EPA/600/R-13/035 | June 2013 | www.epa.gov/ord

United States
Environmental Protection
Agency

Building a Successful Technology Cluster

Office of Research and Development
Environmental Technology Innovation Clusters Program

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Building a Successful Technology Cluster

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March 12, 2013

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Executive Summary

"Clusters" are dense regional networks of companies, universities, research institutions, and other stakeholders involved in a single industry. The iconic cluster is Silicon Valley, a grouping of businesses and universities in California's Santa Clara Valley that has become a leader in high-tech innovation and a primary driver of economic growth in the region.

In keeping with the objectives outlined in its 2012 Technology Innovation Roadmap, EPA aims to encourage technological innovation by supporting the development of clusters focused on environmental technology. This report reviews existing literature on industry clusters by Porter, Smilor, Gibson, Kozmetsky, Phillips, and others to summarize the prerequisites for the successful creation of a technology innovation cluster and promote the practices that will sustain it.

Based on the literature, clusters consist of seven sectors: 1) established companies, 2) start-up businesses, 3) universities or other research institutions, 4) support groups or champions, and 5) state, 6) local, and 7) federal government. The report examines how various prerequisites and success factors apply to each of these sectors. For example, a region must have scientific preeminence within the cluster industry, new technology development, attraction of major technology companies, and the creation of start-up technology companies in order for the development of a cluster to be possible.

As the cluster develops, the roles of the champion and the cluster support organization become crucial for long term success. In successful clusters, they create an environment of collaboration and cooperation. Over time, they encourage interaction between cluster stakeholders, advise companies on potential research and/or commercialization partners, connect members to funding opportunities and investors, engage the three levels of government, encourage the colleges and universities to develop curriculum that will prepare their students for jobs in the cluster, and foster workforce mobility between established companies and start-ups.

The report also looks at three different case studies – the Austin Technopolis, the Massachusetts Biotechnology Cluster, and the Milwaukee Water Technology Cluster – to examine how these factors all played into the development of actual clusters. The final section concludes with recommendations for future cluster efforts, and is intended to advise and encourage those who may be in the process of developing new clusters.

Introduction

The purpose of this paper is to summarize the characteristics of successful technology clusters. Michael Porter, a well known Harvard Business School professor, defines clusters as "geographic concentrations of interconnected companies and institutions in a particular field. Clusters encompass an array of linked industries and other entities important to competition."[1]

Since the late 1980s, research has been conducted to understand why Silicon Valley was successful when other clusters failed. Many cities and towns across the world would like to replicate the Silicon Valley success. In researching this paper, a literature search was conducted for articles and books that define the success factors for business clusters. After reviewing the material, it appears that researchers have approached this topic from two different perspectives: 1) from a macro view by understanding how clusters have evolved and then offering general recommendations on the role of business, universities and government, and 2) from a micro view, by analyzing specific clusters and then offering specific recommendations based on the case studies. The challenge is to take the best advice from both perspectives and apply them to building a successful cluster.

Michael Porter's research has focused on the macro view. He recognizes that "many clusters include governmental and other institutions that provide specialized training, education, information, research, and technical support."[2] Porter does not distinguish clusters with the term "high tech" because it creates "the misconception that only a handful of businesses compete in sophisticated ways."[3] In his view, "a vibrant cluster can help any company in any industry compete in the most sophisticated ways, using the most advanced, relevant skills and technologies."[4]

From a micro view, the authors Raymond Smilor, David Gibson, George Kozmetsky, and Fred Phillips have an excellent understanding of the success factors related to their Austin, Texas cluster, known as the Austin Technopolis. These academics are actual cluster practitioners. After Phillips left Austin, he then worked with the city of Portland, Oregon on the development of their technopolis. In 2006, he authored a definitive book on technopoleis called *Social Culture and High Tech Economic Development: The Technopolis Columns*. Another insightful book is *Regional Advantage* by AnnaLee Saxenian, which offers an analysis of two well known clusters: Silicon Valley and the Massachusetts Miracle, a computer technology cluster which was located near Route 128 and included the minicomputer giants of the 1980s: DEC, Data General, and Wang.

The terms "cluster" and "technopolis" are often interchanged, which can be confusing. A technopolis is defined by Fred Phillips as "a region trying to build and maintain a healthy, technology-driven economy."[5] According to Phillips, a technopolis includes "inter-sectoral cooperation and total regional futures orientation"[6] and places "more emphasis on higher education, research, and formal knowledge"[7] than a cluster. As cluster theory has advanced and more high technology clusters have developed, they have incorporated the features of technopoleis. In the United States, "cluster" appears to be the preferred term.

Based on the research of Smilor et al., clusters require four prerequisites: "the achievement of scientific preeminence, the development and maintenance of new technologies for emerging industries, the attraction of major technology companies, and the creation of home-grown technology companies."[8] Phillips states that a region that succeeds is likely to have "a robust local value chain including strong R&D, manufacturing, marketing and distribution,

and intensive international connections; a critical mass of companies in one or more well-defined 'clusters;' and a relatively compact geography."[9] The well-known business clusters of Silicon Valley, Austin, the Massachusetts Miracle, and Massachusetts Biotechnology were all built on the achievement of scientific preeminence and the development of related technologies. It has been said that Silicon Valley and Boston have a natural advantage in cluster development because they have well-endowed prestigious universities and a concentration of entrepreneurial alumni, who remain in the area because of the desirable locations. Currently, new business clusters in Orlando, Florida and Milwaukee, Wisconsin are being built on achievement in the areas of interactive entertainment and fresh water science respectively.

However, having the prerequisites alone does not ensure success. The Massachusetts Miracle failed because 1) there was minimal interaction within this computer technology cluster, 2) companies "sought technological self-sufficiency"[10] and were vertically integrated, 3) its focus narrowed over the years, and 4) employees were threatened with legal action under their non-compete agreements if they left to start a competitive venture. In contrast, Silicon Valley evolved into a social and business culture that encouraged a collaborative approach. The large companies had a decentralized management style and sought the best suppliers rather than making all the parts internally. "The paradox of Silicon Valley was that competition demanded continuous innovation, which in turn required cooperation among firms."[11] There was significant interaction between engineers of competing firms, and they would frequently contact each other to solve complex problems. These relationships had been formed during previous employment or graduate school and transcended loyalty to one's current firm. "Technology exchange agreements and joint ventures were also commonplace in Silicon Valley long before they became staples of American Industry."[12] Employees frequently left to start new ventures because legal actions languished in the courts. Over the years, it has become clear that "California state law does not recognize non-compete clauses."[13]

In the early 1990s, increasing competition and regional problems forced local businesses, government, and universities to institutionalize Silicon Valley's spirit of regional collaboration by creating an organization known as Joint Venture. Tom Hayes, an executive of Applied Materials and a founder of Joint Venture in 1992, said: "Our aim is to build a comparative advantage for the Silicon Valley by building a collaborative advantage … to transform Silicon Valley from a valley of entrepreneurs into an entrepreneurial valley."[14] Silicon Valley's resilience over the last 50 years is due to "shifting patterns of collaboration and competition among networks of specialist producers. The dynamism of the region's industrial system lies not in any single technology or product but in the competence of each of its constituent parts and their multiple interconnections."[15] In the past, many regional economies focused on a specific technological area. "A network-based regional economy like Silicon Valley, alternatively, generates and pursues a rich array of technological and organizational alternatives."[16] The network is based on "social capital," which is defined by the sociologist James Coleman as "the ability of people to work together for common purposes in groups and organizations."[17]

If the prerequisites of 1) the achievement of scientific preeminence, 2) the development and maintenance of new technologies for emerging industries, 3) the attraction of major technology companies, and 4) the creation of home-grown technology companies are present, then it is important that the major sectors in the cluster interact and collaborate as shown in the Silicon Valley example. The creators of the Austin Technopolis appear to have learned from Silicon Valley's success. Based on their Austin

experience, Smilor et al. developed a concise list of these segments or sectors. The list can be better explained using their Technopolis Wheel (Figure 1). In the following list of the segments, I have modified the first, second, and fifth segments based on my research for this paper:

1. well-endowed high quality research university or universities,
2. "network of influencers or executive champions" and support groups,
3. local government,
4. state government,
5. federal government agencies and laboratories,
6. start-up companies, and
7. large corporations.[18]

Smilor et al. shows "the importance of networking across the seven segments of the technopolis wheel; that is, the ability to link public and private sector entities, some of which have been traditionally adversarial, to effect change.[19] Finally and perhaps most importantly, are key individuals, or influencers, who link the seven segments of the wheel."[20] In the following pages, I will discuss each of the sectors or segments in more detail. Then I will present three case studies based on clusters in Austin, Massachusetts, and Milwaukee with examples of inter-sector coordinated activities in each. It is important to remember that it takes years to build a successful cluster, and according to Phillips, "sustained initiatives are a necessary condition for ultimate regional success."[21] In order to have sustained initiatives, it is crucial that all sectors work with each other.

