

Massachusetts' Clean Energy Cluster

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*Abstract: The renewable energy industry in Massachusetts is identified through a “top-down” and “bottom-up” processes to determine the total employment and boundaries of this sector. Related sectors are also identified that are linked to the core renewable energy sector in the state and policies for enhancing this cluster are suggested.*

JEL codes: Q42: Alternative Energy Sources; L99: Industry Studies: Transportation and Utilities – Other; R58 Regional Development Policy.

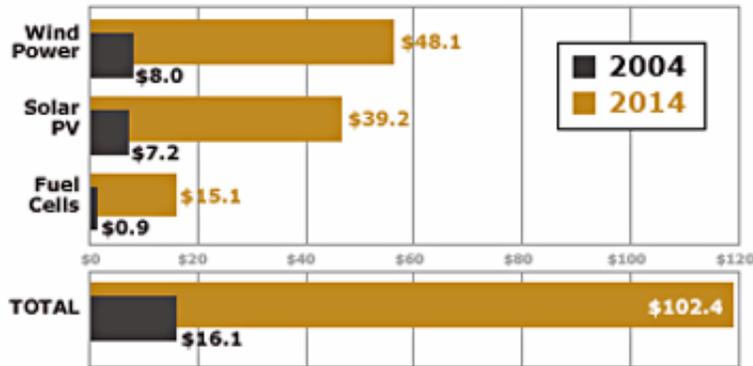
As renewable energy markets begin to develop rapidly around the world, most people do not think of Massachusetts as a hub of renewable energy activity, except perhaps for the controversial proposal for the development of a wind farm off of Cape Cod. However, Massachusetts possesses a number of strengths in industries related to “clean energy” production. By “clean energy” production we mean the entire value chain of activities associated with clean energy from the raw inputs, such as PV cells and electronic control modules, involved in the production of clean energy related materials, to clean energy products themselves, such as solar panels and fuel cells, to the installation of these products.<sup>1</sup> Thus, clean energy refers to four major sectors we have identified in Massachusetts -- renewable energy equipment and generation, power electronics, energy efficiency, and clean energy research -- that are in some way associated with the development, production, distribution, or use of renewable and/or clean energy, or the reduction in use of “dirty” energy sources. This article documents the strength of Massachusetts’ clean energy sector in the context of the industry nationally and worldwide and its potential importance to the Massachusetts economy, and suggests policy options for enhancing its presence in Massachusetts.

Global markets for renewable energy are growing rapidly, creating opportunities not just for individual firms, but also for regions with the appropriate resources and capabilities to develop sectoral clusters. Global markets for wind and solar photovoltaic (PV) power are growing at an annual rate of around 20%. Markets for associated electronics, materials, construction, and services will also experience rapid growth. The global market for energy efficiency products, currently estimated at \$115 billion, is projected to grow to over \$150 billion by the end of this decade (Makower, Pernick, & Wilder, 2005). One estimate of the expected market growth of three clean power technologies is given in Figure 1:

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<sup>1</sup> Note that fuel cells are clean and highly efficient, but are not strictly ‘renewable’, as they require fuels such as natural gas or hydrogen. However, these fuels can be derived from renewable sources, such as landfills.

Figure 1  
Clean Energy Projected Growth 2004-2014  
Global Markets, US\$ Billions



Source: (Makower et al., 2005)

However, these markets are being driven more by public policy rather than by the fundamental economics of the sectors. While the cost of wind energy is approaching that of conventional gas or coal-fired power generation, other renewable energy sources are still significantly more expensive. Authorities at national and regional levels are encouraging these markets with substantial subsidies, incentives, and mandates in an effort to stimulate research and development as well as final demand (Center for Clean Air Policy, 2002; Loiter & Norberg-Bohm, 1999). Public policy is responding primarily to concerns about climate change due to emissions of greenhouse gases, local air quality issues, and the prospect of scarce and unreliable sources for fossil fuels. Hopes for an effective regime to address climate change have shifted from a mandatory multilateral agreement, the Kyoto protocol, to a plethora of regional, national, and sub-national programs and initiatives. These policy responses include carbon emission limits and trading systems, direct subsidies for renewable energy, and Renewable Portfolio Standards that mandate the use of specific proportions of renewable energy in electricity generation (Lee, 2003).

