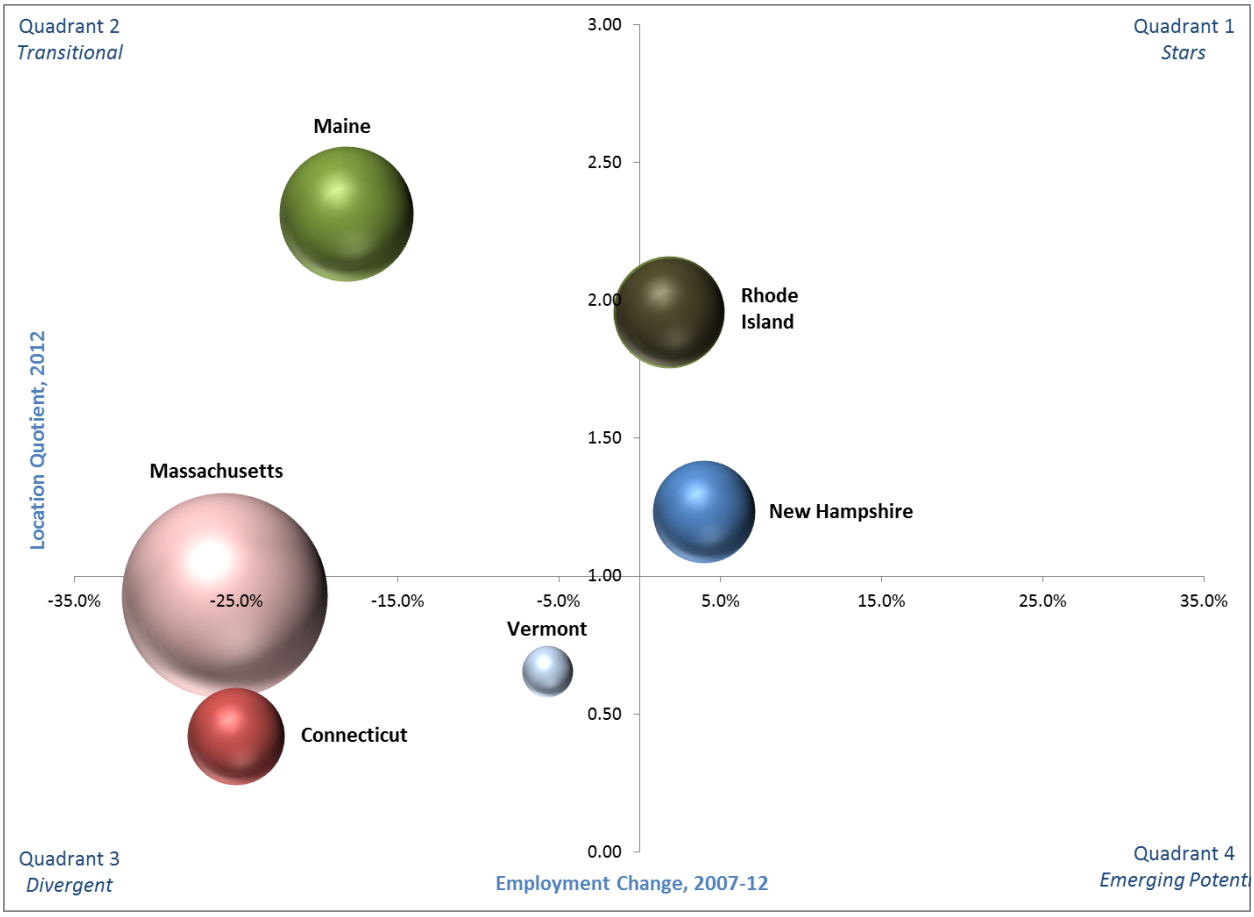
Source: IMPLAN, calculations by Battelle.

Materials for Textiles, Apparel, Leather and Footwear Technology Cluster

Key Finding: Maine is a regional leader

- Maine's Materials for Textiles, Apparel, Leather and Footwear technology cluster is the second largest and most specialized in the New England region.
- The only negative for Maine is that it has lost employment since 2007, while Rhode Island and New Hampshire have gained employment.