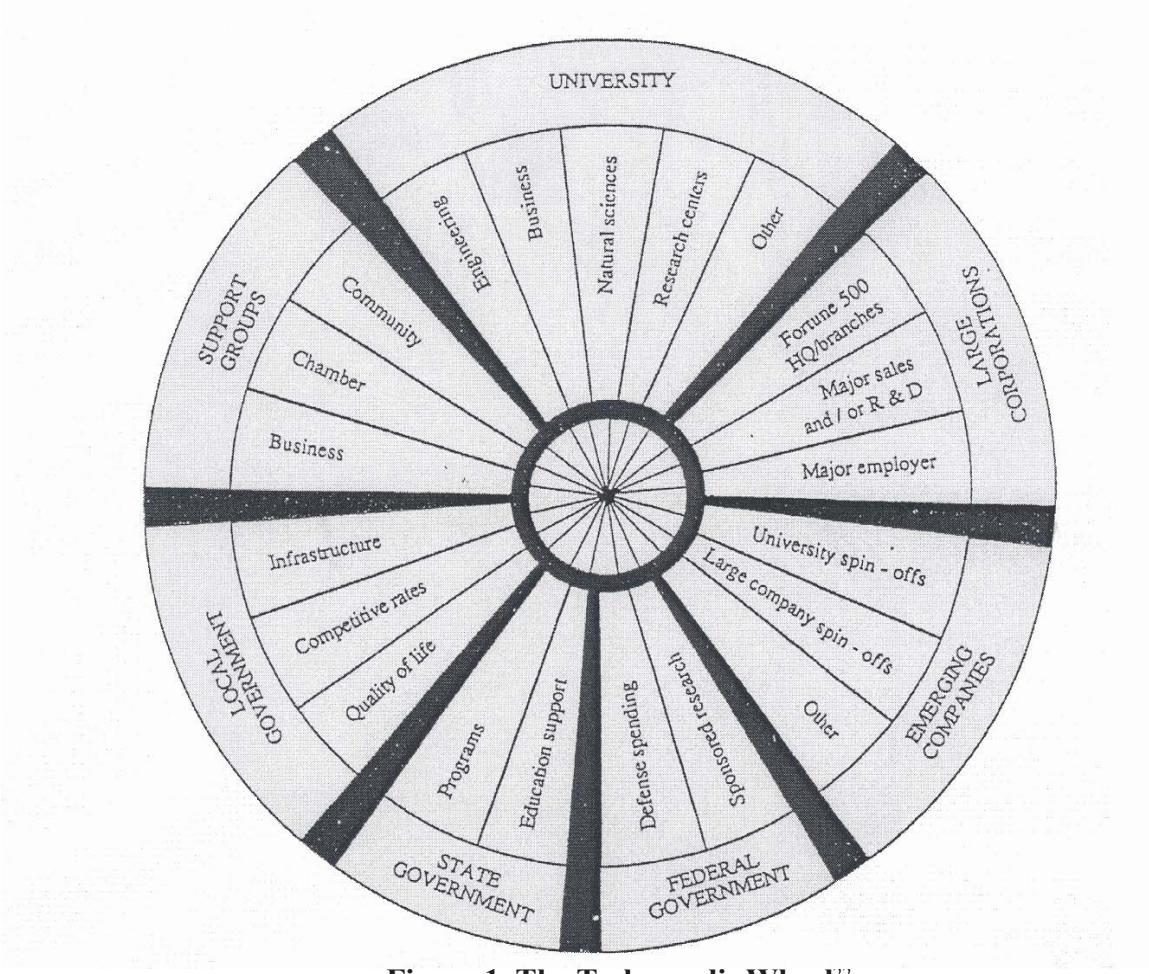

Figure 1. The Technopolis Wheel[22]

The Seven Sectors

1. High Quality Research University or Universities

It is essential that the university or universities have: 1) research units that focus on groundbreaking technology, 2) sophisticated patent support and analysis capability, 3) entrepreneurship courses and if possible, a university business incubator, 4) consistent funding to attract high quality professors and graduate students, and 5) reasonable fees for small businesses to access the universities' research findings and facilities. The most successful business clusters are associated with universities that offer this combination of academic, business, and financial support. During WWII, the Department of Defense funded high technology weaponry research at MIT, Stanford, and Berkeley, with MIT receiving the largest percentage. This initial funding gave these universities a start in high technology development. Since WWII, Stanford has been actively involved in encouraging the development of local technology companies. In the 1950s, it established "three institutional innovations": 1) the Stanford Research Institute, 2) the Honors Cooperative Program, which allowed "engineers at electronics companies to enroll in graduate courses directly or through a specialized televised instructional network,"[23] and 3) the Stanford Industrial Park. Both MIT and Stanford established industrial cooperation programs that gave companies access to university research, staff and facilities. However, MIT's program was geared toward large corporations, and in the 1990s the fee was $50,000 versus Stanford's fee of $10,000 and a willingness to work with any company.

MIT, Stanford, and Berkeley researchers have continued to focus on groundbreaking technology, which the universities have supported by providing sophisticated patent advice and entrepreneurship support. In the successful clusters of Austin and Massachusetts Biotechnology, the universities' business schools have played a key role by offering business and entrepreneurship courses to engineering students and establishing technology incubators. According to a recent Ewing Marion Kauffman Foundation[24] which analyzed university entrepreneurship at eight universities including the three mentioned above, "the successful generation of spinoff businesses requires university policies that encourage entrepreneurship and provide an assortment of support services for start-ups beyond the school's technology transfer office. The eight campuses, the authors discovered, offer services such as mentoring programs, business plan competitions, accelerator programs, entrepreneurship training for students and faculty, and project-based classes that bring together interdisciplinary or MBA student teams to work on business plans and create road maps for commercialization."[25]

Patent Support and Analytics

Since 2000, universities have produced thousands of patents; 4,500 patents were issued to universities in 2010.[26] They can be the drivers of innovation, but developing a business from the patent it requires capital, support services, and a management team. It is difficult to determine the value of a patent unless the university conducts patent analytics which can "provide insight into a patent's value and strategic fit in an industry."[27] Patent analytics is composed of patent component analysis, bibliometric analysis, expert opinion analysis, and financial modeling. According to Oldach and Stabinsky, these analyses "can show linkages between key research trajectories that need to be explored. But clearly one of the most valuable uses of patent analytics is to identify potential licensees or commercialization partners."[28] It can also "help IP professionals focus their time and efforts on those patents and

activities that add the most value"[29] and connect them to other research centers globally.

The 10-campus University of California system produces more patents than any other university and successfully transfers them to businesses for commercialization, but it does not rank in the top ten universities with the most "impactful" patent portfolios. Rice University is the leader for "impactful" patent portfolios, with an impact or asset value of over "four times that of all patents."[30] The Patent Board determines this measurement, and "the score indicates the role each institution's patents play in serving as a foundation for other patents and technologies."[31] So it is not just the quantity that matters, but more importantly the quality of the patents. MIT had the second highest number of patents for 2007-8, and it ranks fourth for "The Most Impactful Patent Portfolio."[32] If a region is considering the creation of a technology business cluster, then patent mapping research should be conducted for the industry under consideration. The mapping should include all patents in the region and analysis on their impact and relationship to technology development in order to assess whether the region has scientific preeminence upon which to build a cluster. Since this is one of the four prerequisites, weakness in this area would need to be balanced by strength in the other three, and it would be advisable for the cluster to consider how they will overcome the lack of patents. The Milwaukee water technology cluster has this weakness, and they are trying to address it by 1) expanding research and development programs at the University of Wisconsin's Graduate School of Freshwater Sciences, 2) increasing the number of graduate research fellowships, 3) hiring an entrepreneurial dean, and 4) establishing a business accelerator to encourage collaborative research between water technology companies and the graduate school's faculty and students.