Among individual states in the U.S., there is also a growing awareness of the economic implications of attracting investment and employment in these rapidly growing sectors. As renewable energy production becomes a foreseeable reality, states are

beginning to try to position themselves as strong centers of activity in this area. Successful development of regional clean energy industrial clusters requires the presence of a critical mass of firms, suppliers, customers, labor skills, and research institutions. Policy makers have increasingly adopted an understanding of “regional competitiveness” in which local prosperity is linked to the ability to attract clusters of related high-value added activities in sectors with rapid growth. Policy makers see states as competing for a share of these markets, and are sometimes willing to invest in their development because early action can yield long-term benefits due to the momentum of sectoral clusters (Bolinger & Wiser, 2001). A recent report on climate policies for California highlighted as the first point in its executive summary that a series of measures could achieve substantial reductions in GHG emissions while “increasing Gross State Product by about \$60 billion and creating over 20,000 new jobs” (Farrell, Hanemann, & Roland-Holst, 2006).

### **Components of the Clean Energy Cluster**

Massachusetts is well positioned to participate in the growing global market for clean energy technologies, as it is host to the prerequisite cluster of specialized firms, skilled labor, research universities, sources of venture capital, and an enthusiastic community of environmental activists and entrepreneurs. Our study identified four clean energy sectors in which Massachusetts currently has a substantial presence. The first is the set of core renewable energy technologies, including wind power, solar photovoltaics (PV), fuel cells, and biomass. Second, Massachusetts also possesses significant strength and growth potential in power electronics, a related, though much less recognized, clean energy sector. Power electronics comprises a range of hardware and software technologies used to control, store, switch, and monitor power production and energy usage. A third major clean energy sector is the energy efficiency industry, which includes a broad range of goods and services, ranging from architects and developers who help in the construction of green buildings or retrofitting of existing buildings to enhance energy efficiency, to the producers of some of the components and materials required for energy efficiency enhancements, to the installers and the repair persons who maintain energy efficient structures or devices. A final component is the substantial “research enterprise”

in Massachusetts, including universities, businesses, and non-profits that engage in energy research and consulting, and that attract substantial sums in grants and private capital.

Together, these sectors have a substantial impact on the Massachusetts economy, employing over 10,000 people in approximately 400 firms and organizations, while undergoing very rapid growth rates as the promotion of clean energy continues to expand nationally and worldwide. Moreover, Massachusetts already has developed a significant presence in the clean energy sector that is far greater than its relative share of the overall national population and/or economy. This is partially due to its early adoption of a set of policies that favor renewable energy and energy efficiency, but it is also due to the nature of the state's economy as one that specializes in cutting-edge technologies and that continues to benefit from a strong university research tradition, highly skilled labor, and access to venture capital. Other states and countries, however, are also recognizing the economic opportunities in clean energy and adopting supportive policies. Without a coordinated approach of supportive policies, regulatory initiatives, and investments and subsidies, Massachusetts risks falling behind.

Before describing the methodology and results of our quantitative analysis of the size of the clean energy sector in Massachusetts, we first provide a more detailed description of each of these sectors.

### **Core Renewable Energy Technologies**

Massachusetts has a vibrant cluster of renewable energy companies, with many research-intensive companies located in the state, as well as some smaller manufacturing companies. Massachusetts has its most substantial presence in PV, and is home to significant manufacturing capacity for solar cells, modules, and related industrial machinery. There are many smaller companies specializing in sub-segments, such as solar-battery combinations for off-grid power, research into low-cost and high-efficiency solar cells, and design and installation services. The development of PV is, however, constrained by the lack of a substantial local market, and none of the five largest PV companies has a manufacturing presence in the state.

