Massachusetts has long been a national leader in the transition to a clean energy future. With its forward-thinking policies, ambitious commitments to reduce greenhouse gas emissions, and culture of innovation, the Commonwealth has worked hard to build a vibrant clean energy economy.

2018 represented another landmark year for clean energy in Massachusetts. In May, as the result of the 2016 law passed by the Massachusetts Legislature and signed by Governor Baker, the Commonwealth selected offshore wind developer Vineyard Wind to construct an 800 Megawatt (MW) project south of Martha's Vineyard. This is the first large-scale offshore wind project in the U.S. and signals the arrival of this industry in the East Coast market. In addition to the selection of Vineyard Wind by Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Delaware, Virginia and North Carolina have all positioned themselves to build offshore wind projects of their own.

Offshore wind is expected to bring significant job creation and new economic activity to the East Coast. This past fall, Vineyard Wind signed a lease to use the New Bedford Marine Commerce Terminal as the primary deployment location for its project. This lease positions the Commonwealth to realize a significant portion of this endeavor's potential job creation and associated economic benefits. The emergence of offshore wind development will help ensure the Massachusetts clean energy industry continues its impressive growth.

Each year the Massachusetts Clean Energy Center (MassCEC) measures the development of the Commonwealth’s clean energy industry, and this year marks the eighth consecutive year of growth. Massachusetts’ clean energy industry reached more than 110,700 workers statewide, representing 3.2 percent of the state’s workforce. Clean energy employment has increased by 83.8 percent since 2010, with nearly 50,500 new clean energy workers over that period. Clean energy employment continues to grow: the industry added 1,500 jobs, a 1.4 percent increase, since 2017.

The clean energy industry saw strong growth in Gross State Product, increasing its value by more than 15 percent between 2017 and 2018. The $13.2 billion industry represents a 2.5 percent share of the state’s GDP.

We are also seeing the evolution of some industry sectors. Massachusetts has built a strong solar industry, with over 88,000 projects and 2,300 MW installed. Mirroring a nationwide trend, the solar industry in Massachusetts is moving away from the residential market, focusing instead on larger commercial customers. Meanwhile, the energy efficiency, demand management, and clean heating and cooling sectors employ more than 79,300 workers across the Commonwealth, and the alternative transportation sector increased employment by nearly 25 percent over the past year.

The outlook for clean energy in the Commonwealth is bright. As the Baker-Polito Administration has adopted forward-thinking energy policies, an active marketplace has emerged, fueling Massachusetts’ transition to a clean, affordable, and resilient energy portfolio. Massachusetts remains the national leader in energy efficiency, as the Commonwealth was named the most energy efficient state in the nation for the eighth straight year.

Over the last year, MassCEC continued its focus on driving the adoption of renewable energy technologies, including solar and air source heat pumps; supporting startup companies and the Commonwealth’s innovation sector through strategic partnerships with incubators like Greentown Labs; and building a supply chain to service the emerging offshore wind industry. In April, MassCEC released the Offshore Wind Workforce Assessment, which estimated 1,600 MW of offshore wind could lead to the creation of 10,000 job years and up to $2.1 billion in economic impact to Massachusetts. We saw the first projects from the state’s $20 million Advancing Commonwealth Energy Storage program move forward, and we expanded our effort to increase access to clean energy for Massachusetts’ low-to moderate income population, dedicating $16.9 million to the initiative in fiscal year 2018.

As the clean energy industry matures, certain sectors evolve, and new business models emerge, we at MassCEC are continuing our evolution as well. We have always worked closely with the clean energy industry to understand its needs and respond quickly to bridge market gaps and address barriers to growth. As we consider developments in the marketplace, it is clear our efforts must also adjust to meet the challenges of a changing landscape.

We are focused on how our resources can be utilized most effectively in the future to ensure this vital sector of the Massachusetts economy surpasses the remarkable progress of the last decade. Your partnership is critical to our efforts, and to the future of this industry, and we look forward to working with you to continue building a robust, dynamic clean energy economy for residents and businesses across the Commonwealth.

Stephen Pike
CEO, Massachusetts Clean Energy Center
Executive Summary

Since MassCEC began tracking clean energy employment in 2010, the industry has seen constant expansion and development. Clean energy firms' and their employees' are increasingly integral to the Massachusetts economy. Energy Efficiency, Demand Management, and Clean Heating and Cooling continue to make up the largest employment segment of the clean energy economy while maintaining strong growth. While growth can be seen across the clean energy value chain, the number of Engineering and Research jobs is quickly approaching the number of jobs in Sales & Distribution and Installation, which are currently the two largest segments of the value chain.

This report discusses clean energy employment data from 2017 and 2018 and builds off the work from prior years. The timing for the 2018 report differs from prior reports; the data for this report was collected six months after the data for the 2017 Massachusetts Clean Energy Industry Report. Though this change in timing makes the comparison to prior reports less straightforward, the methodology of the report is the same as prior years and still presents a thorough evaluation of the Massachusetts clean energy industry. The next full year of data will be available in 2019. This change enables Massachusetts to align more closely with the data collection efforts of other states, and to provide a more accurate benchmark for the Commonwealth relative to other states.

The following are the key findings from the 2018 Clean Energy Industry Report.