2. Network of Influencers or Executive Champions and Support Groups

Literature shows that there are often one or two visionaries who initiate the interaction of the influencers or executive champions from each of the seven sectors. In the initial stage, they invest significant time in the building of social capital with key people before starting the cluster or technopolis. According to Smilor et al., "in short, an important characteristic of a technopolis is to be able to develop or attract and retain first-level influencers and nurture second-level influencers in all segments of the technopolis wheel. Based on the present research and the work of others (Rogers and Kincaid, 1981; Ouchi, 1984; Aldrich and Zimmer, 1986) it can be argued that the more extensive and the higher the level of networks across the different segments of the technopolis wheel, the more likely cooperative economic (and other) activities are to take place at community and state levels."[33] The influencers are often active members or initiators of support groups, which create the venue for interaction and collaboration of the other sectors. Frequently, they know the local angel capital investors and venture capitalists. According to the Kaufman Foundation, most angel groups investigate opportunities in their local communities.[34]

The visionary behind the development of Silicon Valley was Frederick Terman (Saxenian, 1994; Phillips, 2008). As a professor at Stanford in the 1930s, he was known for mentoring his graduate students, which included William Hewlett and David Packard. During WWII, he was the "director of Harvard's Radio Research Laboratory and in 1946 he returned to Stanford as Dean of Engineering."[35] His vision was to transform Stanford's engineering program and build a dynamic industrial community. According to Terman, "Such a community is composed of industries using highly sophisticated technologies, together

with a strong university that is sensitive to the creative activities of the surrounding industry. This pattern appears to be the wave of the future."[36] He became the Provost of Stanford in 1955 and was the driving force behind the university's efforts to connect with local industry. "Terman promoted the development of the Stanford Industrial Park" … which "helped to reinforce the emerging pattern of cooperation between the university and electronics firms in the area."[37] "By 1961 it had grown to 652 acres and was home to 25 companies that together employed 11,000 people."[38] Today it is known as Stanford Research Park, and it has 140 companies with approximately 23,000 people.[39] Terman also "persuaded William Shockley to choose Palo Alto as the site for Shockley Semiconductor Company."[40] The spinoffs from Hewlett Packard (HP), Shockley, and Fairchild created Silicon Valley.

3. Local Government

The role of the local government is to provide high quality schools, infrastructure, open space, good transportation, arts and recreation facilities, and competitive rate structures for services and utilities; these all relate to the quality of life. In the MIT study, which surveyed all MIT alumni in 2003, they found that the following "factors influenced the location of their [the alumni's] companies: 1) where the founders lived, 2) network of contacts, 3) quality of life, 4) proximity to major markets, and 5) access to skilled professional workers (engineers, technicians, and managers)."[41] The same study stressed the importance of "the availability of skilled professionals to build reliable, high-quality, innovative products"[42] for high tech businesses. Local technology infrastructure is also important for economic development. Darrene Hackler devoted a book, *Cities in the Technology Economy*, to analyzing "the role of cities relative to large economic changes and technology infrastructure."[43] In her 2002 survey, she found that many cities realized the importance of having competitive technology infrastructure, but few cities had implemented strategies to make it available. Seventy-seven percent of the respondents did not have an economic development plan that addressed telecommunications infrastructure.

According to Smilor et al., "local [Austin, Texas] government has had a significant impact, both positively and negatively, on company formation and relocation, largely from what it has chosen to do or not to do in terms of quality of life, competitive rate structures, and infrastructure."[44] Based on his Austin experience, David Gibson states that the following factors under the influence of local government are very important: "1) quality education at all levels, from kindergarten to graduate school and beyond; 2) globally competitive infrastructure – both 'physical' as in roads, airports, the Internet, and city services; and 'smart', as in talent, capital, and know-how; 3) a quality of life that attracts and keeps a broad range of talented people … as well as business people and entrepreneurs; and 4) enlightened government with a regional and, increasingly, a global orientation."[45]

Several local governments have expanded their scope of responsibilities to include emerging technology business clusters because they recognize the long-term economic benefits that can be derived from successful clusters. According to Porter, "clusters are key drivers of job growth, wage growth, new business formation, and innovation."[46] These proactive local governments often have economic development staff working in conjunction with nonprofits to promote business development. An example is the role that Austin, Texas played in establishing the Austin Advantage Program in 1988. An enlightened local government can make a difference.

4. State Government

From the macro view, Porter recommends that government involvement should "begin with

the collection of information that identifies the existence of clusters."[47] This information will "allow public policies and public investments to be better aligned with business needs, based on cluster composition in each location."[48] Once clusters are identified then government might consider "convening cluster participants"[49] if support organizations have not already formed. He recommends that government agencies interact with the clusters in order to "understand local constraints to productivity and identity gaps and weaknesses in public policy."[50]

From a review of the relevant literature representing the micro view, it appears that the three most important things states can do to foster economic development are: 1) consistently fund their universities at a high level to attract outstanding professors, researchers and graduate students and to support university R&D, entrepreneurial centers, incubators, and technology licensing offices, 2) establish and fund a state organization to encourage technology start-ups and cluster-building, and 3) establish a state venture capital fund or tax credits for angel and venture capital investments made in the state.

Consistent High Level Funding for Universities

According to Smilor et al., the Texas "state government has had a significant impact, both positively and negatively, on the development of the Austin technopolis through what it has chosen to do or not to do for education, especially in the areas of making and keeping long-term commitments to fund R&D, faculty salaries, student support, and related education development activities."[51] States need to realize that higher education funding has a huge impact on economic development; university graduates are the entrepreneurs of the future. According to the Association of University Technology Managers' 2010 survey, "651 new companies based on findings from academic studies started up at universities — including research institutes and hospitals — an increase of nine percent over 2009."[52] It is interesting to note that 77% of these new businesses were established in the same state as the research institution.

State Organization to Encourage Clusters

Massachusetts has one of the best examples of a quasi-state organization that focuses on cluster development. They responded to the failure of the Massachusetts Miracle by initially establishing four centers that focused on specific technology areas and with boards composed of members from academia, business, and government. Eventually, these centers were replaced with one organization that focuses on biotechnology, renewable energy, and clean tech. It also has a powerful board of well-connected people that represent all the sectors except the federal government. One of the goals of this organization is to leverage state funding with federal funding for universities and small businesses. States are missing a big opportunity if they do not have an organization that focuses on economic development for specific business sectors and convenes the first- and second-level influencers.

Venture Capital

Venture capital is defined as "money and resources made available to start-up firms and small businesses with exceptional growth potential. Venture capital funds pool and manage money from investors seeking private equity stakes in these small and medium-size businesses. Most venture capital funds come from institutional investors such as: public and private pension funds, finance and insurance companies, and endowments and foundations."[53] According to MoneyTree's historical trend data, $29.4 billion of venture capital was invested in 2011.[54] For several years, about 40% of it has been invested in companies located in Silicon Valley. The 2011 data by state shows California with 51.5% of all U.S. venture capital investment and Massachusetts with 10.4%. The next six states account for 21.7%:

New York, Texas, Illinois, Virginia, Colorado, and Washington. Only 16% was invested in companies located in the other 42 states. Since 1981, the top two states have not changed their ranking order; however, New York recently surpassed Texas for third place. Therefore, many states have decided that they need to start venture capital funds in order to attract funding for their local entrepreneurs. There are two types of funds: privately managed and direct investment.