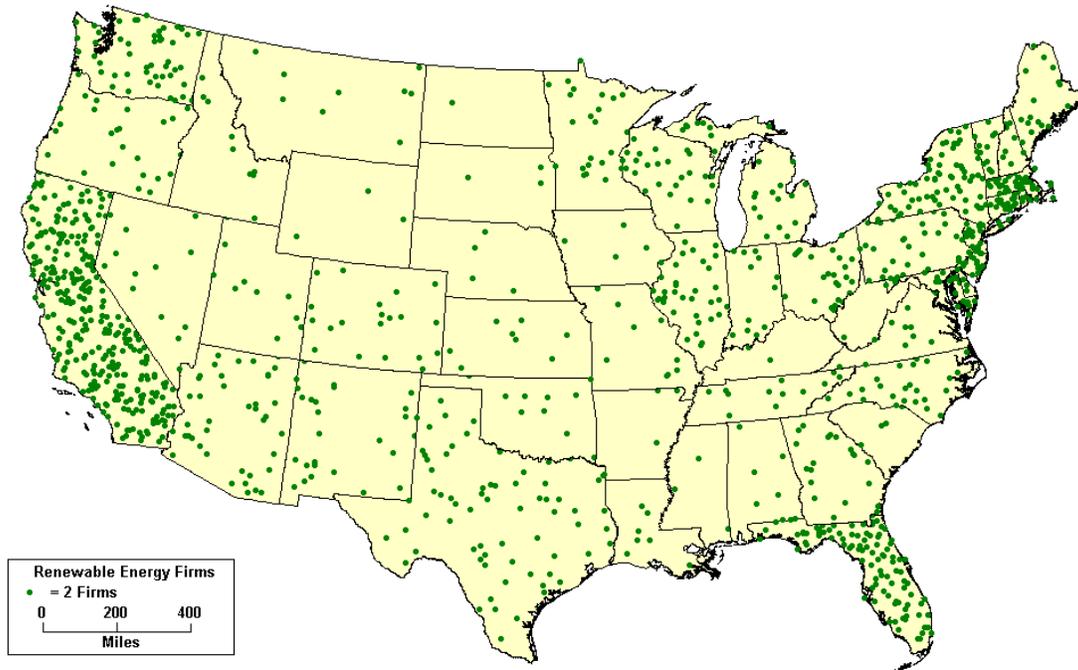
Massachusetts has little commercial presence in wind turbines, even though wind is the only cost-competitive renewable source of power for the grid and the fastest-growing source of electric power. The state does, however, have substantial offshore wind resources, which could stimulate elements of a local industry, and Massachusetts universities have significant research expertise in wind. In fuel cells, Massachusetts is home to a number of smaller, research oriented firms, though three of the top-tier fuel cell manufacturers are located nearby in Connecticut and New York. Commercial activity in biomass and biofuels tends to be small-scale and fragmented. Massachusetts has some research presence but little prospect for dramatic growth on the agricultural or processing side.

Figure 2 shows the distribution of renewable energy companies in the United States.<sup>2</sup> Massachusetts holds sixth place (in terms of number of companies), with the top three being California, Florida, and Texas. Moreover, Massachusetts is clearly part of a very strong regional cluster in the northeastern United States. In addition, Massachusetts currently ranks 6<sup>th</sup> among the continental states in terms of renewable energy production, although most of this is hydroelectric power. In relation to its size and population, the state is clearly in a strong position.

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<sup>2</sup> Data for the map and this ranking are from the University of Massachusetts Donahue Institute and are based on the Sourceguides database ([www.sourceguides.com](http://www.sourceguides.com)), a reasonably comprehensive list of vendors that includes smaller retail, service, and consulting firms. The dots represent the number of firms listed in each state and are distributed randomly within the state, rather than representing the actual location of each firm.

**Figure 2**  
**Distribution of Renewable Energy Companies in the United States**



### **Power Electronics Technology Sector**

This sector encompasses a number of different industries, ranging from firms that specialize in computer sensors and controls for building temperature environments to the components of renewable energy systems that control power and connect it to the grid or other applications. The power electronics sector includes electronics hardware and software firms that specialize in power switching equipment, inverters, advanced energy storage systems, and devices to modify, control, monitor, and connect power output from renewable energy sources. Firms classified as instruments manufacturers are also included in this sector if they produce temperature control devices and or monitors for building environments and services that are related to the implementation of clean energy technologies.