Massachusetts has over 110,700 clean energy workers, which amounts to about 3.1 percent of the state’s workforce. Based on the last data collection, over 1,500 clean energy jobs were created between 2017-2018. Since 2010, the clean energy workforce has grown by almost 84 percent, the equivalent to about 50,500 jobs. Most of the job creation occurred within the Energy Efficiency, Demand Management, and Clean Heating and Cooling sectors, although Alternative Transportation employment increased by nearly 20 percent between 2017 and 2018. Nearly all Alternative Transportation employment growth occurred within the Electric Vehicles sub-sector.

Installation continues to be the largest segment of employment, with more than 30,000 jobs.

The installation value chain grew by 418 (1.4 percent) between 2017–2018. During this same time frame, Engineering & Research was the fastest growing component of the value chain, adding more than 2,400 jobs (12.7 percent increase). Sales & Distribution, the second largest segment of the value chain, declined by about 4 percent.

Clean Energy Gross State Product increased by more than 15.3 percent between 2016-2017, to contribute over $13.8 billion to the Massachusetts economy. This economic contribution is equivalent to about 2.5 percent of the statewide economy. Manufacturing was the largest contributor in the value chain to Gross State Product, amounting to about $3.8 billion (28.6 percent of clean energy Gross State Product). Engineering and Research is the second largest contributor, accounting for more than $1.8 billion in economic activity.

The solar industry shed nearly 1,000 jobs between 2017-2018, but Massachusetts remains the state with the second most solar employees. This decrease is part of a national trend of decline in solar employment. Across the United States, solar employment decreased by 3.8 percent between 2016-2017. Further analysis revealed that while overall installed capacity had increased in preceding years, the number of smaller solar installations decreased by nearly half between 2015–2017. This means that an increasing amount of installed capacity is from larger projects. Larger projects require fewer installation hours per unit of capacity than smaller projects. Under these conditions of market demand, demand for employees declined while installed capacity still increased.

The Southeast region of the Commonwealth grew clean energy employment by nearly 6 percent. The Southeast region also has the second most clean energy employees (26,916) and accounts for nearly a quarter of all clean energy workers across the state (23.5 percent). The Southeast region had the least growth in establishments of all regions (2 percent), suggesting that much of the growth within this region was driven by existing companies hiring additional workers.

Alternative Transportation employment increased by nearly 20 percent over the last year. The number of electric vehicles sold in Massachusetts increased by more than 52 percent. A variety of metrics suggest that Alternative Transportation is an increasingly important cluster of technologies in Massachusetts.

Footnotes:
1 For the purposes of this report, a firm or establishment is a business location in Massachusetts with at least one employee, that is involved with an activity related to the clean energy industry.
2 Full-time and part-time permanent employees who support the clean energy portion of the business, including administrative staff, but excluding interns and other temporary employees.
3 The 2017 report reflected data collected during the second quarter of 2017, while most of the data collected for the 2016 report occurred six months later, in the fourth quarter of 2016. Unlike historical versions of this report that have provided data for the prior twelve-month period, the 2018 report provides data for the six-month period ending December 31, 2017, which does not represent a full twelve months of data.
4 2015 Massachusetts Clean Energy Industry Report
6 For the purposes of this report, technology refers to the primary application or end-use of an establishment’s produced goods or services.
The Southeast region had the greatest growth in clean energy employment with a nearly 6% increase.

Massachusetts added over 1,500 clean energy jobs.

As of 2018, there are over 110,700 clean energy workers in Massachusetts, over 3% of the workforce.

Clean energy employment has grown by almost 84% since 2010.

Small businesses (1-10 employees) employ 62% of the clean energy workers.

Massachusetts has the 2nd highest percentage of clean energy workers in the United States.

The Energy Efficiency, Demand Management, and Clean Heat and Cooling sector employs the largest number of people with over 79,300 employees.

The Northeast region employs 48% of the clean energy workforce.

Wind jobs grew by over 11% between 2017-2018.

Clean energy gross state product increased by more than 15% between 2016-2017, to almost $13.2 billion.

Installation is the largest source of employment with 30,057 jobs, followed by sales & distribution with 27,471 jobs.

The Southeast region had the greatest growth in clean energy employment with a nearly 6% increase.

Massachusetts has the 2nd highest percentage of clean energy workers in the United States.
ENERGY EFFICIENCY, DEMAND MANAGEMENT, AND CLEAN HEATING AND COOLING

Massachusetts continues to be a leader in energy efficiency in 2018, ranked as the most energy efficient state for the eighth year in a row. In 2017, the Mass Save electricity program, which is funded through a surcharge on customers of investor-owned utilities, spent more than $1.1 billion and generated more than $4.1 billion in total lifetime benefits across the state. The amount of kilowatt hours (kWh) of electricity saved through this program has increased 140 percent since 2010 (Figure 1). The Mass Save gas program, which seeks to decrease the demand for gas through the use of more efficient equipment, has also seen significant returns. The program spent more than $426 million in 2017 and generated over $1 billion in lifetime benefits. Between 2010 and 2017 the program’s gas savings have increased by 145.6 percent (Figure 2). This has resulted in fewer greenhouse gas emissions and more money in the pockets of Massachusetts residents.

ALTERNATIVE TRANSPORTATION

Massachusetts ranked 7th in terms of Electric Vehicle (EV) sales by state in 2017, selling 4,632 electric vehicles. The number of EVs sold in Massachusetts increased by 59.4 percent between 2016 and 2017. Massachusetts also ranked 9th in terms of electric vehicle market share within states. Plug-in Hybrid Electric Vehicles (PHEV) increased by 52.6 percent while Battery Electric Vehicles (BEV) sales increased by more than 70.5 percent between 2016 and 2017 (Figure 4).