State Venture Capital Fund – Privately Managed

"State investment in privately managed, geographically restricted funds is one of the most popular state program models. Two of the largest state funds in this category are the New York In-State Private Equity Program and the Oregon Investment Fund. In 1999, the New York State Legislature passed legislation calling on the Common Retirement Fund (CRF) to invest $250 million in New York companies."[55] As of 2011, the program has invested $554 million in 176 companies. "Since its inception, the program has created more than 2,700 jobs and has achieved a 30% rate of return on the investments that it has exited."[56] Obviously, the Program was developed to "stimulate New York's economy but also [to comply] with prudent risk management practices. Former New York State Comptroller Allan G. Hevesi was quoted as saying, 'Although the program, which the Legislature had the vision to create in the late 1990s, has provided significant economic benefits to the State's economy, my primary objective is to obtain an appropriate risk-adjusted return comparable to what would be available for other investments with similar characteristics.'"[57]

"In July 2003, the Oregon State Legislature created the Oregon Investment Council (OIC) to design and implement a $100 million program that encourages the growth of small businesses within the State of Oregon."[58] The OIC created the Oregon Investment Fund (OIF), which is managed by Credit Suisse's Customized Fund Investment Group. From 2004 to 2010, they have invested $160 million in 20 Oregon companies, and the effort has created approximately 1,250 jobs in Oregon. It has also attracted an additional $336 million for the Fund's companies from other investors.[59]

New Mexico provides an additional example of a state creating a venture capital fund through state resources. "The New Mexico Private Equity Investment Program has helped generate a huge increase in local venture capital commitments"[60] since 2005. The Program is managed by Sun Mountain Capital and has achieved the following as of June, 2012: venture investments in New Mexico companies have reached $1.9 billion, there are 1,244 related full time jobs with wages at more than twice the New Mexico average, and it has generated $191 million in annual economic impact.[61] The Program has been very successful in attracting private venture capital funds to the state because it "requires that any funds it provided to investors or invests directly in a portfolio company must be matched by other private investors. Therefore, if New Mexico puts $10 million into one venture capital firm, the firm must invest $5 million from its own fund in New Mexico companies and must arrange for other venture investors to put another $5 million into New Mexico companies as well."[62]

State Venture Capital Fund – Direct Investment

Maryland Venture Fund is the largest direct investment state venture capital fund and was established in 1994. It was expected to close due to the lack of state funding, but the state recently agreed to contribute $70 million to carry it through 2014.[63] A few states have seed capital funds to help launch start-up companies from universities to the early stage when they can attract investors. "Most [seed stage companies] are occupied with tasks such as filing patents, writing business plans, building management teams, completing prototypes

or optimizing compounds for drug discovery. States such as Massachusetts, Pennsylvania, Texas, and Maryland have developed state-supported seed funds."[64]

Another version of direct investment funds are "pre-seed venture capital funds in affiliation with universities or entrepreneur development centers. Examples of these funds include Michigan's Technology Transfer Office Invention Development Fund at Wayne State and the Technology Business Finance Program of the Oklahoma Center for the Advancement of Science and Technology."[65]

In 2002, the State of Ohio created a variation on the above by combining a focus on high technology clusters with seed funding to create the Ohio Third Frontier (OTF).[66] Through a bipartisan effort, the state passed legislation and funded the investment with special state bonds. The voters of Ohio have continued to support the funding of OTF by special referendum, and it has been extended to 2015. It focuses on the following sectors: 1) Advanced Energy, 2) Advanced Materials, 3) Biomedical, 4) Instruments, Controls and Electronics, and 5) Power and Propulsion. Through a competitive grant program, OTF gives funding to Ohio seed funding organizations, business clusters, and businesses. Ohio made an investment of $473 million in Third Frontier from 2003-6, and it has resulted in "$6.6B in follow-on dollars."[67]

5. Federal Government

Traditionally, the role of the federal government has been indirect, except in the case of earmarks and defense research. During WWII, some defense research was conducted by "research organizations set up organizationally within the universities (MIT, Stanford, and Cal Berkeley), but physically separated from the campuses for security reasons; e.g., Lincoln Laboratory at MIT. After the war, these research laboratories were made more independent of their universities and began to function as businesses."[68] Typically, the federal government awards grants and contracts to the other sectors and establishes Cooperative Research and Development Agreements (CRADAs) through federal laboratories with universities and businesses.

According to Phillips, over the years some universities have seen the potential benefit that federal partners can bring to the table and have made connections with federal laboratories in order to advance entrepreneurship initiatives. "Washington State University's program is connected with Battelle-Pacific Northwest National Laboratories, University of New Mexico's with Sandia and Los Alamos, and University of Texas at Austin's with NASA."[69] In 2007, the Department of Energy's (DOE) National Renewable Energy Laboratory (NREL) "helped to create the Colorado Renewable Energy Collaboratory in association with the University of Colorado at Boulder, the Colorado School of Mines, and Colorado State University."[70] Additional examples of federal agencies' involvement in clusters include: National Aeronautics and Space Administration (NASA) and the Enterprise for Innovative Geospatial Solutions (EIGS), which is located at the Stennis Space Center in Mississippi; and the Department of Defense (DoD) with the Advanced Defense Technology clusters.

In Porter's 2007 paper, he proposed "cluster-based economic development policies at the Federal level" because it would connect them to "actual state and local economies" and "would reinforce economic specialization across states and regions, increasing productivity and productivity growth."[71] In a 2008 Brookings paper, Karen Mills (SBA Administrator from 2009-2012) recommended that "the federal government establish an industry clusters program that stimulates the collaborative interactions of firms and supporting organizations in regional economies to produce more commercial innovation and higher-wage employment."[72]

In September 2010, the Small Business Administration (SBA) announced funding for three Advanced Defense Technology cluster nonprofits: Defense Alliance of Minnesota, San Diego Advanced Defense Cluster, and Von Braun Center for Science and Innovation in Huntsville, Alabama. The "awardees will focus on providing business training, commercialization and technology transfer services, counseling, mentoring and other services that support the growth and development of small businesses in the cluster region."[73] EIGS also received funding from SBA in September, 2010 as one of the "Regional Innovation Clusters." It appears that DoD, NASA, and DOE have realized that they can play an important role in the development of clusters, and they are actively working with SBA and the Department of Commerce's (DOC) Economic Development Administration (EDA) to provide funding opportunities to existing clusters. DOE, along with DOC and SBA, awarded one of the largest cluster grants of $129.7 million over 5 years in 2010 to "the Greater Philadelphia Innovation Cluster (GPIC), a team led by Pennsylvania State University, to run the Energy-Efficient Buildings System Design Hub."[74]

As one of the smaller federal agencies, the Environmental Protection Agency (EPA) awards research grants and cooperative agreements to universities through the National Center for Environmental Research's (NCER) Science to Achieve Results (STAR) Program. EPA also awards specific contracts for services through its program offices and regions. "NCER periodically establishes both STAR and non-STAR (Congressional line item) research centers."[75] The NCER web site lists 38 centers, which are not associated with clusters. NCER also manages EPA's Small Business Innovative Research (SBIR) Program.

EPA is one of 11 agencies that offer the SBIR Program. The Agency announces annual Phase I and Phase II solicitations. "Phase I awards of $100,000 for 6 months are used for 'proof of concept' of the proposed technology. Successful Phase I businesses are then eligible to compete for Phase II awards of up to $300,000 for two years to further develop and commercialize the technology. Phase II companies that obtain qualifying third-party investment are also eligible for a commercialization 'option' or supplement of up to $100,000."[76] The EPA SBIR Program also collaborates with the National Science Foundation (NSF) SBIR Program on solicitation topics and refers potential Phase II technologies to NSF when EPA is unable to fund a promising proposal.

Similar to EPA's NCER, NSF funds research centers at colleges and universities across the country, but on a much larger scale than EPA. NSF is responsible for funding cutting-edge research in everything except medicine; it is "the funding source for approximately 20 percent of all federally supported basic research."[77] It has funded several types of centers. The following three programs provide some useful examples for collaboration with industry, but they are not connected to clusters: the Science and Technology Center (STC): Integrative Partnership Program; Engineering Research Center (ERC) Program; and the Industry/University Cooperative Research Center (I/UCRC) Program. The STC Program "supports innovative, potentially transformative, complex research and education projects that require large-scale, long-term awards. STCs conduct world-class research through partnerships among academic institutions, national laboratories, industrial organizations, and/or other public/private entities**,** and via international collaborations, as appropriate."[78] There are 17 active centers. An example of an environmental STC is the Center of Advanced Materials for the Purification of Water with Systems (WaterCAMPWS). The University of Illinois at Urbana-Champaign is the lead university for this center.

The NSF Engineering Research Centers (ERC) "promote partnerships among researchers in different disciplines and between industry

and universities. They focus on integrated engineered systems and produce technological innovations that strengthen the competitive position of industry."[79] In 2011, the ERC for Re-Inventing America's Urban Water Infrastructure was funded with Stanford as the lead university. The goal "is to advance new strategies for water/wastewater treatment and distribution that will eliminate the need for imported water, recover resources from wastewater, and generate rather than consume energy in the operation of urban water infrastructure while simultaneously enhancing urban aquatic ecosystems."[80] The Center includes four U.S. universities, three international universities, and 22 industry partners. Recently, the ERC Program has given five awards for collaborative projects between an established ERC and a small business. This new type of ERC/SBIR award is open to SBIR Phase I or II award winners from any agency. This is an excellent example of SBIR collaboration with the goal of commercializing research from the ERCs.