Power electronics constitute a significant portion, estimated at 20-30%, of the total value of renewable energy and energy efficiency systems, and will benefit from the growth of clean energy usage around the world.<sup>3</sup> As the clean energy industry continues to grow, power electronics firms are likely to play an important role, shifting more of their business to service the clean energy industry, and aiding the development of new technologies for clean energy production and delivery. Massachusetts has traditionally been quite strong in these types of technologies – software, hardware, instrumentation, inverters and associated electronics -- and therefore, it can expect to be major supplier for national and global markets. Massachusetts is home to four or five small-to-medium size companies focusing on power electronics for clean energy, probably the largest concentration in the country. The state is also home to many companies for whom power electronics applications in the clean energy industry is currently only a very small market. Expansion in this area is hampered by the lack of sectoral organization and lack of attention to the opportunities in clean energy applications.

### **Energy Efficiency Sector**

The energy efficiency sector covers firms involved in the construction of materials to enhance energy efficiency, installers of energy efficient components, and developers that coordinate the retrofitting of existing buildings to increase their energy efficiency or the “greening” of new buildings. It includes firms classified under construction, such as installers of environmental controls and building insulation, as well as manufacturers that produce insulating glass for windows. It also includes wholesalers and/or retailers that specialize in materials designed to increase energy efficiency, such as insulation, and more general energy conservation products. Finally, another major component of this sector is the many engineering and consulting firms that specialize in energy conservation.

Though Massachusetts is not home to major suppliers of passive insulating materials, such as Dupont or Dow Chemicals, it does have significant activity in design and installation, driven in part by various state programs to promote energy efficiency and green buildings. The state’s strong presence in specialized electronics and devices, though classified for this study as power electronics, clearly benefits from more active

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<sup>3</sup> Information from personal interview.

energy efficiency systems that monitor and control lighting, heating and cooling. Energy efficiency accounts for the lion's share of current employment in clean energy in Massachusetts, but is growing more slowly than core renewables.

### **Clean Energy Research**

Massachusetts has very significant activity in the area of energy research, which supports innovation in the clean energy sector. The clean energy research sector includes consulting and engineering firms that devote significant research to clean energy, major university research centers in fuel cells, solar energy and wind turbines, and contract research and development firms. MIT, for example, has a very substantial energy research program, while UMass-Lowell has a more specialized research program on wind energy. The research sector is important because it attracts federal research and development funds, it develops and refines technologies, provides a trained workforce, and engages in technology licensing and start-up activity. This sector is actively engaged in next generation product development, from solar- hydrogen production systems to microbial fuel cells, as well as engaged with established firms to solve complex technical and manufacturing challenges such as engineering platforms for deep water wind farms. Many of the research and development firms are DOD, DOE and NASA contract winners, and some are leading major technical consortia. The strength of Massachusetts in clean energy research reflects its broader position in industrial and university research. Massachusetts consistently ranks in the top three or four states (on a per capita basis) on such indicators as federal university funding for science and engineering, SBIR awards, doctoral scientists and engineers, and industrial and academic R&D expenditures.

### **Determining the Size of the Clean Energy Sector**

Because this sector comprises a range of new technologies and a diverse range of firms from a large number of different industries, this is a very difficult industry to track as compared with traditional sectors easily quantified by one or a few standard industrial classifications (NAICs). Moreover, many of these firms are either startups or in the process of merging, changing names or location, or in some cases failing. In addition, many firms are becoming involved in the clean energy sector, while still carrying on business in other more traditional sectors and identifying which firms are shifting their

business into clean energy or potentially likely to do so is often very difficult if not impossible with existing datasets.

Therefore, we cast a very wide net in trying to identify firms likely to be involved in the clean energy sector and then fine-tuned the selection process as we narrowed the relevant categories using interviews with core firms in each sector, a written survey of firms in the industry, and two proprietary databases (IMarket and Corptech). The details of this process and specific codes are described in the Appendix, but the end result is a list of twenty-five 8-digit sectors from the I-Market database, which yielded 321 firms with total employment of 7428. The Corptech database revealed an additional 70 firms employing 3400 that we added to the I-Market data to get our conservative estimate of the total for the clean energy industry. However, the Corptech data did not allow us to determine the disaggregate 8-digit sector identification of these additional firms.