RENEWABLE ELECTRIC POWER GENERATION

The installed capacity under the Class II Solar Carve-out program has ramped up significantly since its inception in late 2013. In 2016, Class I and II Solar Carve-outs accounted for 93 percent of all Renewable Portfolio Standard (RPS)-qualified installed capacity. By 2017 that percentage increased to 99.6 percent. Between the years 2010 and 2017, renewable electric power generation was comprised of 24.7 percent from commercial, 26.6 percent from residential, and 2.9 percent from utility-scale installations (Figure 3).
GROSS STATE PRODUCT

Clean energy firms contributed over $13.18 billion to Gross State Product (GSP) in 2017, which amounts to about 2.5 percent of GSP.\(^\text{17}\) Clean energy GSP increased by more than 15 percent between 2016 and 2017. The Other category within the clean energy value chain, which includes utilities, nonprofits, and select government organizations, experienced the greatest growth, increasing by 50 percent between 2016 and 2017. The remaining segments within the value chain increased anywhere from 12 to 15 percent during this period. The largest component of the value chain is Manufacturing with $3.8 billion (28.6 percent), followed by Engineering and Research with $1.8 billion (13.8 percent) and Sales and Distribution with $1.6 billion (12.5 percent) in economic activity within Massachusetts (Table 1).

As of 2018, Massachusetts is home to just over 110,700 clean energy workers. The state’s clean energy sector is growing at roughly the same rate as the overall economy. Between 2017 and 2018, clean energy jobs grew by 1.4 percent while overall employment grew by 1.6 percent.\(^\text{18}\) Clean energy employment has increased by 83.8 percent since MassCEC began tracking clean energy jobs in 2010; this translates to almost 50,500 new clean energy workers over nine years. The Massachusetts workforce has the second highest percentage of clean energy workers in the United States, with clean energy jobs accounting for about 3.1 percent of Massachusetts employment in 2018 (Figure 5). Massachusetts continues to be a national leader in clean energy, accounting for 3.8 percent of clean energy jobs in the United States, despite accounting for just 2.5 percent of overall jobs nationally.

TABLE 1
CLEAN ENERGY GROSS STATE PRODUCT BY VALUE CHAIN, 2017\(^\text{15}\)

<table>
<thead>
<tr>
<th>GSP</th>
<th>PERCENT OF TOTAL CLEAN ENERGY GSP(^\text{17})</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manufacturing</td>
<td>$3.8 billion</td>
</tr>
<tr>
<td>Engineering &amp; Research</td>
<td>$1.8 billion</td>
</tr>
<tr>
<td>Sales &amp; Distribution</td>
<td>$1.7 billion</td>
</tr>
<tr>
<td>Installation &amp; Maintenance</td>
<td>$2.2 billion</td>
</tr>
<tr>
<td>Professional Services</td>
<td>$1.1 billion</td>
</tr>
<tr>
<td>Other(^\text{15})</td>
<td>$1.9 billion</td>
</tr>
<tr>
<td>Sole Proprietors</td>
<td>$0.7 billion</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>$13.2 billion</strong></td>
</tr>
</tbody>
</table>

\(^{15}\) The clean energy portion of Gross State Product calculated for this report was derived from survey incidence rates and proportional revenue reporting, together with existing data from the Bureau of Economic Analysis, calculated by NAICS code. Utility data and state government spending were included as direct inputs (rather than using a proportional analysis).

\(^{16}\) Extrapolated using data from the Bureau of Economic Analysis; 2017 is the latest available data. See methodology for more details.

\(^{17}\) The other categories include business organizations, utilities, nonprofits, and select government organizations that are all directly involved in clean energy.

\(^{18}\) Does not equal 100% due to rounding.

40,274 64,310 71,523 79,994 88,990 100,214 119,226 119,767


FIGURE 5
TOTAL CLEAN ENERGY EMPLOYMENT, 2010–2018\(^\text{18}\)
Energy Efficiency, Demand Management, and Clean Heating and Cooling remains the largest clean energy technology segment, with just over 79,000 total workers in 2018. This sector grew by about two percent between 2017 and 2018. Alternative transportation saw the greatest proportional growth at 18.9 percent, or an additional 334 workers. For the first time since 2015, Renewable Energy employment declined by about one percent (Figure 6). Declines in the Massachusetts Renewable Energy sector are attributable to job losses in the solar industry, which mirrors losses that were experienced across the nation. In Massachusetts, the solar workforce declined by almost 1,000 workers, or 5.4 percent. Despite this decline, Massachusetts remains the state with the second most solar employees, trailing only California. Further analysis of the data shows that the installation of smaller (15 kW or less) projects has declined by 46 percent between 2015 and 2017, while the number of installations for larger commercial (16–499 kW) and utility (500+ kW) projects have increased by 5 percent and 222.5 percent respectively during this same period. Larger projects require fewer workers per kWh of capacity installed. When solar is excluded from the analysis, the Renewable Energy generation sector grew by about 6.7 percent. Within the Renewable Energy technology category, Wind jobs grew by more than 11 percent between 2017 and 2018, and all other renewable energy generation sub-technologies grew by roughly 5.8 percent (Figure 7).