The third NSF example is the Industry/University Cooperative Research Centers (I/UCRC) program. NSF should encourage clusters to apply for funding under this program. Over the past twenty years, NSF has funded more than 50 of these leveraged partnerships between industry and universities to support "high quality industrially relevant fundamental research … and direct transfer of university-developed ideas, results and technology to U.S. Industry."[81] Submitting a proposal for an I/UCRC center would be an excellent option for a nascent business cluster if it can bring together two or more universities and six or more industry partners, which are willing to contribute a total of $300,000 or more. The NSF funding of $70,000 per year for five years is meant to act as "seed funding" for the center, which would have a goal of self-sufficiency in the long term. In 2010, the Milwaukee water technology cluster received funding for an I/UCRC.

6. Start-up Companies

According to Smilor et al., the Austin start-up technology companies play an important role "in 1) commercializing technologies, 2) diversifying and broadening the economic base of the area, 3) contributing to job creation, 4) spinning companies out of the university and other research institutes, and 5) providing opportunities for venture capital investment."[82] Start-up technology companies are potentially the large corporations of the future, and this transition creates the cluster as it did in Silicon Valley with HP, Fairchild Semiconductor, and others. If a region is considering the creation of a technology business cluster, then it should conduct company and technology mapping research for the specific industry to identify the types of companies and their areas of expertise. Small businesses are often isolated and rarely have the opportunity to meet organizations from other sectors that have the same technology focus. By being a member of a business cluster, these companies will gain knowledge from their interactions, find new business opportunities and possibly develop partnerships or collaborations with members from the other sectors. When state and federal agencies are involved in the cluster, the small businesses become aware of the federal and state funding solicitations and the state organizations that offer proposal preparation assistance and other types of support services.

7. Large Corporations

Some large companies may be reluctant to interact with their competitors in a cluster organization, but in Silicon Valley the competition within the cluster drove the companies to become more innovative and stimulated the formation of new companies. It is one of the reasons for Silicon Valley's success. Porter explains the importance of competition in his 1998 paper: "Without vigorous competition, a cluster will fail. Yet there is also cooperation, much of it vertical, involving companies in related industries and

local institutions. Competition can coexist with cooperation because they occur on different dimensions and among different players."[83] In his 2007 paper, he stated that "the advantages of clusters are more important in global competition. As firms depend more on outside firms, support services, and local institutions, it becomes more important to locate within a strong cluster to access benefits that are difficult for outsiders to tap."[84]

According to Smilor et al., "Large technology companies have played a catalytic role in the expansion of the Austin technopolis by 1) maintaining relationships with major research universities, 2) becoming a source of talent for the development of new companies, and 3) contributing to job creation and an economic base that can support an affordable quality of life."[85] Among the large corporations in the cluster, there are usually one or more anchor companies. An anchor company in a cluster could be defined as a corporation that is a leader in research and development in its industry sector and is also a leader in export and supplier behavior. It is often a role model for other companies in the cluster. The anchor company contributes executives' time to the development of the cluster organization, pursues research with the cluster universities, and contributes to job creation in the cluster. It also contributes knowledge about worldwide suppliers, distributors, and competitors in the industry and provides contacts to the cluster. The anchor company gives the cluster advice about what technologies will be important for the future and how to build the capacity into the university curriculum. As the universities expand their curriculum, the anchor company supports the universities by interviewing their graduates for jobs.[86]

As Silicon Valley developed, Hewlett-Packard played an active role in that cluster. David Packard often helped Terman by "promoting the industrial park."[87] Hewlett and Packard mentored aspiring entrepreneurs, and HP's "semi-autonomous divisional structure and participatory management style offered ideal training in the general management skills needed for a start-up."[88] Eighteen companies spun out of HP from 1974-1984. "HP also built alliances with local companies that offered complimentary technologies."[89] As illustrated in the case studies below, when large corporations are active members of a cluster, they can have a huge impact on the cluster's success.

Case Studies

The Austin technopolis and the Massachusetts biotechnology cluster have been in existence for more than 25 years. The Milwaukee water technology cluster is six years old. In each of the case studies, the champions and support groups stand out as being crucial in the formation, development, and continued success of these clusters.

1. Austin Technopolis

The Austin Technopolis was established over 25 years ago. From Fred Phillips's book, it is evident that the late George Kozmetsky was one of the visionaries and influencers behind the Austin Technopolis. He was a co-founder of Teledyne, Inc., and later the Dean of the College of Business Administration and the Graduate School of Business at the University of Texas (UT) in Austin. In the 1960s, Kozmetsky declared that "technology innovation was the driver of economic development."[90] This well-respected businessman and academic established the IC² Institute (Innovation, Creativity and Capital) at UT in 1976. It appears that IC² is at the core of innovation and economic development in Austin. According to the IC² web site, "The IC² Institute is a globally recognized 'think and do' component of the University of Texas at Austin whose mission is to engage in cutting-edge research to enhance the solving of unstructured problems related to market economies, wealth creation, growth, and prosperity through entrepreneurial activity and the commercialization of technological innovation. The Institute carries out this mission through its primary applied research laboratory at the Austin Technology Incubator as well as through the Bureau of Business Research, the Global Commercialization Group, the Digital Media Collaboratory, the IC² Fellows Network, Visiting Scholars, and the Master of Science in Technology Commercialization degree program."[91]

In the early years of IC², it established a reputation as an innovative think tank. According to Phillips, Kozmetsky and his networking contacts would "identify an issue of emerging or near future importance … The subject is one that has not been widely addressed heretofore, and one that involves creating new wealth or increasing equity by leveraging technological innovation."[92] From this point, a conference would be organized with well-known experts, and the leaders from all seven segments of the Technopolis Wheel would be asked to support and participate in the conference. Therefore, a network would develop from the conference based on the shared issue. An example is the Austin Technology Council. In 1991, Kozmetsky asked Phillips, then the Research Director of IC², "to organize a conference on the Austin area's software industry and its competitive readiness."[93] During the conference, the idea of creating an Austin Software Council was initially proposed. IC² hosted the Council until it was firmly established in 1993. At one point during the development of the technopolis, it became apparent that Austin needed direct airline service to San Jose. According to Phillips, "the Austin Software Council persuaded American Airlines to offer a daily non-stop flight to San Jose. Rarely has there been an empty seat on those flights, and the benefits to Austin's industry have been enormous."[94] By 1995, the Council had 800 members and changed its name to the Austin Technology Council (ATC). The Council is still one of the major networking organizations in Austin.

From the beginning of this technopolis, the University of Texas at Austin has played a major role due to George Kozmetsky's influence and position in the University's administration. According to Smilor et al., the University has been key in "the development of the Austin technopolis by 1) achieving scientific

preeminence; 2) creating, developing, and maintaining new technologies for emerging industries; 3) educating and training the required workforce and professions for economic development through technology; 4) attracting large technology companies; 5) promoting the development of home-grown technologies; and 6) contributing to improved quality of life and culture."[95] The UT Endowed Centennial Program for chairs, professorships and fellowships in 1983-4 "made a significant difference in attracting researchers who in turn attracted research funds and exceptional graduate students."[96] However, in 1984, during the recession, the state cut appropriations for higher education by 3%, and this lack of sustained support sent a different message to scholars and researchers. During this difficult period, the champions developed an alternative plan to assist the University, Austin, and the business community.

Over the years, Austin has demonstrated that it has the "enlightened government" factor. According to the former Austin city manager, Dr. Camille Barnett, it is important for metropolitan regions to "create a visual image of the public-private collaboration and systematic innovation to attract entrepreneurs"[97] and provide incentives "through public/private development policies, tax incentives, and incubators."[98] An example of local government interaction with a support group and a university is the Austin Advantage program started in 1988 by the Greater Austin Chamber of Commerce. The purpose of the program was to help turn around the city after the recession of the 1980s. Funds from the program allowed the Chamber to be a sponsor of the Austin Technology Incubator (ATI) along with the UT Graduate School of Business and the City of Austin. In 1989, they established the Incubator and since then it "has served over 150 companies that have generated $1.5 billion in revenue and created 10,000 direct and indirect jobs in Central Texas. ATI supports the growth and development of emerging technology companies in three vertical incubators: Clean Energy, Biotechnology, and Integrated Communication Technology."[99] In 1991, the Greater Austin Chamber of Commerce raised additional funding for Austin Advantage II, which promised "continued momentum – and new initiatives in job creation, small business assistance, national marketing, technology incubation, support for schools, and overall economic vitality."[100]

Over the years, the large corporations in Austin have supplied the entrepreneurs, the financing and the management talent that have been essential to the start-up companies. A thriving technopolis needs both large corporations and start-up companies. One of the first Austin start-up companies was Tracor, Inc., a defense electronics company that was started by four UT professors in 1955. Since 1962, at least twenty companies have spun out of Tracor. In the late 1960s, Austin attracted IBM and Texas Instruments and then Motorola arrived in 1974. By the end of the 1980s, Schlumberger, 3M, MCC, and SEMATECH had all located in Austin. One of Austin's best known start-up companies, Dell Computer, was started in 1985, and according to Phillips, George Kozmetsky was actually a mentor to Michael Dell.[101]

The success of this technopolis over the last 25 years is due to sustained efforts by IC², Austin, UT–Austin, the large corporations, the start-up companies, ATC, ATI, the state of Texas, and many champions, beginning with George Kozmetsky.