The twenty-five industry sectors chosen from the I-Market database to represent the clean energy industry in Massachusetts are quite diverse, ranging from construction (e.g. solar energy contractors and energy management controls) to manufacturers of rubber and plastic (e.g. insulation materials), glass (e.g. insulating glass), fabricated metals (e.g. solar heaters and collectors), electronics (e.g. power switching equipment, inverters, fuel cells, and PV devices), and instruments (e.g. building monitoring controls) to wholesalers and retail distributors (e.g. of insulation materials and energy conservation products), and engineers and consultants (specializing in energy conservation engineering or research).

When combined with the Corptech data, there were almost 400 firms in these sectors in 2003, employing almost 11,000 people and generating over \$3 billion in sales. We believe this estimate is quite conservative. We are unable to include some employment in power electronics that relates to clean energy because it is not possible with any of the existing databases to separate out the employment in this sector that can be definitively identified as being largely devoted to clean energy. However, a subgroup of firms in this power electronics sector is likely involved in clean energy. If just 10% of the employment in this sector were involved in the support of the clean energy sector, this would represent an additional 2300 jobs. Likewise, in some cases we are unable to separate firms engaged in energy research and development from those involved in

electrochemical research and development services. If we were to assume 10% of employment in this category was involved in clean energy research, this would add another 1400 jobs, bringing total clean energy employment in the state to almost 15,000.

In order also to get some perspective on the breakdown of employment by the major clean energy sectors, Table 1 shows how the employment breaks down for the data that we are able to delineate in this fashion (only data from I-Market allowed for this level of disaggregation). Note this accounts for a little less than 70% of the 11,000 jobs we identified in this sector.

**Table 1**  
**Number of Firms and Employment in Clean Energy in Massachusetts 2003**  
**(IMarket and Levy and Terkla, 2003)**

<b>SECTOR</b>	<b>Number of Businesses</b>	<b>Employment</b>
Renewable Energy Sector	51	899
Power Electronics	33	2879
Energy Efficiency	225	2098
Energy Research	12	1552
<b>TOTAL</b>	<b>321</b>	<b>7,428</b>

Table 1 shows that most of the firms, not surprisingly, are in the energy efficiency sector. However, we believe this is a conservative estimate for this sector. It is not possible to identify as separate firms the many small contractors and subcontractors that install and maintain energy efficiency related materials, and thus these are not included in this count. While there are fewer firms in the power electronics sector, this is the largest sector in terms of employment. This is not surprising since this sector is made up of firms which, while important to the clean energy industry and involved with it to varying degrees, are also involved in the production of other products and services that are not necessarily clean energy related. Finally, the energy research sector includes small university shops and think tanks, but several larger engineering and consulting firms as well.

In order to check our findings on the size of the clean energy sector, we also developed a “top down” approach for estimating the size of this sector that relies on measures in the literature that associate spending on energy efficiency with job creation and that associate installation, maintenance, and manufacturing of clean energy equipment (as measured by megawatts of output) with the number of workers required to generate this output. We estimated total employment in the clean energy sector in Massachusetts using a spreadsheet model that projects employment for each sector based on current installed generation capacity, new installations, and the level of manufacturing and sales activity. This generated estimates of employment in 2003 and 2004 in the 10,000-11,000 range, which helps to validate our estimates derived from the proprietary databases (Levy and Terkla, 2004).

Just as important as the absolute quantity of jobs involved in the clean energy sector is the fact that Massachusetts is home to such a large group of firms in this sector relative to its size nationally. This becomes evident in Tables 2 and 3. Table 2 shows that Massachusetts ranks 11<sup>th</sup> nationally in terms of the number of businesses it has involved in the clean energy sector and third if we weight this by state population.<sup>4</sup> More impressive, as indicated in Table 3, Massachusetts ranks 7<sup>th</sup> nationally in total employment in the clean energy industry.

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<sup>4</sup> These numbers are derived from IMarket using the twenty-five industry sectors identified.