Both the Electric Vehicle sub-technology and the Other sub-technology (which includes biodiesel for on-road vehicles) of Alternative Transportation grew by a respective 19.4 and 10.1 percent between 2017–2018. With regards to Energy Efficiency technologies, the Smart Grid sub-technology (22.9 percent) and the Other Grid sub-technology (16.2 percent) saw the greatest proportional job growth between 2017 and 2018. The sub-technology Microgrids, Advanced Materials and Recycled Building Materials, and Other Biofuels shed jobs over the same time.
The number of clean energy firms has increased across all clean energy technologies, with the exception of those that are listed in the “Other” category. Alternative Transportation firms increased in number by the greatest percentage (32 percent) between 2017 to 2018, followed by Energy Efficiency, Demand Management, and Clean Heating and Cooling (4 percent), and Renewable Energy (3 percent) (Figure 9).

Firms with 1 to 10 employees employ 62 percent of all clean energy workers. Large establishments (50 or more permanent employees) that work within clean energy employ nearly 13 percent of the clean energy workforce. Mid-size firms, or those that employ 11 to 49 employees, employ almost a quarter of all clean energy workers (Figure 10).

### Figure 8: Clean Energy Employment by Value Chain, 2017–2018

<table>
<thead>
<tr>
<th>Value Chain</th>
<th>2017</th>
<th>2018</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manufacturing</td>
<td>17,079</td>
<td>16,635</td>
</tr>
<tr>
<td>Engineering &amp; Research</td>
<td>29,639</td>
<td>21,467</td>
</tr>
<tr>
<td>Sales &amp; Distribution</td>
<td>28,749</td>
<td>27,471</td>
</tr>
<tr>
<td>Installation</td>
<td>29,639</td>
<td>9,246</td>
</tr>
<tr>
<td>Consulting, Finance, etc.</td>
<td>8,830</td>
<td>5,891</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>97,127</td>
<td>78,924</td>
</tr>
</tbody>
</table>

### Figure 9: Number of Establishments by Clean Technology, 2015–2018

<table>
<thead>
<tr>
<th>Technology</th>
<th>2015</th>
<th>2016</th>
<th>2017</th>
<th>2018</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy Efficiency, Demand Mgmt, and Clean Heating and Cooling</td>
<td>6282</td>
<td>7289</td>
<td>8299</td>
<td>9368</td>
</tr>
<tr>
<td>Renewable Energy</td>
<td>3057</td>
<td>2788</td>
<td>2524</td>
<td>2565</td>
</tr>
<tr>
<td>Alternative Transportation</td>
<td>990</td>
<td>1104</td>
<td>1241</td>
<td>1300</td>
</tr>
<tr>
<td>Other</td>
<td>3424</td>
<td>3788</td>
<td>3925</td>
<td>4222</td>
</tr>
</tbody>
</table>

### Figure 10: Percentage of Clean Energy Firms within the Employee Ranges, 2015–2018

<table>
<thead>
<tr>
<th>Employee Range</th>
<th>2015</th>
<th>2016</th>
<th>2017</th>
<th>2018</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 to 10 Permanent Employees</td>
<td>45.8%</td>
<td>48.9%</td>
<td>50.4%</td>
<td>52.8%</td>
</tr>
<tr>
<td>11 to 49 Permanent Employees</td>
<td>40.6%</td>
<td>42.1%</td>
<td>42.1%</td>
<td>41.8%</td>
</tr>
<tr>
<td>50 Permanent Employees or More</td>
<td>12.3%</td>
<td>12.2%</td>
<td>12.2%</td>
<td>11.1%</td>
</tr>
<tr>
<td>No Permanent Employees</td>
<td>1.3%</td>
<td>0.7%</td>
<td>0.1%</td>
<td>0.1%</td>
</tr>
</tbody>
</table>

*Any sort of finance, legal, architecture, or other mathematical or scientific services that support clean energy technology development and deployment.*

*“Other” consists of all firms that could not be classified. The number of “Other” establishments may have declined due to improved classification methodology and better understanding of technology definitions by respondents.*
CLEAN ENERGY TALENT

EMPLOYMENT DEMOGRAPHICS
As of 2018, the clean energy economy workforce is comprised of 70 percent male workers. Additionally, 72.2 percent of the workforce is white, 17.5 percent are Hispanic or Latinx individuals, 9 percent are Two or More Races, 8.7 percent of the workforce is Asian, and 7.7 percent is Black or African (Table 2). Over one in ten workers (11.5 percent) are Veterans and 13.6 percent of the workforce is made up of employees 55 years of age or older.

<p>| TABLE 2 | DEMOGRAPHICS OF MASSACHUSETTS CLEAN ENERGY WORKERS, 2018 |</p>
<table>
<thead>
<tr>
<th>PERCENT OF WORKFORCE</th>
<th>EMPLOYMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hispanic or Latinx</td>
<td>17.5%</td>
</tr>
<tr>
<td>Black</td>
<td>7.7%</td>
</tr>
<tr>
<td>Asian</td>
<td>8.7%</td>
</tr>
<tr>
<td>Two or More Races</td>
<td>9.0%</td>
</tr>
<tr>
<td>Women</td>
<td>30.1%</td>
</tr>
<tr>
<td>Veterans</td>
<td>11.5%</td>
</tr>
<tr>
<td>Workers Over the Age of 55</td>
<td>13.6%</td>
</tr>
</tbody>
</table>

*Respondents were able to choose any combination of race and ethnicity. Consequently, percentages do not sum to 100%.