2. Massachusetts Biotechnology Cluster

Having learned some lessons from the failure of the Massachusetts Miracle, the state now has a very successful biotechnology cluster with influencers and a powerful support group. The cluster was established over 25 years ago. It is difficult to determine who the visionaries were in this cluster; possibly one of the Interneuron, Biogen, Genetics Institute or Genzyme founders

along with the state's economic development team. According to Philip Cooke, the key players in this cluster are: "MA Department of Economic Development, MIT, Harvard University, Mass. General Hospital, Boston University's Bio Square Technology Park, Whitehead Institute of Biomedical Research, Massachusetts Technology Collaborative, and Massachusetts Biotechnology Council (MBC)."[102]

In 1985, Massachusetts played a pivotal role in encouraging the biotechnology cluster by establishing the Massachusetts Centers for Excellence Corporation (MCEC). "Under the MCEC umbrella, four technologies were to be promoted – biotechnology, marine science, polymer science, and photovoltaics."[103] The mission was "to spur innovation and encourage the development of new technologies through alliances between business, universities, and state government."[104] The boards of the Corporation and the centers had members from government, academia, and business. Each center had a matching grant program, which they used to "promote technology transfer and strategic partnering."[105] In the period from 1985-1986, the Biotechnology Center of Excellence "awarded 12 grants totaling $2 million."[106] During this same period, the Massachusetts Biotechnology Council was established. According to Fernando Quezada, director of the Biotechnology Center, "we had a core group of companies already in the commonwealth, possibly a field of 50 … yet there was no organized effort obviously because we were just starting. … So we worked closely with the Council and the universities that were also discovering that they were sitting on some very exciting technologies."[107] In 1991, the Center became a nonprofit known as the Biotechnology Center of Excellence Corporation, and the Massachusetts Technology Collaborative (MTC) assumed state responsibility for the biotechnology cluster.

Currently, the Massachusetts Office of Business Development and the MTC play important roles. The Office of Business Development plays a "key role in business and trade development, improving the business climate (R&D tax credits, investment tax credits), responding to lobbying from industry associations,"[108] and connecting small businesses to Massachusetts organizations that offer financing options. According to MTC's website, it is "a public economic development agency that fosters a more favorable environment for the formation, retention, and expansion of technology-related enterprises in Massachusetts. Through its major divisions — the John Adams Innovation Institute, the Massachusetts e-Health Institute, and the Massachusetts Broadband Institute — MTC is stimulating economic activity in every corner of the Commonwealth. The agency brings together leaders from industry, government, and academia to advance technology-based solutions that improve the healthcare system, expand high-speed Internet access, and strengthen regional economies."[109]

In their role as facilitator, state programs such as MTC direct businesses to federal funding opportunities; MTC focuses on biotech, renewable energy, and clean tech. States are missing an opportunity if they don't coordinate and leverage their programs with federal funding for universities and small businesses. This type of coordination is evident in the Massachusetts biotechnology cluster. According to Cooke in his 2002 paper, "Each year some $770 million in basic research funding flows through the system."[110] MTC board members are from the leading technology companies and the academic and research community. Through the state's MTC and the support organization, MBC, the universities, local government, small businesses, and large corporations interact in business activities and collaborate on funding opportunities.

According to the MBC web site: "The Massachusetts Biotechnology Council is an association of more than 600 biotechnology companies, universities, academic institutions and others dedicated to advancing cutting

edge research."[111] They create a "forum for the biotechnology community to come together, educating the public and policy makers, influencing public policy and advancing the economic interests of individual companies, as well as the sector as a whole."[112] The MBC's lobbying efforts focus on "public policy initiatives and tax incentives in Massachusetts that will enable biotechnology companies to do their best work."[113] In Washington, they have "worked to effectively reform patent laws and expand access to Small Business Innovation Research grants."[114] All the major biotechnology firms in Massachusetts are represented on the MBC Board. The MBC membership directory has a list of twenty-two member categories which includes "government relations," "law firms," "universities and non-profits," and "investment and capital firms." It is estimated that there are more than 150 venture capitalists in the Boston metropolitan area.

The Massachusetts Institute of Technology (MIT) is a very important university in this cluster because it offers outstanding support, including sophisticated patent analysis, for its scientists and entrepreneurs. If a university in a developing cluster is looking for an example to emulate, then it would be Stanford or MIT. After the failure of the Massachusetts Miracle in the late 1980s, MIT established a technology licensing office[115] and became more involved with start-up companies. In a recent report on the entrepreneurial impact of MIT, it is estimated that "6,900 MIT alumni companies are headquartered in Massachusetts. The estimated sales of these companies – $164 billion – represent 26 percent of the sales of all Massachusetts companies."[116] MIT established the now-worldwide MIT Enterprise Forum in the 1970s, and in 1990 it started the MIT Entrepreneurship Center, which is now known as the Martin Trust Center for MIT Entrepreneurship[117] and offers over 25 courses. The Forum and the Center were both established by MIT's Sloan School of Business. Any businessperson involved in technology entrepreneurship can join the Enterprise Forum, whose mission is to promote interaction between entrepreneurs and their communities. It offers a series of entrepreneurship seminars through its 28 chapters.[118] In addition, the University has other services and facilities that further enhance interaction with businesses, support groups, and government. Over the past 10 years, the MIT Technology Licensing Office has licensed 224 new businesses, an average of 22 per year. The university even offers a Venture Mentoring Service, which has been critical in the formation of 88 companies.[119] In the area of biotechnology, MIT offers campus incubators and a technology park. According to Philip Cooke, "the Entrepreneurship Center trains the scientists in entrepreneurship, and the Technology Licensing Center identifies technologies suitable for startups and introduces the technology to potential investors (usually venture capitalists)."[120] All of the MIT programs emphasize the importance of networking with the other sectors through the support groups and the Massachusetts Technology Collaborative.

As of 2002, there were 218 firms in the Massachusetts biotechnology cluster. According to Cooke, "Seventy-nine firms were founded in the 1980s including Biogen, Genetics Institute and Genzyme. A further eighty-eight began between 1990 and 1997; the remainder is more recent start-ups and inward investments. Employment grew from 7,682 in 1991 to 16,872 in 1998."[121] The success of this cluster is due to many factors, one of which is the interaction of the universities (MIT, BU, and Harvard), the support group (MBC), the state development organization (MTC), the local communities (primarily Boston, Cambridge and Worcester), the large corporations (Genzyme, Biogen, and Genetics Institute), and the start-up firms. Since 1985, the MBC has been the central networking organization with membership that includes all of these sectors.

The large corporations such as Genzyme, Biogen, and Genetics Institute have played a key role as cluster anchor companies by

interacting and collaborating with the other sectors. According to Cooke, "Genzyme as a founder member of the Partners Healthcare System with Brigham and Women's and Mass General Hospitals on research funded at $400 million by the National Institutes of Health, reinforces the [generation and diffusion] system [of the cluster] … along with Biogen and Genetics Institute."[122]

3. Milwaukee Water Technology Cluster

In the recently formed Milwaukee, Wisconsin water technology cluster, Rich Meeusen is clearly the visionary, and he is attempting to build the "Silicon Valley of water technology."[123] According to Meeusen, his "Eureka moment" came about six years ago: "I was at a meeting at A.O. Smith where their CEO was showing us their flow lab. As we talked, we realized that each of us had had no idea that the other company had a major flow lab. So, since we're not really competitors, we agreed to share each other's flow lab facilities. And then I thought, wow, there are all these companies in the Milwaukee area involved in the water cycle, but almost none of them compete with each other. The only ones that really did compete were GE and Pentair, and even now they have their joint venture, Pentair Residential Filtration."[124] Shortly after Meeusen had the idea of bringing the water technology companies together in an organization, he approached the Greater Milwaukee Committee and the Milwaukee 7 Council, a regional economic development council for the seven counties. One of the co-chairs of the Milwaukee 7 is the Milwaukee's mayor, Tom Barrett. The Council members include the chancellor of the University of Wisconsin–Milwaukee, CEO of Wisconsin Economic Development Corporation, mayors and county executives for all seven counties, and CEOs of the largest companies.