**Table 2**

**Top 15 State Ranked by Number of Businesses in the Clean Energy Sector  
(Based on IMarket Database)**

<b>State</b>	<b>Number of Businesses</b>	<b>Businesses per one million people (Rank Shown in Parentheses)</b>
California	1,064	30 (11)
Texas	900	41 (4)
Florida	563	33 (8)
New York	447	23 (14)
Michigan	361	36 (7)
Pennsylvania	357	29 (12)
Ohio	353	31 (10)
North Carolina	337	40 (5)
Georgia	332	38 (6)
Illinois	328	26 (13)
<b>Massachusetts</b>	<b>282</b>	44 (3)
New Jersey	275	32 (9)
Colorado	268	58 (1)
Wisconsin	253	46 (2)
Washington	247	40 (5)

**Table 3**

**Top 15 States Ranked by Employment in the Clean Energy Sector  
(Based on IMarket Database)**

<b>State</b>	<b>Total Employment</b>
Texas	14,825
California	11,406
Illinois	10,618
New York	6,678
Tennessee	6,473
North Carolina	6,282
<b>Massachusetts</b>	<b>6,277</b>
Florida	6,021
Ohio	4,156
Wisconsin	3,947
Michigan	3,410
Georgia	3,312
New Jersey	3,176
Virginia	3,175
Minnesota	3,098

## **Conclusion**

Thus, there is clearly a substantial clean energy cluster in Massachusetts. Total employment is in the range of 10,000 – 15,000 and the potential is there for this to grow to over 20,000 within six years if Massachusetts remains at the forefront in terms of both policy and technology in clean energy development (Levy and Terkla, 2004). It is also quite apparent that Massachusetts is already a significant player nationally in the clean energy industry, ranking in the top ten in terms of total employment in these sectors. This is despite the fact that Massachusetts does not have relatively large amounts of clean energy producing installations. Clearly, Massachusetts has been able to use its comparative advantage in being on the cutting edge of new technologies through university and private sector collaborations to position itself as a key exporter of clean energy materials as well as moving forward in terms of advancement of energy efficient buildings and technologies.

Despite this regional strength, there is little reason for complacency. Many research intensive companies are located in the state, as well as some smaller manufacturing companies, but Massachusetts is not currently the home for any of the top four or five largest manufacturers in any of the renewable energy sectors. Moreover, other states and countries are investing substantial resources to build the demand for renewable energy and to develop business infrastructures. If Massachusetts wants to sustain and expand its presence in the rapidly growing renewable energy industry, and to reap the benefits of growing employment and investment, it will also have to invest in the industry as it continues its transition toward full commercialization.

There is no one sector of the renewable energy market that is likely to produce both large quantities of new renewable energy grid power and significant additional employment for the state, at least over the next decade. Wind power is likely to generate most of the power, while fuel cells and solar PV have the potential to generate more employment. As a result, assistance cannot be focused on a single sector. Some forms of assistance are needed by all industries, such as equity funding and installation subsidies, regulatory reform, and better monetization of the benefits of renewable energy. It is also important for the state to help facilitate the recognition of the power electronics and renewable energy research clusters both to help encourage the power electronics industry

to keep expanding into the renewable energy area and to facilitate synergies that tend to develop within well-defined industry clusters.

## APPENDIX

### **Process for Bottom Up Approach**

In the case of the IMarket data, we started with a list of almost 700 eight-digit NAIC codes that at first glance appeared they could have firms classified within them that might be associated with clean energy. This list was then cut down to a more manageable list of around 80 codes based on initial investigations into the types of firms most likely to be associated with clean energy and initial interviews with several experts in the relevant areas.

This list of eighty NAIC codes was then cut down to a list of twenty-five codes based on the relevance to clean energy of firm activities in each of the eighty categories and whether or not Massachusetts firms were present in the category. In order for this to be done, we identified all companies in Massachusetts listed under the eighty NAIC codes and either determined their relevance by examining their web pages or in uncertain cases or where web pages were not available, we contacted them by telephone.