CLEAN ENERGY HIRING
Of new clean energy employee hires, 45 percent were hired to replace workers that had retired or left their firm, 35.4 percent of hires were for newly created positions, and 19.6 percent of new employees were a result of existing employees receiving added clean energy-related responsibilities (Table 3). Nearly three-quarters of clean energy jobs required previous work experience related to the position (73.5 percent), and 39.4 percent of positions required a vocational certificate, technical certificate, or other credential. Just under 33 percent of positions required a bachelor’s degree or beyond, and 23.2 percent of positions required at least an associate degree or academic certificate (Table 4).

<table>
<thead>
<tr>
<th>TABLE 3</th>
<th>REASONS FOR NEW CLEAN ENERGY EMPLOYEES, 2018</th>
</tr>
</thead>
<tbody>
<tr>
<td>Newly created positions</td>
<td>35.4%</td>
</tr>
<tr>
<td>Existing employees that added energy responsibilities</td>
<td>19.6%</td>
</tr>
<tr>
<td>Hired to replace workers due to turnover or retirement</td>
<td>45.0%</td>
</tr>
</tbody>
</table>

| TABLE 4 | EDUCATIONAL REQUIREMENTS FOR CLEAN ENERGY, 2018 |
| Positions that required previous work experience related to the position | 73.5% |
| Required a vocational or technical post secondary certificate or other credentials | 39.4% |
| Required a bachelor’s degree or beyond | 32.9% |
| Required an associate degree or academic certificate from an accredited college, but not a bachelor’s degree | 23.2% |

Of firms that hired employees in 2018, 37.1 percent of respondents stated hiring new employees was very difficult, 34.3 percent stated it was somewhat difficult, and 25.7 percent responded that hiring was not difficult at all. This displays a polarization in 2018, where an increasing percentage of employers found it very difficult or not at all difficult to find new hires (Figure 11).
CLEAN ENERGY INVESTMENTS

The following data are drawn from a combination of public and proprietary datasets that together account for public grant spending, such as Advanced Research Projects Agency-Energy (ARPA-E), The Sunshot Initiative, Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR), and MassCEC grant funding. In addition, it includes public benefit programs, which include utility- and MassCEC-sponsored innovation and investment funding programs designed to increase consumption of clean energy goods and services, and private investments made by venture capitalists and entrepreneurs in clean energy technologies.

A 2018 report from the U.S. Energy Information Administration highlights a decline in federal funding for clean energy projects since 2010. Subsidies and support (including research and development funding) for Renewables declined by 58 percent from $15.7 billion in 2016 to $6.6 billion in 2017. Federal Renewable Energy research and development expenditures declined by 70 percent from $610 million in 2010 to $184 million in 2016. Additionally, conservation (which encompasses energy efficiency and demand management) saw significant declines between 2010 and 2016, with funding reduced from $7.4 billion to $183 million. These steep declines in federal clean energy funding likely played a role in producing the similar trends of clean energy funding decline in Massachusetts.

The Massachusetts Clean Energy Industry Report categorizes investments in the clean energy economy to help identify the innovation-specific drivers, challenges, and opportunities for Massachusetts clean energy firms. In this section, two systems of categorization are used:

1. The technology underpinning the project for which the funding is provided
2. The phase of development of the project for which the funding is provided

These phases of funding cover research and prototyping, demonstration and acceleration, and commercialization and growth. These are roughly based on NASA’s Technology Readiness Levels (TRLs).10

PHASE I: RESEARCH AND PROTOTYPING

This stage is typically carried out in universities and public laboratories and includes everything from basic research and ideation up to bench-testing of prototypes. Funding for these activities is almost always from public sources, though occasionally it includes angel or seed funding as well as private university funding. Other non-funding metrics useful for estimating this phase of activity include academic publications and patent activity. This stage encompasses TRL 1 through 4.

Phase I funding has declined steadily between the first and last three-year rolling averages.11 The 60 percent decline in Energy Efficiency, Demand Management, and Renewable Heating and Cooling during this time frame was primarily responsible for the overall decline in Phase I funding. A contributing factor to this was the decline of federal research and development funding for energy conservation technologies, which falls within the Energy Efficiency, Demand Management, and Renewable Heating and Cooling category. Between 2010 and 2016, federal energy conservation research and development funding declined by more than $250 million (16 percent). Federal research and development funding for smart grid and transmission technologies, also in this category, saw a 91 percent decline from $566 million to $49 million.12

The number of deals13 or individual investments between 2011–2017 increased, suggesting that while investments have grown in number, the average investment size has declined. This is a trend visible across all phases. Many factors may have played a role in this phenomenon, though the decline in clean energy federal funding likely played a role as less funding meant reducing the number of awards, the award amount, or a combination of both. The data suggests that cuts were made to award amounts, as the average award value in 2011 was $7.7 million and had fallen to $2.2 million by 2017.