In 2007, the Milwaukee 7 Council agreed to establish the Milwaukee 7 Water Council, which is now known as the Milwaukee Water Council. Its mission is "to align the regional fresh water research community and water-related industries to establish the Milwaukee region as the World Water Hub for water research, economic development, and education."[125] The Council's Board of Directors has 17 members and includes businesses, nonprofits, academia, investors, and government.[126] The co-chairs of the Council are the CEOs of Badger Meter, Rich Meeusen, and A.O. Smith Corporation, Paul Jones; they would be considered first-level influencers, according to Smilor et al. In terms of working with the local and state government regarding the development of the water technology hub in 2007 through 2009, Meeusen said: "The governor, the mayors, our two U.S. senators, our various legislators - all have been very supportive."[127] At the time, he had never seen such bipartisan political cooperation.

Over the six years from 2007-2013, the Council has pursued an effective strategy of gaining public recognition and attracting state and federal funding to expand water research, boast economic development, and establish the cluster – all of which supports their mission. Public recognition began in 2007 with the Council's first Water Summit, which has been an annual event ever since. In 2009, Milwaukee "gained admission into the United Nations Global Compact Cities Programme (UNGCCP). With this admission, Milwaukee achieves United Nations recognition of the area's expertise and global leadership in fresh water technology and science. Milwaukee and San Francisco are the only two North American cities in the UNGCCP."[128] In 2011, the Council was one of five recipients of the U.S. Water Prize by the Clean Water America Alliance (CWAA) for water sustainability. Ben Grumbles, President of CWAA, stated the following regarding the award: "The Milwaukee Water Council is a world-class example of regional collaboration and technological innovation for a future of clean water and good jobs."[129]

Compared to MIT or UT Austin, the University of Wisconsin in Milwaukee (UWM) is not a well-known research institution nor is it a patent generator. According to 2008 data from the U.S. Patent Office on patents of U.S. origin and an analysis by the Milwaukee Wisconsin Journal Sentinel, Wisconsin ranks 15th among states for percentage of patents[130] and water is barely mentioned. Milwaukee is home to the Great Lakes WATER Institute, a UWM facility whose mission "is to provide the State of Wisconsin with a focal point for research, education and outreach aimed at a thorough understanding of the Great Lakes and other aquatic and environmental resources of local, state, national and international importance."[131] In March 2009, the state of Wisconsin established the university's Graduate School of Freshwater Sciences with a huge vote of support from the state. The former governor announced that "$240 million in bonding over the next six years would allow UWM's Engineering College, School of Freshwater Sciences and School of Public Health to move forward. The university's Milwaukee Initiative is designed to expand research and development programs and gain greater support from business and civic leaders in southeast Wisconsin."[132] The School opened officially in the fall of 2010 and in July 2010 it received a $525,000 award from the National Oceanic and Atmospheric Administration (NOAA) to fund six graduate research fellowships focused on human health issues and the Great Lakes.[133] The School is also establishing a Center for Water Policy with a $2.6 million donation from a local philanthropist. The WATER Institute is now operated by the School of Freshwater Sciences. In July 2011, the School hired David Garman, an Australian water technology scientist and entrepreneur, to be its dean.[134]

In terms of funding for economic development and the cluster, the Council submitted a number of proposals to foundations, state and federal agencies in 2009-11. In September 2009, they received $172,500 for water related economic development from the EDA;[135] part of this grant paid for the hiring of a water industry specialist. They also received part-time assistance from three Greater Milwaukee Committee (GMC) employees, and their office is in GMC space. In January 2010, the Council hired an executive director and in May 2010, they announced the receipt of four foundation grants totaling $210,000.[136] It appears that they also started collecting dues from members in 2010.

The year 2010 continued to be a successful one in terms of raising money for the cluster. The National Science Foundation (NSF) funded an Industry University Cooperative Research Center (I/UCRC) in Milwaukee. The Water Equipment and Policy (WEP) Center is a collaborative involving UWM, Marquette University and six industry members including A.O. Smith and Badger Meter. NSF funded the Center with an initial five year award of $40,000-80,000 for each year.[137] The annual amount is dependent upon the projects submitted. NSF requires that the I/UCRC industry partners each contribute $50,000 for a total industry contribution of at least $300,000. "The WEP Center will help boost economic growth and development by studying water equipment, policy and technology. This will advance understanding of water technologies and help water equipment manufacturers increase competitiveness by adopting new technologies to improve water quality."[138]

In September 2011, the Council received a $500,000 grant from EDA's Jobs and Innovation Accelerator Challenge. The grant supports the development of a business accelerator.[139] In February 2012, the Milwaukee Water Council purchased a 98,000 ft^2 building, which after renovation will house the Council, the water technology business accelerator, Badger Meter, A.O. Smith, Veolia, and UWM's School of Freshwater Sciences.[140] The business accelerator portion of the building "will also be used by water technology-related businesses to do collaborative research work with UWM students and faculty. The idea is to create a

synergy between UWM researchers, established businesses and start-up firms to help them share ideas and launch business ventures."[141]

The announcements and funding outlined above demonstrate the Council's commitment to water research and economic development. According to their mission, the third area of focus is education. Encouraging a regional investment in water education is strategic to the long term success of the cluster. Shortly after the Council was formed, it initiated discussions with the academic community and the water industry to determine what types of college programs could meet the identified need for "legal and business professionals." "Marquette University Law School stepped up to offer the region's only water-law program. Integrated science and business majors at the University of Wisconsin at Whitewater can now pursue a water resources concentration."[142] The Council has established a water internship program with UW – Whitewater.[143] According to Paul Jones of A.O. Smith, "One of our goals is to help develop seamless talent pipelines between universities and water businesses."[144]

The CEOs of the cluster anchor companies, Badger Meter and A.O. Smith Corporation, are playing an important role in the development of the Milwaukee water technology cluster. Their collaboration started with sharing their flow lab facilities and now they have the Milwaukee Water Council with eighty-two companies and organizations as members, state and NOAA funding for the University of Wisconsin's School of Freshwater Sciences, EDA funding for the business accelerator, NSF I/UCRC funding for university and industry water research, a water internship program, admission to the UNGCCP, and local and state government support. Meeusen's decision to approach the Milwaukee 7 Council for assistance in establishing the water support group was significant, as it gave him access to several first-level influencers from the key sectors that could make a difference for the water technology cluster.

Summary

Drawing on the lessons learned by the successful and unsuccessful technology clusters, it is essential that the prerequisites are available and that the seven sectors interact and collaborate. The influencers and champions are important in stimulating the interaction of the sectors, creating social capital, and providing strategic coordination and direction for the cluster. From the examples, it is clear that support organizations such as the Massachusetts Biotechnology Council, the Austin Technology Council, the IC² Institute, and the Milwaukee Water Council play a key role in advocating for clusters and providing a venue for sector interaction. Their advocacy role is important in terms of proposing and sustaining initiatives that will continue to build the clusters. Without champions, support groups and sustained local and state initiatives, a cluster is just a group of struggling entrepreneurs.

Recommendations for the Seven Sectors

In the exploratory stage of developing a cluster, it is important to build social capital with key people from each of the seven sectors and conduct company and technology mapping research for the specific industry. In building social capital, the cluster visionaries will want to meet with a range of influential leaders from the different sectors. The following expanded version of the Technopolis Wheel includes additional organizations that should be considered depending upon the type of technology cluster.