The final twenty-five NAIC codes selected are listed below:

NAIC Code	Name of NAIC-8 Code
1711-0403	Solar energy contractor
1731-0102	Computer power conditioning
1731-0201	Computerized controls installation
1731-0202	Energy management controls
1731-0203	Environmental system control installation
1742-0203	Insulation, buildings
1796-9907	Power generating equipment installation
2296-0302	Fabric for reinforcing fuel cells
2679-0902	Fuel cell forms, cardboard: made from purchased material
3086-9904	Insulation or cushioning material, foamed plastics
3211-0302	Insulating glass, sealed units
3433-9904	Solar heaters and collectors
3613-0209	Power switching equipment
3629-0102	Electrochemical generators (fuel cells)
3629-0105	Power conversion units, a.c. to d.c.: static-electric
3674-0305	Photovoltaic devices, solid state
3674-9901	Fuel cells, solid state
3822-0206	Temperature controls, automatic
3822-9901	Building services monitoring controls, automatic
5033-0200	Insulation materials
5211-0301	Energy conservation products
5211-0303	Solar heating equipment
8711-9906	Energy conservation engineering
8731-0301	Energy research
8748-9904	Energy conservation consultant

We followed a similar strategy in analyzing the Corptech data, first accessing a list of all Massachusetts firms in almost 65 three and two digit categories. Three digit categories (the most disaggregate breakdown available were used whenever possible, but in some cases only two-digit categories were listed). The resulting list of almost 170 firms was then narrowed by examining web pages and in some cases through telephone contact. The codes for the remaining firms were then examined to determine the smallest list of codes that would still capture the relevant clean energy firms. These codes were then divided into three groups. The first group included codes of firms that were clearly central to the clean energy sectors described in the text. A second group included codes that had a few firms that were contributing to the clean energy industry, but many who were not and all of these were associated with the power electronics area. The last group was only one three digit category, but it combined energy research (clean and otherwise) with electrochemical research and development so we did not include it in the core clean

energy category since we could not determine how many firms were in each category without further investigation that was beyond our research resources.

The list of three digit codes and descriptions in each of the three groups is provided below:

**Group I (Large percentage of clean energy firms in each category)**

ENR-SV-C (Energy industry consulting services, HVAC consulting services)

ENR-SV-U (Electric utility/energy providing services)

ENR-SV-CE (Energy management consulting services)

ENR-SV-A (Energy usage analysis services; electric power and lighting design consulting services)

ENR-AL-SO (Solar collector components)

ENR-EM (Energy management)

ENR-EP-U (Uninterruptible power supply systems)

ENR-EP-F (Fuel cell stacks; fuel cells; power modules)

PHO-OE-EV (Photovoltaic cells)

SOF-FM-E (Web-based energy analysis software)

**Group II (Power Electronics)**

SUB-ES-CA (AC-to-DC converters)

SUB-ES-CB (DC-to-DC converters)

SUB-ES-CC (AC-to-AC converters)

SUB-ES-CD (DC-to-AC converters)

SUB-ES-I (Electrical Power Inverters)

SUB-ES-PP (Programmable Power Supplies)

SUB-ES-PY (Switching Regulated Power Supplies)

**Group III (Research)**

ENR-SV-R (Electrochemical research and development services; Energy research and Development)

These Corptech data allowed us to identify additional firms and employment not captured by the I-Market database. Controlling for overlap of the same firms in the two databases still allowed us to add 3400 employees and 70 firms to the I-Market database estimate of the clean energy sector.

### **Surveys**

We conducted a written survey of the firms we could identify from quantitative data sets as being possibly related to the clean energy industry. This was supplemented by telephone interviews of a number of key firms in the energy efficiency and power electronics sector as identified by staff at the Renewable Energy Trust. We also conducted telephone interviews with several industry experts to be sure we had thoroughly canvassed the literature and available secondary data related to clean energy. The written survey was sent to 140 firms. Twelve firms responded that they were not involved in clean energy and so did not want to complete the survey. Twenty six firms responded to the survey. Firms were given 10 days to respond and then an additional two week extension (communicated by phone).

The survey asked firms to list their major products, highlighting those related to clean energy (as defined in the survey), including the proportion of their business devoted to this segment of production. Firms were also asked about current products with potential use in the clean energy sector, as well as lists of their major competitors, customers, and suppliers. Finally, they were asked about their current and projected employment and revenues.

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