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11 https://www.nasa.gov/directorates/heo/scan/engineering/technology/txt_accordion1.html
13 For purposes of this report, a deal can be an award, grant or investment from a public or private organization to a private investment.
14 Sources include ARPA-E, The Sunshot Initiative, SBIR and STTR, MassCEC grant funding, MassCEC-sponsored funding programs, and Crunchbase.
The number of relevant patents and publications across time are a helpful proxy for identifying innovation in an area of study. Clean energy publications have increased by 252 percent since 2010. Energy Efficiency, Demand Management, and Clean Heating and Cooling make up nearly two-thirds of the clean energy publications authored within Massachusetts. Alternative Transportation accounts for 21 percent of all clean energy literature, and Renewable Energy accounts for 13 percent.25

Clean energy patents have increased by more than 89 percent since 2010. In 2017, over 240 clean energy patents were granted to inventors within the Commonwealth. Energy Efficiency, Demand Management, and Clean Heating and Cooling accounted for more than 60 percent of the patents, followed by Alternative Transportation (28 percent), and Renewable Energy (11 percent).26 Given the positive trends in clean energy patents and publications and the general declines in investment, it is possible that firms and researchers are continuing to innovate with existing resources in hopes of renewed funding in the future. The lag in patent-approval timelines may also play a role in this phenomenon; a patent often waits years after being submitted to become approved. Thus, while funding has recently declined, a decline in subsequent patent approvals would likely not appear for another few years.

PHASE II: DEMONSTRATION AND ACCELERATION

Innovation in this stage often involves startup firms’ refinement of their technology and expansion of commercial readiness. Activity in this phase draws in part on private capital, typically in the form of seed funding, and often also on grant programs aiming for economic development. This stage encompasses TRL 5 through 7.

Total Phase II funding has generally remained relatively stable since 2011. While Renewable Energy and Energy Efficiency, Demand Management, and Renewable Heating and Cooling funding has undergone some fluctuation, Alternative Transportation funding increased by 152 percent between the first and last three-year rolling averages (Figure 13).

PHASE III: COMMERCIALIZATION AND GROWTH

In this final stage of innovation, companies bring fully-developed products to wide commercial availability. This stage encompasses TRL 8 through 9.

Phase III funding declined steeply across the earlier three-year rolling averages but remained relatively steady starting in 2013. From a decline in Renewable Energy projects in Massachusetts, such as wind farms, that were planned and funded in recent years, and are no longer moving forward. The resulting decline in funding was precipitous because such projects typically require hundreds of millions of dollars in funding. As was the case in Phases I and II, the amount of funding in Phase III decreased across time but the number of deals has risen slightly, suggesting that a greater number of funding deals are being made, but are generally for smaller amounts (Figure 14).

<table>
<thead>
<tr>
<th>Year</th>
<th>Renewable Energy</th>
<th>Energy Efficiency, Demand Management, and Renewable Heating and Cooling</th>
<th>Alternative Transportation</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>2011-2013</td>
<td>$150,000,000</td>
<td>$200,000,000</td>
<td>$50,000,000</td>
<td>$400,000,000</td>
</tr>
<tr>
<td>2012-2014</td>
<td>$160,000,000</td>
<td>$210,000,000</td>
<td>$60,000,000</td>
<td>$430,000,000</td>
</tr>
<tr>
<td>2013-2015</td>
<td>$170,000,000</td>
<td>$220,000,000</td>
<td>$70,000,000</td>
<td>$460,000,000</td>
</tr>
<tr>
<td>2014-2016</td>
<td>$180,000,000</td>
<td>$230,000,000</td>
<td>$80,000,000</td>
<td>$490,000,000</td>
</tr>
<tr>
<td>2015-2017</td>
<td>$190,000,000</td>
<td>$240,000,000</td>
<td>$90,000,000</td>
<td>$520,000,000</td>
</tr>
</tbody>
</table>

PHASE III FUNDING BY TECHNOLOGY (THREE-YEAR ROLLING AVERAGES)29

**FIGURE 13**

PUBLIC FUNDING BY TECHNOLOGY (THREE-YEAR ROLLING AVERAGES)28

**FIGURE 14**

PHASE III FUNDING BY TECHNOLOGY (THREE-YEAR ROLLING AVERAGES)29

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27 Sources include ARPA-E, The SunShot Initiative, SBIR and STTR, MassCEC grant funding, MassCEC-sponsored funding programs, and Crunchbase.
The Northeast region continues to have the most clean energy establishments (45 percent) and employ nearly half (48.1 percent) of the Massachusetts clean energy workforce. The Southeast region has the next largest proportion of clean energy workers (23.5 percent), followed by the Central and Western regions, which account for 16.5 percent and 11.9 percent of the clean energy workforce respectively. The Southeast region saw the greatest growth between 2017 and 2018, growing more than 5.9 percent. The number of clean energy establishments grew by 5.4 and 5.2 percent in the Central and Northeast regions respectively. In each of the regions in the state, clean energy firms and total employees increased in the past year by at least 1.1 percent (Table 5).