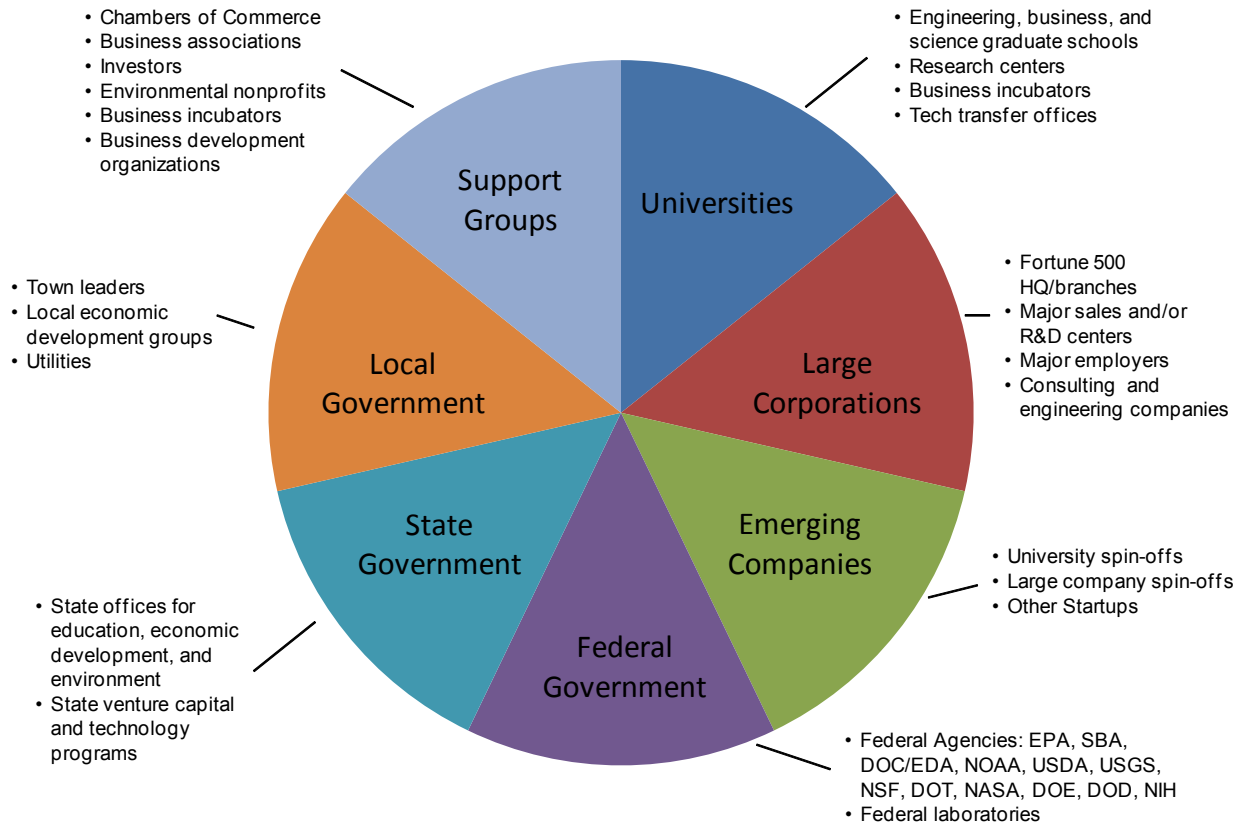

Figure 2. Key Cluster Sectors[145]

Each of the sectors needs to be mindful of the role that it could play in the development and success of a cluster. The following recommendations for the sectors are based on the case studies and the EPA water technology cluster experience in Cincinnati.

Universities

In each of the case studies, the universities have played a key role in the development of the clusters. It is essential that the universities have 1) research units that focus on groundbreaking technology, 2) sophisticated patent support and analysis capability, 3) entrepreneurship courses and if possible a university business incubator, 4) consistent funding to attract high quality professors and graduate students, and 5) reasonable fees for small businesses to access the universities' research findings and facilities. The most successful business clusters are associated with universities that offer this combination and more services as shown by Stanford, which has been a leader since 1950 in encouraging the development of local businesses. The recent Kauffman Foundation report stresses the importance of "university policies that encourage entrepreneurship and provide an assortment of support services for start-ups beyond the school's technology transfer office."[146] State funded universities need to remind their legislators that 77% of new businesses are established in the same state as the research institution where the technology was developed.

Executive Champions and Support Groups

In the Austin and Milwaukee case studies, it is very clear that those clusters were formed because of the vision, persistence, and magnetism of George Kozmetsky and Rich Meeusen. They each initiated the interaction of the influencers or executive champions from the seven sectors. In the initial stage, they invested significant time in social capital building with the key people before starting the cluster or technopolis. They also identified a support organization to act as the initial convener until the cluster was ready to set up a nonprofit. Both clusters were strategic about setting reasonable goals early in their development. Since the Milwaukee Water Council developed more recently, it is easy to track the progress on their goals. One of the key requirements for Economic Development Administration cluster funding is demonstrated success in meeting goals.

Local Government

The proactive role of the mayors of Austin and Milwaukee supported the formation of their clusters, and their involvement is a model for cluster development. It is also important for the local government to provide high quality schools, modern infrastructure, open space, good transportation, arts and recreation facilities, and competitive rate structures because these relate to the quality of life which will help attract and retain businesses. The Department of Commerce's Economic Development Administration has developed a web site to promote regional economic development: the Regional Innovation Acceleration Network (RIAN) at http://regionalinnovation.org. It offers tools, guides and webinars based on the experience of successful clusters.

The local government should also consider which of its departments, in addition to economic development, should be involved in the cluster and how it can have an impact either through purchasing or piloting new technologies. In a water technology cluster, the local drinking water and wastewater utilities could offer test sites for new technologies. In a renewable energy cluster, the department of public works could be involved and government buildings could be demonstration sites for new technologies. Most likely, the city of Austin, Texas was an early purchaser of Dell computers

and software developed by the companies in the Austin Technopolis.

State Government

State governments should look to the example of Massachusetts for the role that they can play in cluster development. Massachusetts has been proactive since the 1980s. The state has an advantage due to its high concentration of well-funded private universities and colleges. It has leveraged that advantage by consistently funding its state universities at a high level, offering an effective state organization to encourage start-ups and cluster building, and funding one of the longest running state venture capital programs, the Massachusetts Technology Development Corporation, now known as MassVentures, established in 1978. The state has also placed emphasis on having a well-educated and skilled workforce that meets the needs of high technology businesses.

When appropriate, states should consider legislation that will encourage the use of innovative technologies that will address their problems and promote technologies of related clusters. An example of how Massachusetts has supported its clean energy cluster can be found in its legislation and regulations that encourage the use of clean energy. If a state has a water technology cluster, then it might consider legislation that would address its water problems.

Federal Government

The federal government has an opportunity to be a catalyst for business clusters that are linked to its goals and research facilities. Over the last five years, several federal DoD, DOE, and NASA laboratories have been involved in business clusters. EPA's National Risk Management Research Laboratory in Cincinnati, Ohio followed their lead and facilitated the development of a water technology cluster. EPA was inspired by Administrator Lisa Jackson's statement that "smart environmental protection creates jobs."[147] On January 18, 2011, the EPA Administrator and the SBA Administrator jointly announced the formation of the Water Technology Innovation Cluster (WTIC) in Cincinnati/Dayton/Northern Kentucky/Southeastern Indiana. EPA used an earlier version of this paper as guidance for the formation of the cluster. Federal government laboratories should continue to look for opportunities to be involved in relevant clusters in their regions.

The recent interagency cluster solicitations organized by SBA and EDA will have a long-term impact on clusters. They have not only encouraged university, business and regional cluster collaboration, but also federal agency collaboration through the development of the solicitations and management of the awards. NSF should consider using their I/UCRC program to encourage the development of clusters; they could even collaborate with other federal agencies and EDA. The program is highly leveraged with significant support from industry partners. By expanding it to clusters, NSF would be increasing the chances that the university and industry partnerships would last beyond the five years of NSF funding.

Start-up Companies

It is important for start-up companies to take the time to participate in the cluster and make the other sectors aware of the barriers that small businesses face and the assistance that would be useful. It may require thinking beyond their individual companies to the needs of their common business sectors. By being members of a business cluster, these companies will gain knowledge from their interactions, find new business opportunities and possibly develop partnerships or collaborations with members from the other sectors.

Large Corporations

The active participation of large companies in cluster committees is important. The role of

anchor companies, such as Badger Meter and A.O. Smith Corporation, is also crucial. Their industry expertise and advice provides essential guidance for the cluster organization. The large corporations should be looking for opportunities to contribute industry knowledge, collaborate with the other sectors, conduct research with the federal laboratories, universities and start-up companies, and advise the states, colleges and universities on curriculum development that is supportive of the cluster and future technology development.

Notes

1. Michael Porter, "Clusters and the New Economics of Competition," *Harvard Business Review,* November-December, 1998, 78.
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3. Ibid, 86.
4. Ibid.
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6. Ibid, 2.
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9. Phillips, 1.
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