Figure C-12. Maine and New England Performance – Materials for Textiles, Apparel, Leather and Footwear



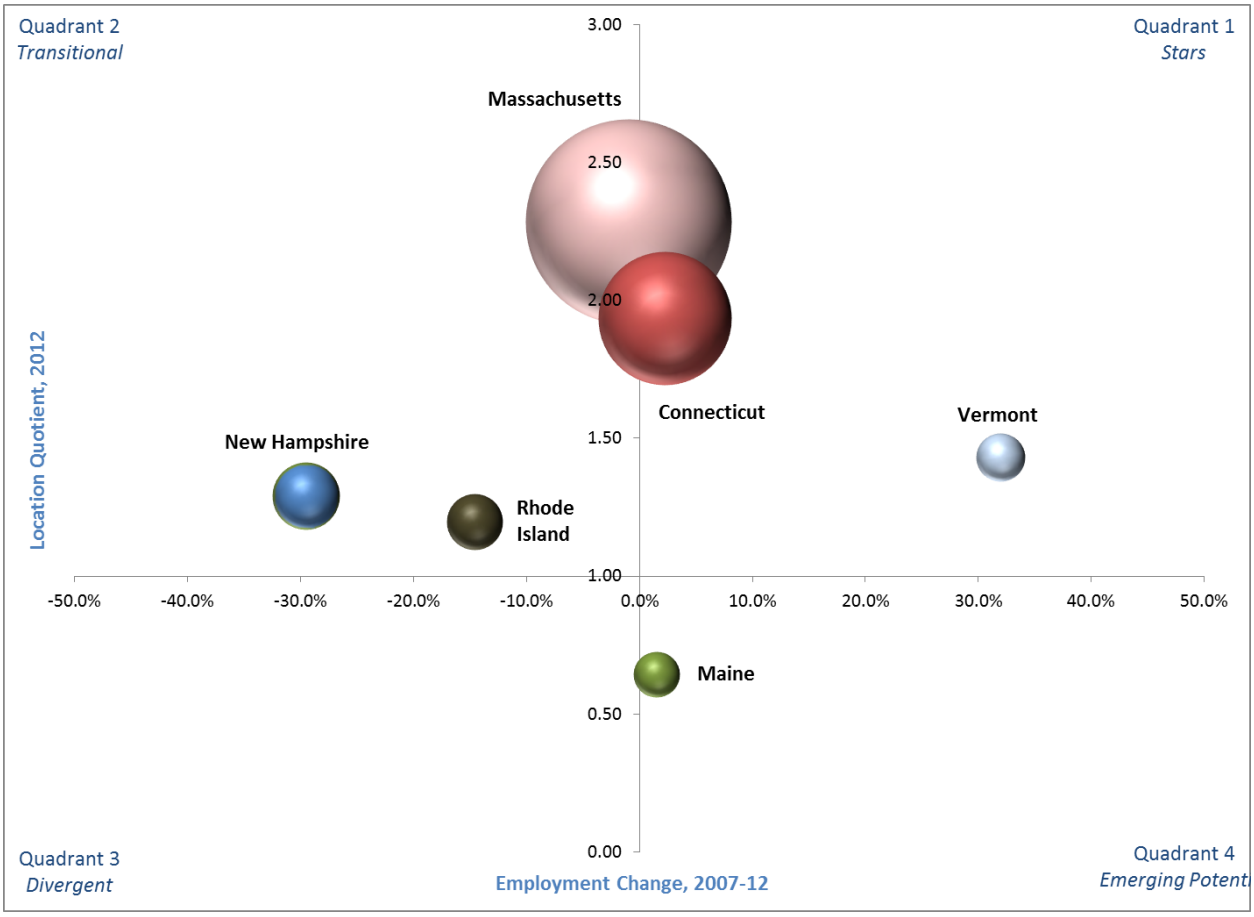
Source: IMPLAN, calculations by Battelle.

Medical Devices Technology Cluster

Key Finding: Maine is a regional follower

- Nearly all of the New England states – other than Maine – have an industry specialization in Medical Devices.
- Maine's Medical Devices technology cluster is the smallest and least specialized among this regionally important cluster.
- Still, Maine is one of only three states in the region to experience growth in this industry – but this growth has been very modest in Maine.

Figure C-13. Maine and New England Performance – Medical Devices



Source: IMPLAN, calculations by Battelle.