### REGIONAL ANALYSIS

**NORTHEAST REGION**
- **Establishments**: 3,249 (2018)

**SOUTHEAST REGION**
- **Employment**: 25,916 (2018)
- **Establishments**: 1,748 (2018)

**CENTRAL REGION**
- **Employment**: 18,246 (2018)
- **Establishments**: 1,140 (2018)

**WESTERN REGION**
- **Employment**: 13,266 (2018)
- **Establishments**: 1,071 (2018)

### TABLE 5
CLEAN ENERGY JOB GROWTH BY REGION, 2016–2018

<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td><strong>NORTHEAST REGION</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Employment</td>
<td>50,712</td>
<td>52,520</td>
<td>53,339</td>
<td>48.1%</td>
<td>1.6%</td>
</tr>
<tr>
<td>Establishments</td>
<td>3,012</td>
<td>3,089</td>
<td>3,249</td>
<td>45.0%</td>
<td>5.2%</td>
</tr>
<tr>
<td><strong>SOUTHEAST REGION</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Employment</td>
<td>24,266</td>
<td>25,706</td>
<td>25,916</td>
<td>23.5%</td>
<td>5.9%</td>
</tr>
<tr>
<td>Establishments</td>
<td>1,636</td>
<td>1,668</td>
<td>1,748</td>
<td>24.3%</td>
<td>2.0%</td>
</tr>
<tr>
<td><strong>CENTRAL REGION</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Employment</td>
<td>17,900</td>
<td>18,041</td>
<td>18,246</td>
<td>16.5%</td>
<td>1.1%</td>
</tr>
<tr>
<td>Establishments</td>
<td>1,051</td>
<td>1,081</td>
<td>1,140</td>
<td>15.8%</td>
<td>5.4%</td>
</tr>
<tr>
<td><strong>WESTERN REGION</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Employment</td>
<td>12,335</td>
<td>12,958</td>
<td>13,266</td>
<td>11.9%</td>
<td>2.4%</td>
</tr>
<tr>
<td>Establishments</td>
<td>1,014</td>
<td>1,038</td>
<td>1,071</td>
<td>14.9%</td>
<td>3.1%</td>
</tr>
</tbody>
</table>
EMPLOYER SURVEY METHODOLOGY

Data for this year’s report is derived from the United States Energy and Employment Report (USEER). The 2018 USEER methodology used the most recently available data from the Bureau of Labor Statistics Quarterly Census or Employment and Wages (BLS QCEW 2017 Q2). The survey was designed and conducted by BW Research Partnership on behalf of the Energy Futures Initiative (EFI) and the National Association of State Energy Officials (NASEEO). The methodology employed for the survey has been used for local, state, and federal energy-related data collection and analysis for nearly a decade.

The survey uses a stratified sampling plan that is representative by industry code (NAICS), establishment size, and geography to determine the proportion of establishments that work with specific energy-related technologies, as well as the proportion of workers in such establishments that work with the same. Survey results are analyzed and applied to the existing public QCEW data series, constraining the potential universe of energy establishments and employment.

The survey was administered by telephone across the nation with approximately 600 emails sent to participants across the state. The phone survey was conducted by IHRI Research. The web instrument was programmed internally, and each respondent was required to use a unique ID in order to prevent duplication.

The sample was split into two categories, referred to as the known and unknown universes. The known universe includes establishments that have previously identified as energy-related, either in prior research or some other manner, such as membership in an industry association or participation in government programs. These establishments were surveyed census-style, and their associated establishment and employment totals were removed from the unknown universe for both sampling and for resulting employment calculations and estimates. As is performed on an annual basis, BW Research cleaned, deduplicated, added to, and refined its database to reflect churn (companies out of business, moved, no longer in energy), unverified (no answer, answering machine, fast-busy, disconnect, etc.), verified, and other available demographic tags (industry, technology, sub-technology, size, etc.).

In addition to cleaning the original known energy database, BW Research also supplemented with industry association contact lists by technology, new companies from the unknown database that took the 2017 survey, and contact lists from subcontractors. BW Research also appended contact information, including six-digit NAICS codes, contact, employment, and location information.

The unknown universe includes hundreds of thousands of businesses in potentially energy-related NAICS codes, across agriculture, mining, utilities, construction, manufacturing, wholesale trade, professional services, and repair and maintenance. Each of these segments and their total reported establishments (within the Bureau of Labor Statistics QCEW) were carefully analyzed by size (employment – provided by the Census Bureau’s County Business Patterns) and state to develop representative clusters for sampling.

In total, 606 business establishments in Massachusetts participated in the survey effort, with 462 providing full responses to the survey. These responses were used to develop incidence rates among industries as well as to apportion employment across various industry categories in ways currently not provided by state and federal labor force information agencies. The margin of error is +/- 4.53 percent for Massachusetts at a 95 percent confidence interval.

Commodity flow data was collected and analyzed for the USEER 2018 report, however, since the industries covered do not transport products that are related to clean energy, they were left out of the analyses for the Massachusetts Clean Energy Report.20 For several industries, particularly transportation of goods, the USEER uses the methodology developed by the DOE and the National Renewable Energy Laboratory for the first installment of the Quadrennial Energy Review. Proportion of employment was calculated by dividing commodity shipments by value (in millions of dollars) for coal, fuel oil, gas, motor vehicles, petroleum, and other coal and petroleum products out of total commodity value at the state level by truck, rail, air, and water transport. This proportion was applied to NAICS employment for truck transportation (NAICS 486), water transportation (NAICS 483), air transportation (NAICS 481), and Railroad Retirement Board employment for rail transportation at the state level. With this analysis, truck transportation represents the majority of energy-related transportation employment (63 percent), followed by rail (27 percent), water (9 percent), and air (1 percent).

All data in the USEER rely on the BLS QCEW data for the end of the second quarter of 2017. The USEER survey was administered between November 1, 2017 and January 19, 2018 and averaged 14.5 minutes in length.

GROSS STATE PRODUCT DATA

Gross State Product (GSP) is presented for both the overall clean energy economy and each of the four major technologies; the data supports the economic index portion of each of the BW indices. The input-output data for GSP is derived from data from the U.S. Bureau of Economic Analysis, by NAICS code. GSP is an important measure of economic activity, measuring the value and flow of goods and services produced in the economy.

Each NAICS industry’s Gross State Product is multiplied by the ratio of clean energy establishments to all establishments within the NAICS segment. This produces the Gross State Product contribution of establishments engaged in clean energy activities. To generate the clean energy proportion, this figure is further reduced by multiplying it by the mean reported revenues attributed to clean energy goods and services from the survey.

INVESTMENT CAPITAL / INNOVATION DATA

Investment capital and innovation data were derived from an array of sources in order to achieve a more comprehensive picture of clean energy investment within Massachusetts. Investments included SBIR/STTR awards and Sunshot Initiative awards, both of which are publicly available at https://www.bir.gov and https://www.energy.gov/downloads/solar-projects-downloads. Data on MassCEC grants were received from MassCEC. Investment data were also retrieved through Crunchbase, a commercial database which collects and organizes self-reported company information, news, and investments. Information is typically verified through press releases. Investment descriptions were analyzed to determine relevancy and technological classification. BW Research decided to use Crunchbase due to the enhanced transparency in investment descriptions and verification through third-party news outlets which allowed for greater vetting of investments and subsequently avoiding overcounting. The technological categories are as follows:

Energy Efficiency and Building Envelope (e.g., lighting, energy efficiency appliances, energy efficient programming, energy efficient building materials); Energy Storage and Grid Modernization (e.g., fuel cells/hydrogen, solid state batteries, flywheels, compressed air energy storage, thermal, pumped hydro-power, smart grid, smart computing/software, demand response services, micro-grids); Renewable Energy for Electrical Power Generation (e.g., solar, offshore wind, onshore wind, river/wave/tidal hydropower, bioenergy, landfill gas, biogas, anaerobic digestion, woody biomass); Renewable Fuels (landfill gas, bioenergy, anaerobic digestion, woody biomass, biodiesel); Alternative Transportation (e.g., electric vehicles and systems, charging stations, biodiesel for on-road vehicles).

PATENT AND PUBLICATION DATA

Patent data used in this report was retrieved from the United States Patent and Trademark Office (USPTO) PatentsView data retrieval tool in July 2018. The USPTO’s Cooperative Patent Classification (CPC) provides a transparent and descriptive methodology of classifying patents. These classifications were then utilized to place patents into technology categorizations. The categories are as follows:

Energy Efficiency and Building Envelope (e.g., lighting, energy efficiency appliances, energy efficient programming, energy efficient building materials); Energy Storage and Grid Modernization (e.g., fuel cells/hydrogen, solid state batteries, flywheels, compressed air energy storage, thermal, pumped hydro-power, smart grid, smart computing/software, demand response services, micro-grids); Renewable Energy for Electrical Power Generation (e.g., solar, offshore wind, onshore wind, river/wave/tidal hydropower, bioenergy, landfill gas, biogas, anaerobic digestion, woody biomass); Renewable Fuels (landfill gas, bioenergy, anaerobic digestion, woody biomass, biodiesel); Alternative Transportation (e.g., electric vehicles and systems, charging stations, biodiesel for on-road vehicles).

Publication data used in this report is from Clarivate Analytics’ Derwent Innovation database. The publications database is a compilation from numerous renowned and trusted scientific literature sources that include Web of Science, Current Contents Connect, Conference Proceedings, and Inspec. The firm’s combined database provides a comprehensive way to monitor technological trends across the academic literature landscape. This platform does not yet provide publications by sub technologies, so keyword search was utilized to retrieve and categorize publications. The technological categorizations are the same as those described above in the patents section.

20Transportation of motor vehicles is included in commodity flows, however, vehicle by fuel type is not collected.
ACTIVITY
For the purposes of this report, an establishment’s activity refers to the primary value-chain industry to which it most associates its work. Activities include research, development and engineering, manufacturing, sales and distribution, installation and maintenance, legal, finance, and other professional services, and other.

CLEAN ENERGY INDUSTRY
The aggregate of establishments that are directly involved with researching, developing, producing, manufacturing, distributing or implementing components, goods or services related to Renewable Energy, Energy Efficiency or Conservation, Smart Grid, Energy Storage, Carbon Management and/or Electric or Hybrid Vehicles.

CLEAN ENERGY ESTABLISHMENT
For the purposes of this report, an establishment is any establishment that is involved with an activity related to the clean energy industry.

CLEAN ENERGY WORKER
Full-time and part-time permanent employees who support the clean energy portion of the business, including administrative staff, excluding interns and other temporary workers.

ESTABLISHMENT
For the purposes of this report, a business location in Massachusetts with at least one employee.

FIRM
A business organization, such as a corporation, company, or partnership. A firm can have multiple establishment locations.

GROSS STATE PRODUCT
The clean energy portion of Gross State Product calculated for this report was derived from survey incidence rates and proportional revenue reporting, together existing data from the Bureau of Economic Analysis, calculated by NAICS code. Utility-data and state government spending were included as direct inputs (rather than using a proportional analysis).

PRE-COMMERCIAL
Work that has yet to reach market or products that are in the development phase.

PROFESSIONAL SERVICE
Any sort of finance, legal, architecture, or other mathematical or scientific services that support clean energy technology development and deployment.

SUB-TECHNOLOGY
For the purposes of this report, sub-technology refers to the specific technologies with which an establishment works, within each technology area. The sub-technologies for Energy Efficiency and Renewable Energy are listed under the respective definitions.

TECHNOLOGY
For the purposes of this report, technology refers to the primary application or end-use of an establishment’s produced goods or services.

GLOSSARY OF TERMS
NOTES

Braintree Electric Light Department - energy storage project.